emScon 3.0

Programmers Manual
Tracker Programming Interface

- when it has to be **right**

Leica Geosystems

Programmers Manual

emScon TPI

Metrology Division

Preface

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Software and version	emScon TPI; V3.0
Manual update	May 26, 2008
Manual order number	None

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2.1 Prerequisites

2.1.1 Targeted Users and Terminology

This manual applies to software developers who need to write software that directly communicates with Leica- Tracker hardware (or **Tracker servers** - aka **emScon servers**, respectively).
This manual hence describes the **Application Programmers Interface** (API) for Leica Trackers / Tracker Servers (emScon).
API is a widely used term in the programming world. In order to clearly distinguish from other APIs (Win32 API, Winsocket API…) referenced in this manual, we are rather using the term **Tracker Programming Interface (TPI)**.
TPI therefore stands as a synonym for **Leica Tracker API** throughout this manual.
Note that this is **not** a **User- Manual** for trackers! Users of this Reference Manual need to be familiar with tracker operation concepts and tracker-specific terms such as 'Bird bath', 'Absolute Distance Meter' etc. These terms are usually not explained here. The Programmers Manual just means an **extension to** the provided **User-, Reference- and Training- Manuals** for Leica Trackers and emScon.

2.1.2 Common Abbreviations

IT / Windows / Microsoft specific

API	Application Programmers Interface
ATL	Active Template Library

COM	Component Object Library
DLL	Dynamic Link Library
GUI	Graphical User Interface
IDE	Integrated Development Environment
IDL	Interface Description Language
LAN	Local Area Network
LED	Light Emitting Diode
OCX	ActiveX Control
NYI	Not yet implemented
TCP/IP	Transmission Control Protocol / Internet Protocol
UI	User Interface
VB	Visual Basic
VBA	Visual Basic for Applications (a subset of VB, Macro Language)
VC++	Visual C++
VS	Visual Studio (= IDE)

Leica / emScon specific

ADM	Absolute Distance Meter
BB	BirdBath (sometimes also BallBar)
BUI	Base User Interface
CS	Coordinate System
DoF	Degrees of Freedom (mainly used as 6DoF)
ES	Embedded System (= server-based system)
FW	Firmware
HV	Horizontal / Vertical (2DoF angular measurement pair)

HVD	Horizontal / Vertical / Distance (3DoF measurement triplet)
IFM	Interferometer
LT	Laser Tracker (w/o ADM)
LTD / AT	Laser Tracker with ADM
NYI	Not yet implemented
TPI	Tracker Programming Interface (= API)
TS	Tracker Server
TP	Tracker Processor
Trafo	Transformation
T-Cam / TCam	Tracker Camera
T-Probe	Tracker Probe
T-Mac	Tracker Machine Control Probe
V-Cam	Video Camera (overview camera)
WM	Weather Monitor

2.1.3 Supported Leica Hardware

The emScon TPI supports the following Laser Trackers and T-Products:

- LT500 & LTD500
- LT600 & LTD600 Series
- LTD700 Series
- LT800 & LTD800 Series
- T-Cam 700 and 800 Series
- AT Tracker Series (AT901-B/MR/LR)
- T-Cam LR and MR Series

2.1.4 Network requirements

Communication between user- applications and emScon tracker server is based on the TCP/IP protocol. The application PC thus must be equipped with a TCP/IP-enabled LAN Board.

- **This manual does not cover hardware and network installation/configuration issues.**

2.1.5 Programming Environment

This manual (notation, samples) is mainly based on Microsoft Visual Studio 6.0 (VC++ 6.0, Visual Basic 6.0). Some samples refer to VisualStudio 7.0 (C# and VB .NET samples).
Compatibility to Microsoft Visual Studio 7.0 (8.0) is granted for all C/C++/COM interfaces/Samples. The samples written in VB 6.0 require a conversion and possibly some minor code-adjustments in order to compile under VB.NET.

2.2 TCP/IP Communication

Communication through TCP/IP requires platform specific communication functions. These are not part of the emScon TPI; they are provided by the Operating System or by the IDE. There exist several so-called **Socket APIs**. Keywords under Windows/VC++ include *Win32 Sockets API*, or (if using MFC) *CAsyncSocket* and *CSocket*. Visual Studio even contains a TCP/IP communication library, *MSWinsck.ocx*, as an ActiveX control (COM object). Any of these socket interfaces may be used in order to communicate with emScon.

2.2.1 Socket Functions

For writing emScon applications, only few socket-functions are required (names may be different, depending on used Library/API):

- **Connect** – Establishes a TCP/IP connection from the application to the Tracker Server. IP- address/hostname and port number of the Tracker Server are required as parameters.

- **SendData –** Send a packet of data to the server, usually by passing a pointer to a byte array data-block and the size of that block.
- **ReceiveData** – **Callback**- or **Event-Notification.** A mechanism to notify the application when data has arrived from the server and is ready to be read.
- **ReadData –** To read waiting data into a byte-array buffer, upon a notification.
- **Close –** Closes a previously established TCP/IP connection.

Availability of socket functions:
There are several options. The decision, which one to use, may depend on several facts: the platform, the programming language, the type of the application (Console Application, Windows Application with GUI, Server Application running in background...) etc.

- Operating system provided low-level socket API (e.g. Winsock 2.0 API of Windows). This approach requires some advanced programming knowledge.
- Class libraries, for example MFC, provide a higher-level abstraction of the Winsock functions. Easier to use.
- ActiveX Controls / COM libraries. For example **MSWINSCK.OCX**. Suitable especially for VB/VBA applications.
- Third party TCP/IP communication library or component.
- Self developed TCP/IP library (based on low-level Win32 API).

2.3 Tracker Programming Interface

EmScon provides a TCP/IP interface. Communicating with the emScon server hence means sending and receiving byte-array data-blocks over an (asynchronous) network connection. This technique has no specific relation to emScon - it's how any TCP/IP communication works - including Internet browsing.
EmScon specific issues are brought into by just **publishing the structure** of the sent/received data packets. The emScon TPI (low-level interface) is therefore a **collection of Data Types**, namely **Enumeration Types** and **Data Structures**. That's all! These data types fully describe the structure of the data blocks traveling over the TCP/IP network. They are required to '**construct**' blocks to be sent to the tracker-server and can be used to '**mask**' incoming data blocks in order to interpret these.
The definition of these data-types is provided in C-language notation, as an include-file called ***ES_C_API_Def.h*.** This file is compatible to the IDL-language, and its types are therefore fully transparent to COM interfaces (except constants). (Note the subtle differences between C and C++ notation for structs and enums)

The *ES_C_API_Def.h* file is the only interface definition of the emScon TPI, also referred to as the '**native**' emScon interface.
All other interface levels (C++ TPI, C# TPI, LT-Control COM - interface) are higher level abstractions and are strictly based on this native include-file. They are, therefore, just provided for convenience.
This enables the client programmer to design alternate C++/C# interfaces and/or other high-level interfaces (e.g. even COM components). However, **the *ES_C_API_Def.h* file should not**

be changed on any account.

2.3.1 Platform and Programming Language Issues

- The versatility of the emScon TPI based on standard TCP/IP allows its usage on different operating systems (Windows, Linux, UNIX, Macintosh…).
- Despite the C-language native interface, the programming language for writing emScon applications is not restricted to C. All languages that can deal with structures in C-notation (or have the same byte-align policy), can be used.
  The use of languages other than C/C++ may, however, require translation of C-structures (*ES_C_API_Def.h*) to the target language's notation, with matching structures on the byte level (4 Byte alignment).
  Such translations require some advanced programming knowledge and are not covered by this Manual.
- The use of programming languages other than C/C++ is **not recommended for low-level TPI programming**, and no support is provided.
  Translating the TPI's Enumeration Types and Data Structures into other language's syntax may encounter potential errors (different size of basic data types, byte alignment issues etc.).
- Applications therefore should not be based directly on the C- native interface. Usage of provided C++, C# or COM emScon interfaces is highly recommended instead.

2.3.2 Prefixes and Suffixes used in Type Names

Prefixes	
ES	'**E**mbedded **S**ystem' (or emScon). They identify type-names of the TPI
DT	Data type (Packet type)
C	Command
RS	Result Status
SSC	System Status Change (Events)
Suffixes	
T	**T**ype; usually used for general sub-structures
RT	**R**eturn **T**ype (used for data transfer **from** server)
CT	**C**ommand **T**ype (used for data transfer **to** server)

These are only the most frequent ones. Other prefixes explain themselves as they mostly are derived from the enum-type- names.

2.3.3 Asynchronous Communication

As for any TCP/IP communication, low-level communication (C/C++) to the tracker server is **asynchronous**. In particular, this means:

- A **SendData** function will always return immediately without waiting for an answer. Depending on the command, several seconds may expire before the answer arrives (through a notification or callback).
- Each TPI command causes an (asynchronous) answer (sort of an acknowledgment). Hence, commands and answers usually occur 'pair- wise'. Some commands, however, will result in more

than one result packet.
There is no command at all that does not respond with an answer of some sort!

- Some Error Event types (for example 'beam broken') can occur at any time and are not direct reactions to a command (So called unsolicited events). An application should be prepared to 'catch' these at any time.
- There are numerous 'System Change Events' that can occur at any time. An application may evaluate these (mainly for GUI update);
- The tracker server high-level interface (COM) provides both asynchronous and, to a certain degree, synchronous communication. However, some answer types are always asynchronous by their nature, even when using the synchronous interface.

2.3.4 Working Conditions

The tables below show valid working ranges for selected parameters.

Level 1

Commands in the specific contexts will return a warning status when range is outside level 1 limits, but within level 2 limits. (These values are outside Leica specified working ambient conditions but are still accepted; nevertheless they should be used with caution).
Some other values are just for information (for example height above sea level).

Working ambient conditions	Minimum value	Maximum value
Temperature	+ 5°C	+ 40°C
Height above sea level/elevation (not relevant for software)	-500 m	+3000 m
Air pressure	600 mbar	1170 mbar
Relative humidity	10%	90%
Refraction index IFM	1.00015	1.000331
Refraction index ADM	1.000152	1.000336

Level 2

An Error message occurs when trying to set a value outside the specified range. The values are rejected.

Storage ambient conditions (extended working range)	Minimum value	Maximum value
Temperature	-10°C	+ 60°C
Height above sea level/elevation (not relevant for software)	-2000 m	+7000 m
Air pressure	330 mbar	1400 mbar
Relative humidity	0%	100%
Refraction index IFM	1.000077	1.000419
Refraction index ADM	1.000078	1.000425

2.3.5 Coordinate Parameter Triplets

The values of coordinate parameter triplets (often named as Val1,Val2 and Val3) in most data structures, depend on the currently active coordinate system type and the currently active units.
In addition, measured coordinate values (output) and positioning values (input) are transformed according to currently set transformation- and orientation parameters. Coordinate values for 'filters' (Sphere, Box, Grid) differ from case to case. Details and exceptions are explained in the reference section.
The orientation / transformation filters can be switched off through flags provided by the system settings. Using the default values for orientation and transformation parameters' (0,0,0,0,0,0)/(0,0,0,0,0,0,1) mean invariant transformations. Switching off these filters through the appropriate system settings flags may result in a more performing data-throughput; apart from this, the values are the same as if default values were set (while parameter settings actually are other than default).

Coordinate system type	**Val1**	**Val2**	**Val3**
Cartesian (RHR, LHR)	X	Y	Z
Spherical	H	V	D (=R)
Cylindrical	R	Phi (=H)	Z

X, Y, Z	Cartesian coordinate values
H	Horizontal angle
V	Vertical Angle
D	Distance (=Radius)
R	Radius

PHI	Horizontal Angle (=H)

Different notations of values in different systems (Phi instead of H, D instead of R) maintain continuity with previous releases of application software.

2.3.6 Persistency

The tracker server keeps most settings (such as Units, CS-type, Reflector type etc.) persistently. Recent values will be restored on restart of the Tracker- server.

It is recommended to initially set the required settings, on every client startup – as good programming practice. An application should never rely on certain settings already be done - another application/user may have changed these in the meantime!
Some (mainly critical) settings are intentionally set back to default values upon server reset.

2.3.7 Default Settings

List of the most common parameters and their default factory- settings:

- Orientation parameters: {0,0,0,0,0,0}
- Transformation parameters: {0,0,0,0,0,0,1} (scale factor is 1)
- CS-Type: RHR (right handed rectangular)
- Length: Meter
- Angle: Radian
- Temperature: Celsius
- Pressure: Hecto-pascal = Millibar
- Rel. Humidity: 70%
- Temperature: 20.0°C
- Pressure: 1013.25 mbar (760 mmHg)

- Measurement mode: Stationary
- Temperature range: Medium
- Reflector: None
- Interferometer refr. index: 1.0002711152
- ADM refraction index: 1.0002748652
- Stationary point measurement time:2500 ms
- Continuous measurement; time: 500 ms
- Continuous measurement; number of points: 0 (means infinite)
- Statistic mode: Standard
- Region and grid mode parameters: Arbitrary.

Other, less- common settings, are described in the command reference section.

2.3.8 Application Backward Compatibility

New data types/packets with evolving server versions

This is a very important issue in order to prevent existing application software will break when used in combination with future emScon server software upgrades.
Future versions of emScon may provide new/extended data over the TCP/IP connection, such as **new packet types (new commands)**, **new status messages and new error messages**.
Backward compatibility will be provided, in that existing packets/information structure are neither changed nor removed from the TPI definition (except when explicitly announced), but new one may be added/appended with new server versions.
However, **applications must be designed in a way so they ignore any unknown or unexpected data.** In practice, this generally means that default cases in switch statements should always be

treated as 'neutral' (no action).

Example:

The enum 'ES_SystemStatusChange' in emScon V1.2 contained only two members:

```
enum ES_SystemStatusChange
{
    ES_SSC_DistanceSet,
    ES_SSC_LaserWarmedUp,
};
```

EmScon V1.2 had only two system status change events, as shown above. With emScon version 1.4 (and higher), many more status change events have been introduced (See C- API def file).

A programming statement in a client application (originally developed under V1.2) as shown below, would cause an 'Unexpected Status' message with V1.4 (and higher) emScon servers upon any of the new status events; the application thus would probably fail in combination with a V1.4 emScon server and would require code- adjustments.

```
switch (status)
{
   case ES_SSC_DistanceSet:
      AfxMessageBox("ADM Distance re-established");
          break;

   case ES_SSC_LaserWarmedUp:
      AfxMessageBox("Laser is now ready");
          break;

   default:
      AfxMessageBox("Unexpected Status");
      break; // WRONG!!!
};
```

Solution:

Ignore the default case by doing no action at all (or one that just has an effect to debug versions).

```
   default: // No action at all
      break;

or

   default: // no effect to retail versions
      TRACE("Unexpected Status");
      ASSERT(false);
      break;
```

Summary: emScon client application only must interpret KNOWN, i.e. defined data according to enums/structs in current C- API file. All other data must be ignored.

Only if this rule is attended, existing emScon client applications will also run with future emScon server upgrades. Otherwise, application source may need to be adjusted to be compliant to new server versions.

Applications supporting different server versions

If an application is required to support tracker hardware with different capability and/or several emScon server versions, some important version checking issues apply.
Consider for example that the same application should be able to deal with emScon V1.5 (3D only) as well as with emScon V2.0 and up (3D trackers as well 6DoF systems).
Since newer emScon server versions always are backward compatible - that is, all previous commands are also covered by the newer versions - there is usually no problem to run an already existing application on a newer server version (exceptions see previous chapter).
The problem starts for applications that should support 6DoF systems (emScon server V2.0 and up), but should also be able to deal with 3D trackers running on an emScon V1.5 server.
In order to run properly, such an application should check the server version upon startup and make provisions to prevent calls not suitable to a particular server version.
The version info can be queried from the server; it is part of the information delivered by the 'GetSystemStatus' command (ESVersionNumber).
Depending on this version, the application has to allow/prevent commands for execution.
If the queried server version for example evaluates to 1.5, the application would have to block (for example gray-out menus) all 6DoF related commands.
See 'enum ES_Command' in file ES_C_Api_def.h for availability of commands in what version.

There are comments such as
```
// New commands added for release 2.0
```

2.3.9 Sample Code

The samples/tutorials, which are part of the SDK and which have to be regarded as integral part of this manual, show the principles of TPI programming in terms of ready to compile/use applications.
However, most sample applications may **not be of real practical use**, with respect to the specific TPI commands they implement. The focus of the samples is set to show **principles** of tracker control.

Initial Steps

In a practical application, in order to get accurate results, it is crucial to implement all the steps as listed under 'Initial steps'.

Minimal Code

The number of files and code- overhead in the samples has been kept to a minimum. Code generated from wizards, such as *recompiled headers, icon, res2 includes* and 'cosmetic functions', have been stripped off.
See also the numerous comments in the sample source files and the 'ReadMe.txt' files in each sample folder.

Error Handling

The samples do not always implement complete error handling and may need to be run through the debugger in order to find failure reasons.

Interface Design

The user interface design is kept at a minimum level (for example, unavailable buttons are not grayed out). Such items are general issues of

Windows programming.

Hard Coded Information

The samples may contain some hard-coded information (IP address/coordinate values) that might be adapted to the local environment.

2.4 Application Initial Steps

2.4.1 Essential Steps

A client application must carry out all steps listed below upon startup. Omitting some of these steps may prevent the tracker from measuring or lead to inaccurate results. Inaccurate results are difficult to detect.
Setting correct environment parameters (temperature, pressure, humidity) or configuring the system for automatic, environment parameter reading is crucial.
Most of the Settings ('Set'- commands) remain persistent. That is, they will be the same after a system restart. However, it is strongly recommended that an application always confirms these settings upon startup. This is because another application (e.g. emScon Base User Interface) could have accessed the tracker server in the meantime and could have changed the settings.
Note that most of the sample applications are not complete to this respect – the intention of the Samples is to show programming principles only. See also Leica Tracker/Training Manual.

Important: The emScon Compensation Application (Web Application) sets the system into a special mode called **Compensation Mode**. If this mode is active, all commands will return with an error status 'ES_RS_InCompensationMode'.
In other words: The TPI interface is locked while a Compensation / Field check is being performed. A client application, upon startup, should therefore verify the system is not in compensation mode. This can be done explicitly by using any

'Get...' command: If the command completes with 'ES_RS_AllOK', the system is NOT in compensation mode. If the status 'ES_RS_InCompensationMode' is returned, the application should inform the user and exit. Checking the compensation mode can also be done 'implicitly' by evaluating the status of the very first command the application sends after connecting to the server. This can be any 'Set...' or a 'Get...' command.

2.4.2 Command Sequence for 3D Measurements

3D Measurements are performed to a (currently selected) Reflector. The selected Measurement Mode must apply to one of the 3D modes. The tracker does not require a T-Cam, although there might be one mounted during 3D measurements.

Steps	**TPI command**
1. Establish TCP/IP connection.	Depends on TCP/IP communication API – See different samples
2. Set units (length, angle, temperature and pressure)	ES_C_SetUnits
3. Set current environmental temperature, pressure and humidity	ES_C_SetEnvironmentParams,
4. Initialize the Laser Tracker	ES_C_Initialize
5. Select desired 3D Measurement mode (Stationary, ContinuousTime..)	ES_C_SetMeasurementMode
6. Query all defined Reflectors (optional)	ES_C_GetReflectors
7. Select the Reflector being used	ES_C_SetReflector

8. Go Bird Bath (optional, if Tracker equipped with an ADM) For 6D modes, the tracker will move to zero position instead; GoBirdBath does not make sense for Probes	ES_C_GoBirdBath
9. Set Station Orientation parameters	ES_C_SetStationOrientationParams
10. Set Transformation parameters	ES_C_SetTransformationParams
11. Set Coordinate system type (RHR, LHR…)	ES_C_SetCoordinateSystemType
12. 'SendUMessages' should always be enabled. `(boolean in struct SystemSettingsDataT)`	ES_C_SetSystemSettings

In addition, a valid Mechanical Tracker Compensation must be active. This is usually always the case (supposed the Tracker compensation once has been performed or imported). However, there can be exceptions when installing new software or importing compensation data.
The active compensation is a persistent setting which can be changed by a 'SetCompensation' TPI command (or by selection within the compensation tree- representation in the Compensation- application).
See description of 'GetCompensations / GetCompensation / SetCompensation'.

2.4.3 Command Sequence for 6DoF Measurements

6DoF Measurements are performed to a T-Probe, which will be recognized automatically by the system. The selected Measurement Mode must apply to one of the 6DoF modes. A T-Cam must be mounted.

Steps	**TPI command**
1. Establish TCP/IP connection.	Depends upon TCP/IP communication API – See different samples
2. Set units (length, angle, temperature and pressure)	ES_C_SetUnits
3. Set current environmental temperature, pressure and humidity	ES_C_SetEnvironmentParams,
4. Initialize the System	ES_C_Initialize
5. Select desired 6DoF Measurement mode	ES_C_SetMeasurementMode
6. Ensure that 'Keep Last Position' flag is enabled	ES_C_SetSystemSettings OR ES_C_SetLongSystemParameter
7. Set Station Orientation parameters	ES_C_SetStationOrientationParams
8. Set Transformation parameters	ES_C_SetTransformationParams

9. Set Coordinate system type (RHR, LHR…)	ES_C_SetCoordinateSystemType
10. 'SendUMessages' should always be enabled. `(boolean in struct SystemSettingsDataT)`	ES_C_SetSystemSettings

In addition, apart from a valid Mechanical Tracker Compensation (see 3D), compensations must be present and active for TCamToTracker, Probe and TipToProbe (supposed all these compensations have once been performed or imported). Active compensations are persistent settings that can be changed by the several 'Set…Compensation' TPI commands (or by selection within the compensation tree-representation in the Compensation- application). See description of 'Get…Compensations / Get…Compensation / Set…Compensation'.

Selection of TCam and Probe compensation only mean a 'hint' to the system. The compensations themselves only become really active if a matching TCam (i.e. compensation matches the serial number of TCam) is mounted, respectively if a matching Probe is connected and recognized by the camera.

2.4.4 Initial Steps Description in Detail

Description of some commands that require more explanation.

Initialize Laser Tracker

Implication	Comment
Initialize encoders and internal components	This command has to be performed every time you set up a new Leica Tracker system station. It is strongly recommended to use this function 2-3 times a day to initialize encoders and its internal components. This is important due to thermal expansion of the tracker hardware, which has a direct influence on the measurements

Set Current Environmental Parameters

Implication	Comment
Calculate and Set index of refraction	With the input of the environmental temperature, pressure and humidity, the system calculates the light refraction index of the interferometer (IFM) and the absolute distance meter (ADM). These parameters have a direct influence on the distance measurement A change of 1°C causes a measurement difference of 1ppm. A change of 3.5mbar causes a measurement difference of 1ppm. Change environmental parameters when significant changes take place. Default values: 20.0 °C, 1013.3 mbar

Set Reflector

Implication	Comment
Select a specific reflector	A wrong reflector results in a wrong initial IFM distance, e.g. when using the *Go Birdbath* command. This has a direct influence on the distance measurement. Tooling ball reflector (TBR) = 5.310 mm Cat eye = 59.114 mm There is usually more than one reflector defined. These can be queried from the system by using the 'GetReflectors' command. This shows the relation between the ID and the Name (Reflector Type). The ID can then be passed to the 'SetReflector' command to activate it. Note that this setting remains persistent. Nevertheless it's strongly recommended that an application upon launch at least checks whether the desired Reflector is set More info: Chapter 8: 'Get Reflectors' command

Set Compensation

Implication	Comment
Select a specific Mechanical Tracker Compensation	More than one mechanical Tracker Compensation may be defined for a tracker (although often there is only one). If there is more than one, these can be queried from the system by using the 'GetCompensations' command. This will show the relation between the ID (a number) and the Name (a Date- String) of the available compensation. The ID can then be passed to the 'SetCompensation' command in order to activate it. Note that this setting remains persistent. Nevertheless, it's a good idea that an application upon launch at least checks whether the desired compensation is set (command GetCompensation). The principle of dealing with compensations is the same as for Reflectors. For more details see chapter 8: 'Get Reflectors' command

Set T- Cam To Tracker Compensation

Implication	Comment
Select a specific T- Cam to Tracker Compensation. Related to 6DoF modes only.	More than one T- Cam to Tracker Compensation may be defined for a tracker/ camera (although often there is only one). If there are more than one, these can be queried from the system by using the 'GetTCamToTrackerCompensations' command. This will show the relation between the ID (a number) and the Name (a Date- String) of the available compensation. The ID can then be passed to the 'SetTCamToTrackerCompensation' command in order to activate it. Note that this setting remains persistent. Nevertheless, it's a good idea that an application upon launch at least checks whether the desired compensation is set (command 'GetTCamToTrackerCompensation'). The principle of dealing with compensations is the same as for Reflectors. For more details see chapter 8: 'Get Reflectors' command

Set Probe Compensation

Implication	Comment
Select a specific Probe Compensation. Related to 6DoF modes only.	More than one Probe Compensation may be defined for a tracker/ camera (although often there is only one). If there is more than one, these can be queried from the system by using the 'GetProbeCompensations' command. This will show the relation between the ID (a number) and the Name (a Date- String) of the available compensation. The ID can then be passed to the 'SetProbeCompensation' command in order to activate it. Note that this setting remains persistent. Nevertheless, it's a good idea that an application upon launch at least checks whether the desired compensation is set (command 'GetProbeCompensation') The principle of dealing with probe compensations is the same as for Reflectors. For more details see chapter 8: 'Get Reflectors' command

Keep Last Position Flag

Implication	Comment
Makes the laser beam stay at its current position if the beam is broken.	Enabling this flag is optional for 3D measurements (it makes only sense if the Tracker is equipped with an ADM). This flag is cleared by default. For 6DoF measurements, enabling this flag is compulsory to prevent the laser going to home position upon a beam break. (Automatically re-measures reference distance to the Reflector or T-Probe after the laser beam has been lost.) There are two ways to control this flag, either through the command 'SetSystemSettings' or through 'SetLongSystemParameter'

Station Parameters

Implication	Comment
The station parameters describes the translation and rotation of the tracker station in a coordinate system: X, Y, Z, Omega, Phi, Kappa	Orientation parameters can be determined using the Transformation functionality of emScon (see chapter 'Points to points Transformation') or can be individually set by the application. By default, the orientation parameters are as follows: (X=0/Y=0/Z=0/Omega=0/Phi=0/Kappa=0).

Transformation Parameters

Implication	Comment
A transformation describes a change into another coordinate system, which is different from the tracker coordinate system. It has the following parameters: X, Y, Z, Omega, Phi, and Kappa and scale factor.	Transformation parameters can be determined using the Transformation functionality of emScon (see chapter 'Points to points Transformation') or can be individually set by the application. By default, the transformation parameters are as follows: (X=0 / Y=0 / Z=0 / Omega=0 / Phi=0 / Kappa=0 / Scale = 1.

Coordinate System Type

Implication	Comment
Selects the coordinate system type: RHR/LHR X, LHR Y, LHR Z/CCW/CCC/SCW/SCC	The TPI delivers the data in the current coordinate system type. By default the tracker system will work in the right handed rectangular coordinate system (RHR) type: 3D rectangular coordinates are defined by 3 mutually perpendicular axes X, Y and Z given in the order (X, Y, Z). Since the axes can be arranged in two different ways, right and left-handed systems are defined according to the convention illustrated in a simple 2D case. Cylindrical Clockwise (CCW), Cylindrical Counter Clockwise (CCC). In a cylindrical system, the X and Y values are expressed in terms of a radial (distance) offset from the Z-axis and a horizontal angle of rotation. The Z coordinate remains the same.

Implication	Comment
	Spherical Clockwise (SCW), Spherical Counter Clockwise (SCC). In a spherical system, a point is located by a distance and two angles instead of the 3 coordinate values along the rectangular axes. For axes labeled XYZ, with Z vertical, the point is located by its distance from the origin, horizontal angle in the XY plane and zenith angle measured from the Z-axis.

2.4.5 Automatic External Device Recognition

This is an improved new feature that comes with emScon version 3.0 (except for systems running on external emScon servers).
This subject applies to so-called 'external devices' (Meteo Station, Overview Camera, Inclination Sensor [Nivel]).
In former versions, it was necessary to explicitly enable these devices by setting related flags (`[hasVideoCamera, hasNivel, weatherMonitorStatus]`) on using the 'SetSystemSettings' or 'SetLongSystemParameter' command. See chapter about struct **SystemSettingsDataT** for details.
In order to keep backward compatibility, these commands/flags still exist and will behave in a way that should not cause any problems to existing applications, although their behavior has slightly changed.
Here is a description of the new automatic device recognition behavior:

- **General Behavior**
  When the system is initialized any device that is currently plugged in will be recognized and set accordingly. If the operator forgot to plug something in prior to initializing, he can simply connect it and re-initialize the system to find the device.
- **OVC Recognition**
  During initialization the system will check to see if an Overview Camera (OVC) is attached. If yes, then the flag will be set to true, and communication should start to the device.
  If the operator (application) tries to set the flag false after the system has set it as true, then the system should allow it and end communication to the device, but will reset the flag and communication correctly on the next initialization.
  If the system sets the flag to false, but the operator (application) tries to force it to true, then the system should check to see if an OVC is attached before it allows the flag to be set as requested.
- **Inclination Sensor [Nivel] Recognition**
  During initialization the system will check to see if a NIVEL is attached. If yes, then the flag will be set to true, and communication should start to the device.
  If the operator (application) tries to set the flag false after the system has set it as true, then the system should allow it and end communication to the device, but will reset the flag and communication correctly on the next initialization.
  If the system sets the flag to false, but the operator (application) tries to force it to true, then the system should check to see if

a NIVEL is attached before it allows the flag to be set as requested.

- **Meteo Station Recognition**
  During initialization the system will check to see if a Meteo Station is attached. If yes, then the flag will be set to true, and 'ReadAndCalculateRefractions' should start. If the operator (application) wants to switch to 'ReadOnly' this will have to be done through the appropriate command.
  If the operator tries to set the flag false after the system has set it as true, then the system should allow it and end communication to the device, but will reset the flag and communication correctly on the next initialization.
  If the system sets the flag to false, but the operator (application) tries to force it to true, then the system should check to see if a Meteo Station is attached before it allows the flag to be set and 'ReadAndCalculateRefractions' to start as requested.

Note that this automatic device recognition feature is not supported by external emScon servers – these still follow the ‘old’ behavior.

3 C - Interface

3.1 Low-level TPI Programming

3.1.1 Preconditions

Using the C interface requires some particular C-programming knowledge. A programmer should at least know about asynchronous programming concepts, TCP/IP socket programming and multi-threading.

The description of the enums and structs in this chapter sometimes may be slightly discrepant to the contents of the 'ES_C_API_Def.h' file. **In such cases, the information in the 'ES_C_API_Def.h' file should be regarded as correct.**

This chapter completely and exclusively relates to the file 'ES_C_API_Def.h', which is part of the EmScon SDK. All Enumeration types and Structures are described in this header file. This header file acts as an integral part to this manual and it might be helpful to have it open in parallel to this document since the information is much more condensed there.

3.1.2 Recommendation

Although the C- interface makes up the native programming- interface to emScon, it is not usually recommended to write applications directly using the C- interface.
Rather use the much more convenient C++ (or C# or COM) interface.
In contrast to the C++ interface, the C-interface requires much more coding lines and comprises

the danger of doing initialization errors for structures (aka 'copy/paste errors').
However, since it's the native interface, the enumeration types and structures of the C-interface serve as main- reference.
The same enumeration types and parameters will show up - in slightly different contexts with slightly different terminology - in the other interfaces as well.
Hence, even when working with the C++-interface (or C#, COM), looking up information in this chapter 'C- Interface' might be essential.

3.1.3 Byte Alignment

Data packets have a 4-Byte alignment convention. The VC++ statement *#pragma pack (push, 4)*, before user-defined structure definition, uses 4 Byte alignment – VC++ default is 8 Byte. The statement *#pragma pack (pop*) sets the alignment back to the previous value.

Use only 4 Byte alignments for TPI structures.

These are Microsoft VC++ specific statements. When using a non-Microsoft compiler, *#pragma pack (push, 4)* and *pragma pack (pop)* may have to be replaced by appropriate directives.

The following include statement prepares the *C_API_Def.h* file for Byte alignment in Linux/ Win32.

4 Byte alignments for other platforms must be forced

```
#ifdef _WIN32
#pragma pack (push, 4)
#elif defined __linux__
#pragma pack (4)
#elif
#error Insert here directive to ensure 4 Byte alignment for
other platforms (Unix, MAC)
#endif
```

3.1.4 Little/Big Endians

Non-Intel based workstations, for example M68000 based workstations like SUN, Apple or

IBM RS6000 series, use different *endians* for double values. The client application (the TCP/IP communication interface respectively) requires appropriate measures to interpret numerical values correctly.

The Tracker Server is Intel based. All values are provided in the *little endian* format.

3.1.5 Preprocessor Statements

The following statements show a common practice to avoid multiple inclusion of the same include-file while compiling a *.CPP* module. In case of nested inclusion of the *ES_C_API_Def.h* file, these statements will prevent warnings for multiple definitions of data types.

```
#ifndef ES_C_API_DEF_H
#define ES_C_API_DEF_H
…
#endif
```

3.1.6 TPI 'Boolean' Data Type

No native Boolean data-type is available in C. C uses the integer basic type for Boolean values. For convenience, a platform- independent *ES_BOOL* type has been introduced for the *ES_API*:

typedef int ES_BOOL

Neither BOOL (which is 2 Bytes and Microsoft-specific) nor bool (which is 1 Byte and specific to newer C++ revisions) has been used. By using a 4 Byte Boolean (= int), pure C compliance and maximal portability is assured.

This relates only to the C interface, *ES_C_API_Def.h*. The C++ interface as well as custom programs may use any compatible Boolean type. Boolean type variables used in *ES C API structs* must be 4 bytes.

3.1.7 Enumeration-Type Members Numerical representation

Enumeration-type members in C are internally represented by integer values. Numbers can be assigned explicitly to particular enum values; this is the case for all enumeration types defined for emScon.
This approach has some advantages for application debugging . However, applications should never use the numerical values directly. Always use the according symbol-names.

3.1.8 Basic C Data Type size of TPI Structures

This is relevant for programming languages other than C/C++. However, some non-standard C/C++ compilers may provide different sizes of basic data types. For TPI clients, it is necessary to use the following standard sizes:

Data type	**Size**
Enum values	4 Bytes (= int 32 or long)
Long	4 Bytes
Int	4 Bytes
Short	2 Bytes (for Unicode strings exclusively)
Double	8 Bytes
ES_BOOL	4 Bytes (= int 32 or long)

3.2 Communication Basics

3.2.1 Sending Commands

The Tracker Server can be controlled only through commands sent over TCP/IP. Commands differ in the count of parameters they take.

- *GoBirdBath* is an example for a non-parameter taking command.
- *PointLaser (x,y,z)* takes 3 parameters.

The majority of commands taking parameters are used for so- called property setting

Set<CommandName> commands. The syntax of each command – whether taking parameters or not – is defined by its *<CommandName>CT* structure.

These structures need to be initialized properly. Refer to C- Programming instructions section.

3.2.2 Command Answers

Every command causes an asynchronous answer. At least this is an acknowledgment (for non data-returning commands).
The command-type (one of the members of the enum ES_Command) previously sent to the Tracker Server is echoed back, padded with information whether the command succeeded or not, and (optionally) padded with command specific data. The command type thus can be seen as 'cookie' to match the received data properly with the issued command. Depending on the command type, this echo can occur immediately, or may take several seconds (for example for *FindReflector* or *Initialize Tracker*).

Generally, a *<CommandName>RT* structure defines the contents of a command answer. However, there are some special cases in the case of measurements commands.
The command answers can be categorized into several subtypes as listed below.

Non-data Returning Command Answers

This command answer-type essentially consists of a command type 'cookie' with the return status 'succeeded' or 'failed'. In case of failure, the return status (its numerical representation or enum-status value) may indicate the reason. Non-data returning commands all share the same basic return type structure. *Find Reflector* is an example of a non-data returning command.

Property-data Returning Command Answers

Properties are the (current) system settings of the Tracker Server. Properties can be retrieved by *Get<xxx>* commands. All *Get<xxx>* commands return their results in a *Get<xxx>RT* structure. The RT structure for each command differs with respect to its data members. Data members with only a *Get…* with no corresponding *Set…* command can be individual basic-type or enum parameters (int, double , enum...) . Example: *GetSystemStatusRT*.
However, the normally there is a command-specific sub structure (example *GetUnitsRT* contains a *SystemUnitsDataT* sub structure).
In other words: a sub- structure is available, when the same parameters are used for more than one command. This avoids code duplication.

Set/*Get* commands rarely fail. If a *Set* command fails (return status not OK), the supplied parameters are usually out of valid range. The return status informs about the failure reason.

Single Measurement Answers

These are answers that follow to a previously issued *Start<xxx>MeasurementCT* command. Single measurements are often also referred to as Stationary measurements.

This applies only when the measurement mode is set to stationary.

- In case of a failure (which is frequent for measurement commands), a *Start<xxx>MeasurementRT* structure with the error code is returned.
- In case of success, instead of a *Start<xxx>MeasurementRT* (not designed to take sensor results), a specifically designed measurement type-related data packet is received. For example, a

ES_DT_SingleMeasResult type indicates a SingleMeasResultT structure, and *ES_DT_StationaryProbeMeasResult* indicates arrival of a ProbeStationaryResultT.
A successful measurement always returns such a data-packet.

Multi-Measurement Answers

These apply to tracker related continuous measurements only. The measurement mode is set to one of the non- stationary modes.

- In case of failure, as with single measurement answers, a *Start<xxx>MeasurementRT* with error code is returned.
- In case of success, not only one packet, but also a series of multi-measurement packets arrive. Each one of these packets contains a various-sized array of 'single' (atomic) measurements.
  See also structures 'MultiMeasResultT', 'MultiMeasResult2T' and 'ProbeContinuousResultT'.
- Only the first element of the measurement array is covered by these structures, although the index is valid from 0…numberOfResults-1. There is another significant difference to single measurements. Before the measurement data packet stream starts, a *StartMeasurementRT* with command status *OK* arrives (acknowledge that the 'start' command has arrived).
- Single measurement results always arrive within a certain time span. This is not the case with continuous measurements (Grid Mode, big time separation criteria.). A *StartMeasurementRT* confirmation is therefore essential for continuous modes.

A multi-measurement stream runs until explicitly stopped, *StopMeasurement* or until specified time or count thresholds are reached.

Special Command Answers

Some commands, such as *ES_C_GetReflectors* and *ES_C_GetTransformedPoints, ES_C_GetCompensations, ES_C_GetTipAdapters.* do not fit any of the above categories.
Generally spoken, all commands starting with 'Get' and ending with an 's' (i.e. plural) are treated in a special way.

ES_C_GetReflectors must not to be mixed up with *ES_C_GetReflector* (missing 's').

Convention:

The answer to these commands is made up of as many answer-packets as reflector types (or transformed points, Compensations, Tips...) are available from the Tracker Server.
These answers mainly resolve the relation between item name (string) and item ID (numerical ID), for example the relation between Reflector name and Reflector ID.
Apart from different other information, the packets also contain (redundant) information on the total number of items and the number of packets expected to arrive.

Convention:

All string-type names are in Unicode representation – Example: short cReflectorName[32] declaration. It can consist of a maximum of 32 characters, however, since 'short' is 16 bit, there are 16 bits for every character (two Bytes).

ReflectorPosResultT and *ProbePosResultT* can also be seen as a special command answers. These are *ES_DT_ReflectorPosResult* / *ES_DT_ProbePosResult* type packets and are received whenever the tracker is locked onto a reflector (3 measurements per second), supposed the 'SendReflectorPositionData' system- setting flag is enabled. This mechanism can be used in applications providing graphical representation of reflector/probe motion, even while no continuous measurement is in ongoing.
Note that the accuracy of the positions provided are limited. The receipt of these measurements can be switched on/off. It is switched off by default.

3.2.3 Error Events

Most error-type data packets *ES_DT_Error* are not direct reactions to commands. They are 'unsolicited' and can occur at any time. These confirm the highly 'asynchronous' behavior of emScon communication. A typical example is the 'Laser beam broken' event.

Commands contain the error status in their answer structure in case of failure.
ES_DT_Errors type answer packets are only used for so called 'unsolicited errors' (which can occur at any time, regardless of a command).

3.2.4 System Status Change Events

Although already present in version 1.2 (only two events), there has been an inflation of such events since then. The appropriate packet type is *ES_DT_SystemStatusChange.* The handling is the same as with error events, with the only difference that there is only one parameter.

IMPORTANT: See chapter 'Version Backward Compatibility' for convention about handling 'unknown' data.

3.2.5 3D / 6 DoF – Related commands

The essential change between emScon v1.5 and emScon V2.0 is the introduction of 6DoF measurement structures (6 degrees of freedom). Some were already present in v1.5. However, these were declared as preliminary and have significantly changed since then.
From programming point of view, handling 6DoF measurements is principally the same as 3D measurements. The only difference is that other data structures are to be used. Here is an overview of the related commands / packets / structures:

3D Packets/Commands	***6DoF (Probe) Packets/Commands***
ES_DT_SingleMeasResult	ES_DT_StationaryProbeMeasResult
ES_DT_MultiMeasResult	ES_DT_ContinuousProbeMeasResult
ES_DT_ReflectorPosResult	ES_DT_ProbePosResult

3D Structures	***6DoF Structures***
SingleMeasResultT	ProbeStationaryResultT
MultiMeasResultT	ProbeContinuousResultT
ReflectorPosResultT	ProbePosResultT

The *ES_DT_SingleMeasResult2* / *SingleMeasResult2T* and *ES_DT_MultiMeasResult2* / *MultiMeasResult2T* packets / commands are extended variants of the relatives without the '2' in their name. The only difference is that these versions contain extended (statistical) information. Applications passing measurements to the 'CallTransformation' command should use the '2'- variants since the transformation routine requires these extended statistics. See also 'SetStatisticMode' command.

3.3 C- Language TPI Reference

3.3.1 Constants

This section names the constants that can be used with C/C++ TPI programming.

The application needs to include the file 'Constant.h' in addition to 'ES_C_API_Def.h'.

Constants for Transformation

These constants are used exclusively for the Weighting Scheme of the Transformation process (see Section 9.2.6).

ES_FixedStdDev

```
const double ES_FixedStdDev = 0.0;
```

Use this value (= 0.0) to indicate a parameter as fixed.

ES_UnknownStdDev

```
const double ES_UnknownStdDev = 1.0E+35;
```

Use this value to indicate a parameter as unknown (not fixed).

ES_ApproxStdDev

```
const double ES_ApproxStdDev = 1.0E+15;
```

Use this value to weigh parameters according to its related Standard Deviation.

See command 'SetTransformationInputParams' for details.

Other Constants

The other constants defined in 'Constant.h' (Unit-Conversion related constants) are for informational reasons only and should not be directly referenced by emScon applications.

3.3.2 Enumeration Types

This section describes all enumeration types and their individual values.

ES_DataType

The ES_DataType enumeration values are used to identify the type of data packets that are sent to/received from the Tracker Server on TCP/IP. There are 11 different packet types that differ in size and structure.

The ES_DT_Command comprises many sub-types that all differ in size and structure as well. A related data type is PacketHeaderT, which serves as a sub-structure in all packets.

```
enum ES_DataType {
   ES_DT_Command,
   ES_DT_Error,
   ES_DT_SingleMeasResult,
   ES_DT_MultiMeasResult,
   ES_DT_StationaryProbeMeasResult,
   ES_DT_ContinuousProbeMeasResult,
   ES_DT_NivelResult,
   ES_DT_ReflectorPosResult,
   ES_DT_SystemStatusChange,
   ES_DT_SingleMeasResult2,
   ES_DT_MultiMeasResult2,
   ES_DT_ProbePosResult,
};
```

- ES_DT_Command
  The data packet contains a command (sent), or a command answer (received).
  Related data structures: BasicCommandCT and BasicCommandRT (which are used as sub-structures of each command-related structure).
- ES_DT_Error
  The data packet contains error information. Such a packet means an 'Error event' (For example 'beam broken'). It is not a reaction of some previous command and can occur at

any time.
Related data structure: ErrorResponseT.

- ES_DT_SingleMeasResult
  The data packet contains the result of one single (stationary 3D) measurement. 'Result'-type packets can only be received.
  Related data structure: SingleMeasResultT.
- ES_DT_MultiMeasResult
  The data packet contains results of a continuous 3D measurement. This type of result block is of variable size and depends on the number of single measurements within a block. 'Result'- type values can only be received.
  Related data structure: MultiMeasResultT.
- ES_DT_StationaryProbeMeasResult
  The equivalent to SingleMeasResult, but with 6 degrees of freedom, i.e. the data block contains 3 angular values in addition to 3 coordinate values (apart from other data).
  Related data structure: ProbeStationaryResultT.
- ES_DT_ContinuousProbeMeasResult
  The equivalent to MultiMeasResult, but with 6 degrees of freedom, that is, the data block contains measurements each with 3 rotation parameters in addition to 3 coordinate position values (apart from other data).
  Related data structure: ProbeContinuousResultT
- ES_DT_NivelResult
  The data packet contains the result of a Leica 'Nivel' sensor (inclination sensor) measurement.
  Requires a Leica 'Nivel' (inclination sensor of type 'Nivel20' or 'Nivel230') being connected to the Tracker directly. 'Result'-type values can only be received.
  Related data structure: NivelResultT.

- ES_DT_ReflectorPosResult:
  The data packet contains position information about the reflector. This type of information is foreseen for special purposes and can be suppressed.
  Related data structure: ReflectorPosResultT.
- ES_DT_SystemStatusChange
  The data packet contains information about a status change. Other than an error event, a SystemStatusChange event does not mean a failure.
  Related data structure: SystemStatusChangeT.
- ES_DT_SingleMeasResult2
  The data packet contains the result of one single (stationary) measurement, in case the statistic mode is set to 'extended'. These types are mainly used for measurements used as input to the Transformation routine.
  See command 'SetStatisticMode'.
  The difference is that SingleMeasResult2T contains more statistical information than the standard SingleMeasResultT. This is an advanced feature. The default statistic mode is 'standard'. (This 'type 2 meas result' has been introduced to avoid changes to already published TPI definitions with earlier versions, in order not to break existing applications.).
  Related data structure: SingleMeasResult2T.
- ES_DT_MultiMeasResult2
  The data packet contains results of a continuous measurement, in case the statistic mode is set to 'extended'.
  See command 'SetStatisticMode'.
  The difference is that MultiMeasResult2T contains more statistical information than the standard MultiMeasResultT.

The default statistic mode is ‘standard’.
Related data structure: MultiMeasResult2T.

- ES_DT_ ProbePosResult
  The equivalent to ES_DT_ReflectorPosResult, but related to probes with 6 Degrees of freedom. I.e. Not only the position, but also the rotation is supplied.

ES_Command

This enumeration type names all commands that are provided by the TPI. A data packet of type ES_DT_Command contains exactly one of these values. The answer packet to a command returns the same value for acknowledgment.
See struct 'BasicCommandCT' for details.

General Information related to each command:

1.) Naming Convention Send / Receive Structs

The related data- structures for sending and receiving data can be derived from the command name as follows:

- Remove the ES_C_ Prefix from the command
- Add CT postfix to get name of related send-structure (CT stands for CommandType)
- Add RT postfix to get name of related receive-structure (RT stands for ReturnType)

Example: Structures related to command 'ES_C_Initialize' are 'InitializeCT' and 'InitializeRT'

If CT/RT structures contain sub- structs, these are mentioned at each commands description.

Explanations are available at the command descriptions (ES_C_...) and also at the related structure descriptions (..CT, ..RT). To avoid too much redundancy, descriptions are usually not repeated at both locations. Thus it might be necessary to look- up command descriptions and related structure descriptions.

2.) Dimensions / Units of Parameters

Unless stated explicitly in the command description, the following units of all parameters are always in 'current units'. That is, in those units the application/programmer has selected with the SetUnits command:

- Length- units

- Angle- units

- Temperature- units

- Pressure- units

- Humidity- units (currently only one: percent)

This applies to parameters sent as well as those received such as coordinates, standard deviations, meteorological values...

- Currently, there is only one exception to this rule: The command StartNivelMeasurement delivers the native Nivel inclination readings. These are milli-radiants and degrees Celsius, regardless of currently selected units.
- Other units include:
  - Time – units:
  These are always in milliseconds – unless stated differently. Example: a Stationary Measurement Time of '2000 'means two seconds.
- String- type parameters:
  Strings as far as handled through the TPI are always in UNICODE (arrays of unsigned short). That is, two bytes are reserved for each character. As far as pure ANSI text is used, an application can just ignore each second byte. See sample applications for examples.
- Enumeration-type parameters: These are type-safe with the related enum definition. The

parameters are described at the enum-definition location.

3.) Valid Parameter Ranges

This applies to parameters being sent to the system, typically with one of the 'Set..' command. Where limitations apply, these are mentioned at the command description.
See also chapter 'Working Conditions' in the 'Introduction' main chapter of this manual.
Note that it is never possible to violate valid parameter ranges in such that the related 'Set..' commands do not accept values outside valid range and therefore will return with an error.

Reading Instructions Set/Get Command- pairs.

Information about parameter representation in terms of current Units, Coordinate System- Type (CS-type), Transformation and Orientation is provided at the Description of the 'Set..' command, but not repeated at the description of the related 'Get..' command.
It is obvious that these information apply to both 'Set..' and 'Get..'. (Although the valid range information is obsolete for 'Get..' commands).

```
enum ES_Command
{
   ES_C_ExitApplication,
   ES_C_GetSystemStatus,
   ES_C_GetTrackerStatus,
   ES_C_SetTemperatureRange,
   ES_C_GetTemperatureRange,
   ES_C_SetUnits,
   ES_C_GetUnits,
   ES_C_Initialize,
   ES_C_ReleaseMotors,
   ES_C_ActivateCameraView,
   ES_C_Park,
   ES_C_SwitchLaser,
   ES_C_SetStationOrientationParams,
   ES_C_GetStationOrientationParams,
   ES_C_SetTransformationParams,
   ES_C_GetTransformationParams,
   ES_C_SetBoxRegionParams,
   ES_C_GetBoxRegionParams,
   ES_C_SetSphereRegionParams,
   ES_C_GetSphereRegionParams,
   ES_C_SetEnvironmentParams,
   ES_C_GetEnvironmentParams,
   ES_C_SetRefractionParams,
   ES_C_GetRefractionParams,
   ES_C_SetMeasurementMode,
   ES_C_GetMeasurementMode,
   ES_C_SetCoordinateSystemType,
   ES_C_GetCoordinateSystemType,
   ES_C_SetStationaryModeParams,
   ES_C_GetStationaryModeParams,
   ES_C_SetContinuousTimeModeParams,
   ES_C_GetContinuousTimeModeParams,
   ES_C_SetContinuousDistanceModeParams,
   ES_C_GetContinuousDistanceModeParams,
   ES_C_SetSphereCenterModeParams,
   ES_C_GetSphereCenterModeParams,
   ES_C_SetCircleCenterModeParams,
   ES_C_GetCircleCenterModeParams,
   ES_C_SetGridModeParams,
   ES_C_GetGridModeParams,
   ES_C_SetReflector,
   ES_C_GetReflector,
   ES_C_GetReflectors,
   ES_C_SetSearchParams,
   ES_C_GetSearchParams,
   ES_C_SetAdmParams,
   ES_C_GetAdmParams,
   ES_C_SetSystemSettings,
   ES_C_GetSystemSettings,
   ES_C_StartMeasurement,
   ES_C_StartNivelMeasurement,
   ES_C_StopMeasurement,
   ES_C_ChangeFace,
   ES_C_GoBirdBath,
   ES_C_GoPosition,
   ES_C_GoPositionHVD,
   ES_C_PositionRelativeHV,
   ES_C_PointLaser,
   ES_C_PointLaserHVD,
   ES_C_MoveHV,
   ES_C_GoNivelPosition,
   ES_C_GoLastMeasuredPoint,
   ES_C_FindReflector,
   ES_C_Unknown,
   ES_C_LookForTarget,
   ES_C_GetDirection,
   ES_C_CallOrientToGravity,
   ES_C_ClearTransformationNominalPointList,
   ES_C_ClearTransformationActualPointList,
   ES_C_AddTransformationNominalPoint,
   ES_C_AddTransformationActualPoint,
   ES_C_SetTransformationInputParams,
   ES_C_GetTransformationInputParams,
   ES_C_CallTransformation,
   ES_C_GetTransformedPoints,
   ES_C_ClearDrivePointList,
   ES_C_AddDrivePoint,
   ES_C_CallIntermediateCompensation,
   ES_C_SetCompensation,
   ES_C_SetStatisticMode,
   ES_C_GetStatisticMode,
   ES_C_GetStillImage,
   ES_C_SetCameraParams,
   ES_C_GetCameraParams,
   ES_C_GetCompensation,
   ES_C_GetCompensations,
```

```
    ES_C_CheckBirdBath,
    ES_C_GetTrackerDiagnostics,
    ES_C_GetADMInfo,
    ES_C_GetTPInfo,
    ES_C_GetNivelInfo,
    ES_C_SetLaserOnTimer,
    ES_C_GetLaserOnTimer,
    ES_C_ConvertDisplayCoordinates,
    ES_C_GoBirdBath2,
    ES_C_SetTriggerSource,
    ES_C_GetTriggerSource,
    ES_C_GetFace,
    ES_C_GetCameras,
    ES_C_GetCamera,
    ES_C_SetMeasurementCameraMode,
    ES_C_GetMeasurementCameraMode ,
    ES_C_GetProbes,
    ES_C_GetProbe,
    ES_C_GetTipAdapters,
    ES_C_GetTipAdapter,
    ES_C_GetTCamToTrackerCompensations,
    ES_C_GetTCamToTrackerCompensation,
    ES_C_SetTCamToTrackerCompensation,
    ES_C_GetProbeCompensations,
    ES_C_GetProbeCompensation,
    ES_C_SetProbeCompensation,
    ES_C_GetTipToProbeCompensations,
    ES_C_GetTipToProbeCompensation ,
    ES_C_SetExternTriggerParams,
    ES_C_GetExternTriggerParams ,
    ES_C_GetErrorEllipsoid,
    ES_C_GetMeasurementCameraInfo,
    ES_C_GetMeasurementProbeInfo,
    ES_C_SetLongSystemParameter,
    ES_C_GetLongSystemParameter,
    ES_C_GetMeasurementStatusInfo,
    ES_C_GetCompensations2,
    ES_C_GetCurrentPrismPosition,
    ES_C_SetDoubleSystemParameter,
    ES_C_GetDoubleSystemParameter,
    ES_C_GetObjectTemperature,
    ES_C_GetTriggerBoardInfo,
    ES_C_GetOverviewCameraInfo,
    ES_C_ClearCommandQueue,
    ES_C_GetADMInfo2,
    ES_C_GetTrackerInfo,
    ES_C_GetNivelInfo2,
    ES_C_RestoreStartupConditions,
    ES_C_GoAndMeasure,
    ES_C_GetTipToProbeCompensations2,
};
```

- ES_C_ExitApplication
  Stop and reset the Tracker Server.
  Other than most commands, 'ExitApplication' takes effect even while another command may still be busy (Initialization, FindReflector..). However, there might be a delayed reaction in certain cases. This command thus can be used for 'emergency aborts' in those cases where 'StopMeasurement' is not sufficient. Applications cannot rely on that this command will send any confirmation (command completed, SystemStatus change events). Depending on context, there may be a reaction or not. Applications should close the TCP/IP connection after having sent the

‘ExitApplication’ command.
Note: ‘ExitApplication’ and ‘StopMeasurement’ are the only two exceptions of commands that cause immediate reaction while some other command is still pending. All other commands will return ‘Server busy instead’. (Hint: This does not apply to the synchronous emScon COM interface (LTControl)).

- ES_C_GetSystemStatus
  Request status information about the system.
- ES_C_GetTrackerStatus
  Request status information about the tracker.
- ES_C_SetTemperatureRange
  Set the Trackers working temperature range.
- ES_C_GetTemperatureRange
  Get the Trackers working temperature range.
- ES_C_SetUnits
  Set Current Units.
  All length, angular, temperature, pressure and humidity- type parameters of all TPI-commands are represented in the currently selected units.
  Exception: Leica 'Nivel' (inclination sensor) readings are provided in the sensors native units (milli-rad, Celsius).
  Related structure: SystemUnitsDataT.
- ES_C_GetUnits
  Queries the currently active unit- settings.
  Related structure: SystemUnitsDataT.
- ES_C_Initialize
  Initializes the tracker.
- ES_C_ReleaseMotors
  Release the motor for horizontal and vertical tracker head movement in order to allow manual tracker head movement.

- ES_C_ActivateCameraView
  Activates the camera view. The mirror is turned upwards in order to direct camera view towards tracker head orientation. Command only applies to Trackers equipped with an overview camera.
- ES_C_Park
  Send tracker to park position. The laser beam points towards the floor on the opposite side of the Bird bath.
- ES_C_SwitchLaser
  Switch the laser off or on. Usually used to switch off the laser overnight.
- ES_C_SetStationOrientationParams
  Set the 6 orientation parameters to be applied to measurements and positioning coordinates. Invariant orientation parameters are {0,0,0,0,0,0}. With these default settings, the tracker delivers measured coordinate values (and takes positioning values) in the instrument's CS. Orientation parameters values are also ignored if the *applyStationOrientationParams* system settings flag is not set.
  Station orientation parameters itself are in current units and current CS-type, but neither according to applied transformation settings nor to applied orientation settings (which would mean recursive). No range limitations apply.
  Related structure: StationOrientationDataT.
- ES_C_GetStationOrientationParams
  Queries the currently applied 6 orientation parameters.
  Related structure: StationOrientationDataT.
- ES_C_SetTransformationParams
  Set the 7 transformation parameters to be applied to measurements and positioning coordinates and to (part of) the input filters

such as region parameters.
Invariant transformation parameters are {0,0,0,0,0,0,1}. With these default settings, the tracker delivers data in the instrument's CS, (or in the 'oriented system', if non-invariant orientation parameters are present).
Transformation parameters are also ignored if the *applyTransformationParams* system settings flag is not set.
Transformation parameters itself are in current units and current CS-type, but neither according to applied orientation settings nor to applied transformation settings (which would mean recursive)! No range limitations apply.
Related structure: TransformationDataT.

- ES_C_GetTransformationParams
  Queries the currently applied 7 transformation parameters.
  Related structure: TransformationDataT.
- ES_C_SetSphereRegionParams
  Defines a spherical region. If the corresponding mode is active, measurements outside the region are suppressed. The interpretation of the parameters is subject to units, coordinate type, and transformation parameters.
  Related structure: SphereRegionDataT
- ES_C_GetSphereRegionParams
  Queries the currently valid sphere region parameters.
  Related structure: SphereRegionDataT.
- ES_C_SetBoxRegionParams
  Defines a box region. If the corresponding mode is active, measurements outside the region are suppressed. The box is connected to the object system given by the transformation parameters. It is defined by its diagonal, i.e. by two points in the object

system. The coordinates of the points are subject to units and coordinate type (They are NOT subject to transformation parameters!)
A box region is described by a coordinate system parallel to the box edges and two opposite vertices. All coordinates of the first point must be less than those of the second one. If this condition fails on input, the corresponding coordinates are switched.
Related structure: BoxRegionDataT.

- ES_C_GetBoxRegionParams
  Queries the currently valid box region parameters. Note that the retrieved point coordinate values can be different from those previously set by SetBoxRegion (Because of the condition that the coordinates of the first point must be less than those of the second one). However, the defined box will remain the same.
  Related structure: BoxRegionDataT.

- ES_C_SetEnvironmentParams
  Sets the environment parameters. (Temperature, pressure and humidity). Parameters are in current units.
  For valid parameter ranges, refer to chapter 'Working Conditions' in the 'Introduction' main chapter of this manual.
  Trying to set values outside the valid ranges will result in command failure.
  Related structure: EnvironmentDataT.
  See enum 'ES_WeatherMonitorStatus' for details on explicit and implicit updates of environmental parameters.
  Like for any 'Set...' command, a 'Status Change Event' is thrown, supposed the change exceeds the currently valid threshold. In this case, it will be

'ES_SSC_EnvironmentParamsChanged' event.

- ES_C_GetEnvironmentParams
  Queries the currently valid environment parameters.
  Related structure: EnvironmentDataT.
  See enum 'ES_WeatherMonitorStatus' for details on explicit and implicit updates of environmental parameters.
- ES_C_SetRefractionParams
  Set explicit Refraction Indices for Interferometer and ADM. This is an advanced command and should only be used in real special situations. That is, if one wants to use his own formula for calculating the refractions from the environment parameters. SetRefractionParams will override those refraction parameters indirectly calculated and implicitly set by a previous call to SetEnvironmentParams.
  Note SetEnvironmentParams and SetRefractionParams are 'concurrent' commands. Both update the refraction parameters.
  Refraction indices are dimension-less.
  For valid parameter ranges refer to chapter 'Working Conditions' in the 'Introduction' main chapter of this manual.
  Trying to set values outside the valid ranges will result in command failure.
  A change of the environment parameters automatically causes an internal, implicit refraction parameter setting.
- ES_C_GetRefractionParams
  Query the currently valid Refraction Parameters for Interferometer and ADM.
- ES_C_SetMeasurementMode
  Sets the measurement mode of the tracker. Depending on this mode, a subsequent 'Start

measurement' command will result in a 'Stationary measurement' (=single point measurement), a 'Continuous measurement' etc.
See enum 'ES_MeasMode' for a list of modes supported.

- ES_C_GetMeasurementMode
  Queries the currently active measurement mode.
- ES_C_SetCoordinateSystemType
  Sets the coordinate system type.
  See 'ES_CoordinateSystemType' for a list of CS- types supported. All coordinate- type parameters of all TPI commands are represented in the currently selected CS-type.
- ES_C_GetCoordinateSystemType
  Queries the currently active CS-type.
- ES_C_SetStationaryModeParams
  Sets the properties for a stationary measurement, i.e. Measurement time and ADM use (usually do not use ADM upon measurement). Measurement time must lie between 500 ms and 100000 ms (0.5 – 100 seconds).
  Related structure: StationaryModeDataT.
- ES_C_GetStationaryModeParams
  Queries the currently valid Stationary Mode Parameters.
  Related structure: StationaryModeDataT.
- ES_C_SetContinuousTimeModeParams
  Sets the properties for a continuous time measurement.
  Related structure: ContinuousTimeModeDataT.
- ES_C_GetContinuousTimeModeParams
  Queries the currently valid Continuous Time

Mode Parameters
Related structure:
ContinuousTimeModeDataT.

- ES_C_SetContinuousDistanceModeParams
Sets the properties for a continuous distance measurement.
Distance parameter is in current Length-units. No range limitation applies to distance parameters in theory, but there is a practical limitation given by tracker working space.
Related structure:
ContinuousDistanceModeDataT.
- ES_C_GetContinuousDistanceModeParams
Queries the currently valid Continuous Distance mode parameters.
Related structure:
ContinuousDistanceModeDataT.
- ES_C_SetSphereCenterModeParams
Sets the properties for a Sphere Center measurement. Radius and SpatialDistance parameters are in current Length- units. No range limitation apply to distance and radius parameters in theory, but there is a practical limitation given by tracker working space.
Related structure: SphereCenterModeDataT.
- ES_C_GetSphereCenterModeParams
Queries the currently valid SphereCenterMode Parameters.
Related structure: SphereCenterModeDataT.
- ES_C_SetCircleCenterModeParams
Set the properties for a Circle Center measurement.
Radius and SpatialDistance parameters are in current Length- units. No range limitation apply to distance and radius parameters in theory, but there is a practical limitation given by tracker working space.
Related structure: CircleCenterModeDataT.

- ES_C_GetCircleCenterModeParams
  Queries the currently valid Circle Center Mode Parameters.
  Related structure: CircleCenterModeDataT.
- ES_C_SetGridModeParams
  Sets the properties for a Grid measurement. Grid value parameters are in current units, and according current CS-type. No range limitation apply to grid parameters in theory, but there is a practical limitation given by tracker working space.
  Related structure: GridModeDataT.
- ES_C_GetGridModeParams
  Queries the current Grid Mode Parameters.
  Related structure: GridModeDataT.
- ES_C_SetReflector
  Sets the valid reflector type by its numerical ID. Attention: Reflector ID's must not be hard coded. They differ from emScon system to emScon system. Use command 'GetReflectors' to query the system for defined reflectors and appropriate ID-name/type mapping.
- ES_C_GetReflector
  Queries the ID of currently valid Reflector .
- ES_C_GetReflectors
  Queries all known reflectors of the Tracker Server. Apart from other information, mainly delivers the association between reflector names and their numerical IDs.
- ES_C_SetSearchParams
  Set criteria for reflector search abort (search radius and time out). Search radius is in current Length- units. Maximal search parameter is 0.5 meters.
  The search time should be set into a reasonable relation to the search radius. Large search radii result in extended search

times unless limited by the search timeout value. The minimum value for the SearchTimeout is 10’000 ms (10 seconds); the maximum is 240'000 ms (4 minutes).

Related structure: SearchParamsDataT. For a detailed description see there.

- ES_C_GetSearchParams
  Queries the currently valid criteria for aborting a reflector search.
  Related structure: SearchParamsDataT.
  For detailed description see there.
- ES_C_SetAdmParams
  Set parameters for the ADM (stability, time, retries). Attention: This is a 'dangerous' command. Lowering the stability criteria will result in measurement precision loss. Only change these values if really required due instable conditions (ground vibrations etc.) TargetStabilityTolerance is a distance parameter and is in current length- units. *TargetStabilityTolerance* must lie between 0.005 and 0.1 Millimeter. Leave this value as low as possible! (Default is 0.005). *RetryTimeFrame* is in milliseconds in the range between 500 and 5000.
  Related structure: AdmParamsDataT.
- ES_C_GetAdmParams
  Queries the currently valid ADM parameters.
  Related structures: SetAdmParamsCT, SetAdmParamsRT and AdmParamsDataT.
- ES_C_SetSystemSettings
  Sets system settings, a collection of flags to control the behavior of Tracker Server.
  See struct 'SystemSettingsDataT' for details.
  Related structures: SetSystemSettingsCT, SetSystemSettingsRT and SystemSettingsDataT .

- ES_C_GetSystemSettings
  Queries the currently valid System Settings. Related structure: SystemSettingsDataT.
- ES_C_StartMeasurement
  Triggers a measurement – regardless of the measurement mode. I.e. depending on selected mode, Start Measurement may start a Stationary3D- a StationaryProbe-, a Continuous3D- or a ContinuousProbe measurement.
  Once a continuous measurement (with unlimited time/points) has been started, it can only be stopped on using ES_C_StopMeasurement (apart from beam break).
  Note: 'StopMeasurement' can also be used to interrupt some other lengthily taking (but deterministic) commands (Except on using the emScon COM [LTControl] synchronous interface – See Chapter 'Proper Interface Selection'). Further details see description of 'ES_C_StopMeasurement'.
- ES_C_StartNivelMeasurement
  Triggers a Leica 'Nivel' (inclination sensor) measurement, if sensor is available. Note: result are in native Nivel units (milli-radiant, Celsius), regardless of the currently set angular and temperature units. This is an exception to the common convention. Reason: It does not make sense to provide very small angles (parts of milli- radiants) in Degrees or Gons.
- ES_C_StopMeasurement
  Stopping a continuous measurement is the main purpose of this command.
  However, this command can also be used to interrupt other long taking, but deterministic actions (This is a new feature introduced with V2.0 and is not available on earlier

emScon versions).
Commands that can be interrupted include: Stationary Measurements (if a long measurement time is applied), those Positioning Commands including a spiral reflector search (GoPosition, FindReflector..), and finally the 'OrientToGravity' and 'Automated Intermediate Compensation' processes.
Note: the Tracker 'Initialize' command cannot be interrupted.
Interruption of long taking commands is also not possible when using the emScon COM [LTControl] **synchronous** interface. If an issue, use the asynchronous COM interface. For details see chapter 'Proper Interface Selection'.

- ES_C_ChangeFace
  Changes the tracker face before the laser beam is attached to the same position.
- ES_C_GoBirdBath
  3D Modes: Laser beam is sent to the Bird bath. The beam is 'attached' to the reflector in the Bird bath and the Interferometer distance is set to the known Bird- bath distance. This command is especially important for LT-series trackers without ADM. For such tracker, there is no other way to set the interferometer distance.
  6D Modes: GoBirdBath does not make sense for a Probe. This command thus has a different effect while one of the 6D measurement modes is active. The laser beam is sent to zero position instead (which is on the opposite side of the BirdBath), where it can then be catched with the probe.
- ES_C_GoPosition
  Laser beam is sent to a specified location, followed by an implicit 'Find reflector'. The

beam is 'attached' to the reflector (if found). Input is in current units, CS-type and according to applied orientation / transformation parameters. No range limitations apply to these parameters in theory, but there is a practical limitation given by tracker working volume. The useADM flag should always be set for trackers equipped with an ADM.
If ADM flag is not set, the IFM distance is calculated from the supplied coordinates and is set as the valid one. To be used with caution!

The search time depends on the search radius. Large search radii result in extended search times, unless limited by the search timeout value selected by 'SetSearchParams'. See command 'SetSearchParams' for details. A 'GoPosition' command in progress can be interrupted with 'ES_C_StopMeasurement'.

- ES_C_GoPositionHVD
  Laser beam is sent to specified location, followed by an implicit 'Find reflector'. Input is in current units as horizontal, vertical and distance parameters related to the values of the 'instrument CS' and 'raw' measurement values, regardless of current CS and CS-type. Range limitations apply with respect to the tracker elevation limits. The useADM flag should always be set for trackers equipped with an ADM.
  If ADM flag is not set, the provided distance is taken as new IFM distance. To be used with caution!

  The search time depends on the search radius. Large search radii result in extended search times, unless limited by the search timeout value selected by 'SetSearchParams'.

See command 'SetSearchParams' for details. A ‘GoPositionHVD’ command in progress can be interrupted with ‘ES_C_StopMeasurement’.

- PositionRelativeHV
  Position (relative)the tracker head to the given horizontal and vertical angles. The angles are 'signed' values in order to specify the direction. Parameters are according to currently set angular units. Range limitations apply with respect to the tracker elevation limits.
- ES_C_PointLaser
  Similar to ES_C_GoPosition, but laser beam is sent to the specified location only. A reflector is neither searched nor attached.
- ES_C_PointLaserHVD
  Same as ES_C_GoPositionHVD (laser beam is sent to the specified location), but a reflector is neither searched for nor attached.
- ES_C_MoveHV
  Command to start laser beam movement in horizontal, vertical direction, or to stop movement. Zero values mean 'stop movement'.
  The parameters for MoveHV are 'signed' values in order to specify the direction of movement. The parameters are 'speed values in the range between -100 < x < 100
- ES_C_GoNivelPosition
  This command moves the tracker head to one of the defined 'Nivel' positions (1 to 4). The laser tracker moves at a slow speed to avoid disturbing the 'Nivel' inclination sensor. This command is used for the orient to gravity procedure.
- ES_C_GoLastMeasuredPoint
  Positions the laser beam to the location that

has been last measured successfully in stationary mode.

- ES_C_FindReflector
  Searches a reflector at the given position. Reflector is attached if found. The approx distance is only required to calculate the 'opening angle' of the laser beam from the given search parameter. An inaccurate approx distance only has the effect that the real search radius will be bigger or smaller than specified in SetSearchParams. It has no effect to measurement quality. Approx distance parameters are in current Length Unit. Although no range limitation applies in theory, there is a practical limitation given by tracker working space: 100 mm < approxDist <= 50000 mm. Note: the minimum value is 101 mm, not 100 mm!
  The search time depends on the search radius. Large search radii result in extended search times.
  See also command 'SetSearchParams'.
  A ‘FindReflector’ command in progress can be interrupted with ‘ES_C_StopMeasurement’
- ES_C_Unknown
  Used for initialization purposes only. Does not appear as an answer to a command .
- ES_C_LookForTarget
  Looks for a reflector at the given position and returns H, V values, if a reflector is present. Values are in current angular units. This command is mainly useful for LT- series of Tracker without ADM and should not be used in general.
- ES_C_GetDirection,
  Returns H, V values even without a reflector locked on. Values always are in current angular units.

- ES_C_CallOrientToGravity
  Triggers an 'Orient to Gravity' process. The 2 inclination parameters are returned as a result. Result values are in current angular units and are typically used as RotVal1, RotVal2 input values for the SetStationOrientationParams command.
  Note: this is a rather long-taking command. It can be interrupted with 'ES_C_StopMeasurement'.

- ES_C_ClearTransformationNominalPointList
  Clears the current nominal point list (which is used as input data for the Transformation process).
  For all transformation related commands, see Section 9.2 for details.
- ES_C_ClearTransformationActualPointList
  Clears the current actual point list (which is used as input data for the Transformation process).
- ES_C_AddTransformationNominalPoint
  Adds a point to the transformation input nominal point list. Values are expected in current units, current CS-type. Transformation parameters are not taken into account.
- ES_C_AddTransformationActualPoint
  Adds a point to the transformation input actual point list. Values are expected in current units, current CS-type and according current transformation settings (in contrast to AddTransformationNominalPoint).
- ES_C_SetTransformationInputParams
  Sets the input params for the transformation. . Values are expected in current units and current CS-type (No transformation applies). For all transformation related commands, see

Section 9.2 for details.
Input Standard deviations should take one of the constant values defined in the chapter 'Constants for Transformation' (TPI Reference).
In particular, they one of the following values should be assigned:
0.0 – If parameter to be fixed,
1.0E+35 – If parameter unknown, or
1.0E+15 – If parameter approximately known.
Rather use the predefined constant symbols than hardcoded numerical values!

- ES_C_GetTransformationInputParams
  Gets the currently active transformation input parameters.
- ES_C_CallTransformation
  Triggers the transformation-parameter calculation process. The 7 transformation parameters (including statistical information) are returned as a result. Values are delivered in current units and current CS-type (the same as with TransformationInputParams). For all transformation related commands, see Section 9.2 for details.
- ES_C_GetTransformedPoints
  Retrieves the 'secondary' transformation results (= transformed points including statistical information and their residuals to nominal points) after a successful 'CallTransformation'. Values are provided in current units, current CS-type (but not according to current orientation settings). Transformed points do match the nominal points (apart from residuals). For all transformation related commands, see Section 9.2 for details.
- ES_C_ClearDrivePointList
  Clears the current drive point list (used as

input data for the Intermediate Compensation).

- ES_C_AddDrivePoint
  Add a point to the drive point list for the Intermediate Compensation. Values are expected in current units, current CS-type and according current orientation / transformation settings.
  For all intermediate compensation related commands, see main chapters 8 (sub- chapter Automated Intermediate Compensation).

- ES_C_CallIntermediateCompensation
  Triggers an 'Intermediate Compensation' process and calculation.
  A successful result will not automatically become the active compensation.
  For all intermediate compensation related commands, see main chapters 8 (sub- chapter Automated Intermediate Compensation).
  Note: this is a long-taking command. It can be interrupted with 'ES_C_StopMeasurement'.
  Note: After successful termination, the calculated (in-work) compensation must be activated by performing a 'SetCompensation(0)' command.
  See detailed description of 'ES_C_SetCompensation' (enum ES_C_Command) about the meaning of parameter zero.

- ES_C_GetCompensations
  Reads all Tracker- compensations stored in the database. Apart from the internal ID and name (which is made up of the compensation date), a series of properties is delivered. This command should no longer be used. Rather use the following:

- ES_C_GetCompensations2
  Enhanced version of

ES_C_GetCompensations. Delivers comment for ADM compensation and active compensation as additional information. ES_C_GetCompensations only left for backward compatibility reasons. New applications should use ES_C_GetCompensations2. The older ' 'ES_C_GetCompensations' is only kept for compatibility reasons.
(Remark: This command should have better be named 'GetTrackerCompensations2' in order to distinguish between other compensation types)

- ES_C_SetCompensation
  Sets the specified tracker compensation with the given ID as the active one. The available Tracker compensations including their IDs can be retrieved with the command 'GetCompensations'.
  Note: Compensations have internal IDs > 0. Nevertheless, ID 0 is a valid value to SetCompensation() in a special situation: After an Automated Intermediate Compensation has been performed (on using the command 'ES_C_CallIntermediateCompensation'), this new compensation is still in a temporary state (which we call an 'in-work' state). It will not be accepted and activated before confirmed with SetCompensation(0).
  The reason for that is that an application will show the quality results (RMS etc.) of the Intermediate Compensation to the user. Based on these results, the user decides whether to accept or to discard this compensation . Sending 'SetCompensation(0)' means 'Accept'. Doing nothing (respectively re-start another intermediate compensation) means discard. Note that the 'philosophy' used here is very

similar to a Manual Intermediate (or Full) compensation performed with the Compensation application: An 'in-work' compensation is being created upon the first measurement. When all measurements done, the compensation result is calculated and displayed. Based on these results, the user decides to Accept the result or not.

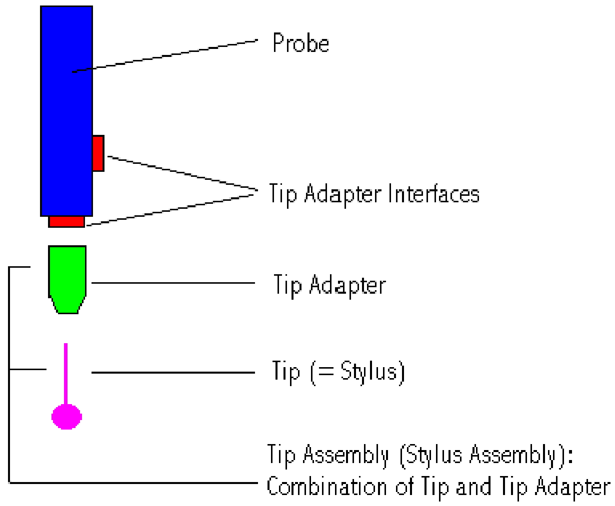
- ES_C_GetCompensation
  Reads the currently active compensation ID. Only the internal ID is returned. For additional information, the properties need to be looked up in the list delivered by ES_C_GetCompensations
- ES_C_SetStatisticMode,
  Switches the statistic mode between ‘standard’ and ‘extended’. This mode only influences the Single- and Multi-measurement results. This is an advanced feature. Extended statistic mode should only be used if enhanced statistical information is required. This is for example the case when using stationary measurements as input to the transformation routine.
  See difference between Single/MultMeasResultT (standard) and Single/MultMeasResult2T enhanced).
- ES_C_GetStatisticMode
  Gets the current statistic mode.
- ES_C_GetStillImage
  Requests a still image (in case the tracker is equipped with an Overview Camera).
  For all Still Image related commands, see main chapters 8 (sub- chapter Still Image).
- ES_C_SetCameraParams
  Sets the current contrast and brightness parameters of the Overview Camera. Valid values are between 1..255. Saturation is currently ignored and should be zero.

- ES_C_GetCameraParams
  Get current Overview Camera parameters.
- ES_C_CheckBirdBath
  Carries out Bird bath check routine. Returns Initial and current differences of BirdBath Angles and Distances. Values are expected in current units.
- ES_C_GetTrackerDiagnostics
  Returns Tracker diagnostic information. This is an advanced / diagnostic command. Not usually used by common applications. See Tracker hardware manual for details.
- ES_C_GetADMInfo
- ES_C_GetADMInfo2
  Returns Absolute Distance Meter feature information (Version and Serial Number), if available (i.e. If a LTD/AT series tracker).
  See also extended command ES_C_GetADMInfo2 (introduced with emScon V2.3).
  New applications should always use ES_C_GetADMInfo2. The former one is only kept for compatibility reasons.
- ES_C_GetTPInfo
  Returns Tracker Processor feature information. See Tracker/TP hardware manual for details.
- ES_C_GetNivelInfo
- ES_C_GetNivelInfo2
  Returns 'Nivel' (Inclination sensor) feature information, if a 'Nivel' is available. (Version and Serial Number). See also extended command ES_C_ GetNivelInfo2 (introduced with emScon V2.3)
  New applications should always use ES_C_ GetNivelInfo2. The former one is only kept for compatibility reasons.

- ES_C_SetLaserOnTimer
  Switches the laser on in predefined time
- ES_C_GetLaserOnTimer
  Reads the remaining time left before it is switched on
- ES_C_ConvertDisplayCoordinates
  Converts display coordinate triples from base to current and back.
  This is a private function/command and is not documented/supported. It should not be used for any client programming
- ES_C_GoBirdBath2
  Sets the laser beam to the Bird bath by turning tracker head in specified direction (clockwise or counter clockwise). Note: This command only applies to 3D measurement modes. See description of ES_C_GoBirdBath for more details.
- ES_C_SetTriggerSource
  Sets the Trigger Source for triggering measurements from remote (e.g. Probe buttons, or clock signal).
  See 'Tracker Trigger Interface' Appendix for a more detailed description of trigger- issues.
- ES_C_GetTriggerSource
  Get the currently active Trigger source
- ES_C_GetFace
  Get the currently active Tracker- Face (I or II)
- ES_C_GetCameras
  Enumerate all Measurement cameras known to the system (i.e. those defined in the database). Apart from the 'internal' ID, a selection of properties is delivered (Name, Type, Serial number....). This approach is the same as used for the command 'ES_C_GetReflectors' or 'ES_C_GetCompensations'.

- ES_C_GetCamera
  Get the currently active, i.e. mounted camera. Only the internal ID is returned. For additional information, the properties need to be looked up in the list delivered by ES_C_GetCameras
- ES_C_SetMeasurementCameraMode
  This command only applies to tracker systems equipped with a T-Cam. Allows to switch between Measurement- and Overview mode. If in Overview mode, the T-Cam plays the role of a 'classic' camera as already available with LT/D 500 series. That is, commands such as 'ActivateCameraView', Set/GetCameraParams, GetStillImage apply.
- ES_C_GetMeasurementCameraMode
  Get the currently active T-Cam mode (Measurement, Overview).
- ES_C_GetProbes
  This command only applies to tracker systems equipped with a T-Cam.
  Delivers all T-Probes known to the system, including ID and other properties. This command is the 6DoF relative to ES_C_GetReflectors of a 3D system.
- ES_C_GetProbe
  Gets the ID of the currently active Probe.
- ES_C_GetTipAdapters
  This command only applies to tracker systems equipped with a T-Cam.
  It delivers all Measurement Tip Adapters known to the system, including ID and other properties. This command is similar to ES_C_GetReflectors of a 3D system.

  Explanation of Terms:



Note that the terms 'Tip' and 'Stylus' are equivalent. The former is used in by the TPI, while the Compensation Application mainly uses the latter.

A 'TipAssembly' (= StylusAssembly) addresses the actual combination of Tip and TipAdapter. The TipAssembly is designed as a property of a TipAdapter and mainly consists of Tip Length and the diameter of the ruby sphere. There is one and only one TipAssembly for each TipAdapter. TipAssemblies can only be defined from within the Compensation Module (apart from importing TipAdapters with already existing valid TipAssembly). The TipAssembly must be redefined each time a different Type of Tip (Stylus) is attached to a TipAdapter. Moreover, a TipAssembly definition must be followed by a TipToProbe Compensation.

Note that a particular Tip – other than a TipAdapter – does not have its own ID. For that reason, there is no 'GetTips' command. Tips can only be identified indirectly through the TipAdapter they are mounted to It is the users responsibility to correctly define length and radius (upon defining a TipAssembly for a particular TipAdapter).

These values (in addition to a user- defined comment) can be retrieved through the command GetTipAdapters.

- ES_C_GetTipAdapter
  Gets the ID of the currently active Tip Adapter.
- ES_C_GetTCamToTrackerCompensations
  Reads all T-Cam to Tracker- compensations stored in the database. Apart from the internal ID and name, a series of properties is delivered.
- ES_C_GetTCamToTrackerCompensation
  Reads the currently active T-Cam to Tracker compensation ID. Only the internal ID is returned. For additional information, the properties need to be looked up in the list delivered by ES_C_ GetTCamToTrackerCompensations
- ES_C_SetTCamToTrackerCompensation
  Sets the specified tracker compensation with the given ID as the active one. The available TCamToTracker compensations including their IDs can be retrieved with the command ' GetTCamToTrackerCompensation '.
- ES_C_GetProbeCompensations
  Reads all Probe- compensations stored in the database. Apart from the internal ID and name, a series of properties is delivered.
- ES_C_GetProbeCompensation
  Reads the currently active probe compensation ID. Only the internal ID is returned. For additional information, the properties need to be looked up in the list delivered by ES_C_GetTCamToTrackerCompensations
- ES_C_SetProbeCompensation
  Sets the specified Probe compensation with the given ID as the active one. The available

Probe compensations including their ID's can be retrieved with the command ' Get GetProbeCompensations '.

- ES_C_GetTipToProbeCompensations
Reads all TipToProbe- compensations stored in the database. Apart from the internal ID and name, a series of properties is delivered. This command should no longer be used. It is only kept for compatibility reasons. Rather use ' ES_C_GetTipToProbeCompensations2' instead (see further below).
- ES_C_GetTipToProbeCompensation
Reads the currently active TipToProbe compensation ID. Only the internal ID is returned. For additional information, the properties need to be looked up in the list delivered by ES_C_GetTipToProbeCompensations
- ES_C_SetExternTriggerParams
Set the behavior of the external trigger. related structure: ExternTriggerParamsT. See 'Tracker Trigger Interface' Appendix for a more detailed description of trigger- issues.
- ES_C_GetExternTriggerParams
Set the parameters of the external trigger.
- ES_C_GetErrorEllipsoid
Convenience function to calculate an error ellipsoid from a given point with Standard Deviations and Covariance.
Input is in current units, current CS-type and applied orientation / transformation settings. Output is always in RHR.
- ES_C_GetMeasurementCameraInfo
Returns Measurement Camera feature information. See Tracker/T-Cam hardware manual for details.
See also GetMeasurementCameraInfoRT structure.

- ES_C_GetMeasurementProbeInfo
  Returns Probe feature information. See Tracker/Probe hardware manual for details. See also GetMeasurementProbeInfoRT structure.
- ES_C_SetLongSystemParameter
  This is an advanced command to set SystemSettings parameters of type Long, Boolean and enum- types individually. This approach was chosen to avoid extending the existing 'SystemSettingsDataT' structure.
  There are now some parameters covered by both commands (For example WeatherMonitorStatus). For these, either command (SetSystemSettings or SetLongSystemParameter) can be used.
  See enum ES_SystemParameter for values supported by this command.
  Some system parameters are new and can only be addressed by this command and not by the former SetSystemSettings command (Example: ES_SP_AllowProbeWithoutTip).
- ES_C_GetLongSystemParameter
  Get current (long- type) system parameter. The opposite of ES_C_SetLongSystemParameter
- ES_C_GetMeasurementStatusInfo
  Get information about availability of all types of compensations and related hardware.
  The information data is delivered as a long value representing a bit-mask. Use the enum ES_MeasurementStatusInfo values to identify / mask the long parameter information.
- ES_C_GetCurrentPrismPosition

  Get the current position of the prism the laser beam is currently attached to. This can be a reflector or the prism of a probe.

Delivered position parameters are with all 'filters' applied (Units, CS- Type, Transformation, Orientation). In other words: the 'same' values as a stationary measurement would deliver. However, these position values are NOT as accurate as stationary measurements. **Do NOT use these values as measurements where precise measurements are required.**
The background for this command is as follows: If a probe is attached, it is not possible to take 3D measurements to the probe prism. A measurement to the probe delivers the tip position, not the prism position. However, there exist situations where the position of the probe prism may be of interest (for example when issuing a GoPosition as a reaction of a beam broken event – supposed the probe is always placed to the same location).
Thus, this command is probably only of interest for Probe related enterprises.

- ES_C_SetDoubleSystemParameter
  This command is virtually the same as ES_C_SetLongSystemParameter. The only difference is that it takes 'double- type' parameters.
  See ES_SystemParameter, where items suitable to this command have been marked with a D_ prefix.
  Example for such a parameter: ES_SP_D_ObjectTemperatureTolerance.

- ES_C_GetDoubleSystemParameter
  Get current (double- type) system parameter. The opposite of ES_C_SetDoubleSystemParameter.

- ES_C_GetObjectTemperature
  Get the Object Temperature. This command only succeeds if there is a weather monitor

(Leica AT meteo station or Thommen station) connected to emScon.
A temperature device must be connected to the weather stations TEMP2 port (applies to Thommen and AT station).
For the AT meteo station, TEMP1 relates to an integrated temperature sensor while for the Thommen station, it is assumed that **both, TEMP1 and TEMP2 ports have a sensor assigned**. TEMP1 is used for air temperature and TEMP2 serves for Object Temperature.
Note (Thommen only): if TEMP1 is not used and there is only a device assigned to TEMP2, then TEMP2 is interpreted as air temperature. In this case, there is no object Temperature available and the 'GetObjectTemperature' command will fail with a usage conflict error.

- ES_C_GetTriggerBoardInfo
Returns feature information about the trigger board. This is an advanced / diagnostic command. Not usually used by common applications. See Tracker/T-Cam hardware manual for details.
See GetTriggerBoardInfoRT structure.
See also 'Tracker Trigger Interface' Appendix for a more detailed description of trigger- issues.
- ES_C_GetOverviewCameraInfo
Returns feature information about the (optional) overview camera. See Tracker/T-Cam hardware manual for details.
See also GetOverviewCameraInfoRT structure.
- ES_C_ClearCommandQueue
With emScon version V2.3, command buffering has been introduced.
'Server Busy' errors will therefore no longer

apply under normal conditions. Instead, commands will be appended to a queue when sent while a previous command is still busy. The queued command(s) will be executed as soon as the previous command finishes.

However, this mechanism is disabled by default (due to compatibility reasons to existing client applications). The buffering-level must be explicitly enabled with the 'ES_SP_TcpCommandQueueSize' system setting (to be used with SetLongSystemParamter). The maximum level is 10 (= max queue- size).

Example: if queue size is set to 5 and an application is trying to buffer more than 5 commands, then a 'Server Busy' is being issued. The default level is zero (command buffering disabled)

- ES_C_GetADMInfo2
  Returns Absolute Distance Meter feature information (Type, Version, Serial Number, measuring range), if available (i.e. if a LTD/AT series tracker).
  This is an extended version of the former command 'GetADMInfo'. 'GetADMInfo' is only kept for compatibility reasons to existing applications. New applications should use 'GetADMInfo2' instead.
- ES_C_GetTrackerInfo
  Returns Tracker feature information (Version and Serial Number, tracker- type, measuring ranges, configuration etc). This is a new command introduced with emScon V2.3.
- ES_C_GetNivelInfo2
  Returns 'Nivel' (Inclination sensor) feature information, if a 'Nivel' is available. (Type, Version, Serial Number, measuring

ranges..).
This is an extended version of the former command 'GetNivelInfo'. 'GetNivelInfo' is only kept for compatibility reasons to existing applications. New applications should use 'GetNivelInfo2' instead.

- ES_C_RestoreStartupConditions
  Resets the system to a state as if there was a reboot of the tracker server. The effect is virtually the same as for the 'ES_C_ExitApplication' command, except the server does not stop and thus the connection does not get lost.
  All non- persistent settings (such as 'trigger source', 'show all 6DoF measurements' etc.) are reset to defaults.
  This command is convenient during development of an application, when crashes or immediate stopping upon debugging occurs.
  Nevertheless, it's a good idea to perform this call every time at startup of an application - even for retail versions.
  Attention: It is recommended to execute this command upon startup and only upon startup of a client- application (i.e. just after connecting to emScon server). This command may only be called with caution later at runtime. It may have side effects the application is not aware of.

- ES_C_GoAndMeasure
  The 'GoAndMeasure' command is just for convenience. Its primary intention is for automated inspection tasks.
  'GoAndMeasure' combines the functionality of the command 'GoPosition' and a stationary 3D measurement.
  The advantage is an improved speed, especially if a T-Cam is mounted. (A

'traditional' Go Position - if a T-Cam is mounted - takes a longer time because the system first needs to detect whether the target is a Probe or just a Reflector. The 'GoAndMeasure' command - since restricted to 3D - can surpass this detection task).
Note that 'GoAndMeasure' always performs a 3D stationary measurement, regardless of the current measurement mode! However, the measurement parameters are the same as those set with 'SetStationaryModeParams'.
The three input values of 'GoAndMeasure' have the same meaning as those of the command 'GoPosition': They specify the location where the laser is directed to, followed by a spiral search and a measurement. The input Values are in current units / CS-type and according to applied orientation / transformation parameters.
The result (i.e. the coordinates of the measured point, if command successful), is returned the same way as for an ordinary stationary measurement: through either a 'SingleMeasResultT' or a 'SingleMeasResult2T', depending on the selected statistic level. Only in case of failure, the error code is returned through a 'GoAndMeasureRT' structure.
Note that the implementation of the 'GoAndMeasure' command in the emScon COM interface (LTControl) is slightly different from the description here (which relates to the C- interface). However, the COM Type-Library describes the functionality in a self- explaining manner.

- ES_C_GetTipToProbeCompensations2
  Reads all TipToProbe- compensations

stored in the database. Apart from the internal ID and name, a series of properties is delivered.
This command replaces the former ES_C_GetTipToProbeCompensations' command.

ES_ResultStatus

Defines the supported result status values received as an answer to TPI commands.

The ES_ResultStatus enum only defines those errors that originate on the emScon server.
It does not cover those errors that originate at the sensor controllers. **For a complete listing of possible hardware/controller errors,**
see the Appendices at the end of this manual.

```
enum ES_ResultStatus
{
   ES_RS_AllOK,
   ES_RS_ServerBusy,
   ES_RS_NotImplemented,
   ES_RS_WrongParameter,
   ES_RS_WrongParameter1,
   ES_RS_WrongParameter2,
   ES_RS_WrongParameter3,
   ES_RS_WrongParameter4,
   ES_RS_WrongParameter5,
   ES_RS_WrongParameter6,
   ES_RS_WrongParameter7,
   ES_RS_Parameter1OutOfRangeOK,
   ES_RS_Parameter1OutOfRangeNOK,
   ES_RS_Parameter2OutOfRangeOK,
   ES_RS_Parameter2OutOfRangeNOK,
   ES_RS_Parameter3OutOfRangeOK,
   ES_RS_Parameter3OutOfRangeNOK,
   ES_RS_Parameter4OutOfRangeOK,
   ES_RS_Parameter4OutOfRangeNOK,
   ES_RS_Parameter5OutOfRangeOK,
   ES_RS_Parameter5OutOfRangeNOK,
   ES_RS_Parameter6OutOfRangeOK,
   ES_RS_Parameter6OutOfRangeNOK,
   ES_RS_WrongCurrentReflector,
   ES_RS_NoCircleCenterFound,
   ES_RS_NoSphereCenterFound,
   ES_RS_NoTPFound,
   ES_RS_NoWeathermonitorFound,
   ES_RS_NoLastMeasuredPoint,
   ES_RS_NoVideoCamera,
   ES_RS_NoAdm,
   ES_RS_NoNivel,
   ES_RS_WrongTPFirmware,
   ES_RS_DataBaseNotFound,
   ES_RS_LicenseExpired,
   ES_RS_UsageConflict,
   ES_RS_Unknown,
   ES_RS_NoDistanceSet,
   ES_RS_NoTrackerConnected,
   ES_RS_TrackerNotInitialized,
   ES_RS_ModuleNotStarted,
   ES_RS_ModuleTimedOut,
   ES_RS_ErrorReadingModuleDb,
   ES_RS_ErrorWritingModuleDb,
   ES_RS_NotInCameraPosition,
   ES_RS_TPHasServiceFirmware,
   ES_RS_TPExternalControl,
   ES_RS_WrongParameter8,
   ES_RS_WrongParameter9,
   ES_RS_WrongParameter10,
   ES_RS_WrongParameter11,
   ES_RS_WrongParameter12,
   ES_RS_WrongParameter13,
   ES_RS_WrongParameter14,
   ES_RS_WrongParameter15,
   ES_RS_WrongParameter16,
   ES_RS_NoSuchCompensation,
   ES_RS_MeteoDataOutOfRange,
   ES_RS_InCompensationMode,
   ES_RS_InternalProcessActive,
   ES_RS_NoCopyProtectionDongleFound,
   ES_RS_ModuleNotActivated,
   ES_RS_ModuleWrongVersion,
   ES_RS_DemoDongleExpired,
   ES_RS_ParameterImportFromProbeFailed,
   ES_RS_ParameterExportToProbeFailed,
   ES_RS_TrkCompMeasCameraMismatch,
   ES_RS_NoMeasurementCamera,
   ES_RS_NoActiveMeasurementCamera,
   ES_RS_NoMeasurementCamerasInDb,
   ES_RS_NoCameraToTrackerCompSet,
   ES_RS_NoCameraToTrackerCompInDb,
   ES_RS_ProblemStoringCameraToTrackerFactorySet,
   ES_RS_ProblemWithCameraInternalCalibration,
   ES_RS_CommunicationWithMeasurementCameraFailed,
   ES_RS_NoMeasurementProbe,
   ES_RS_NoActiveMeasurementProbe,
   ES_RS_NoMeasurementProbesInDb,
   ES_RS_NoMeasurementProbeCompSet,
   ES_RS_NoMeasurementProbeCompInDb,
   ES_RS_ProblemStoringProbeFactorySet,
   ES_RS_WrongActiveMeasurementProbeCompInDb,
   ES_RS_CommunicationWithMeasurementProbeFailed,
   ES_RS_NoMeasurementTip,
   ES_RS_NoActiveMeasurementTip,
   ES_RS_NoMeasurementTipsInDb,
```

```
   ES_RS_NoMeasurementTipCompInDb,
   ES_RS_NoMeasurementTipCompSet,
   ES_RS_ProblemStoringTipAssembly,
   ES_RS_ProblemReadingCompensationDb,
   ES_RS_NoDataToImport,
   ES_RS_ProblemSettingTriggerSource,
   ES_RS_6DModeNotAllowed,
   ES_RS_Bad6DResult,
   ES_RS_NoTemperatureFromWM,
   ES_RS_NoPressureFromWM,
   ES_RS_NoHumidityFromWM,
   ES_RS_6DMeasurementFace2NotAllowed,
   ES_RS_InvalidInputData,
   ES_RS_NoTriggerBoard,
   ES_RS_NoMeasurementShankCompSet = 10001,
   ES_RS_NoValidADMCompensation = 10002,
   ES_RS_PressureSensorProblem = 10003,
   ES_RS_MeasurementStatusNotReady = 10004,
};
```

- ES_RS_AllOK
  Meaning: The command terminated successfully.
- ES_RS_ServerBusy
  Meaning: A previously invoked command was being processed when the next command was invoked. The 'next' command was not executed.
  Note: The application should always wait, until the previous command has terminated, before issuing the next command. This is due to the asynchronous communication behavior of the emScon C/C++ TPI. This indicates a programming error in the application – The application did not await the termination of the previous command, before issuing a new one.
  This error should not occur when using the synchronous interface of the COM TPI.
- ES_RS_NotImplemented
  Meaning: A command that is already specified in the programming interface, but not yet implemented/supported, was being executed.
  This may occur in pre-releases (Beta versions) of emScon.
- ES_RS_WrongParameter
  This error applies to commands with only one parameter.
  Meaning: The parameter of the issued

command was not accepted and executed. This error is issued if, for example:

- A positive value is expected but the user passed a negative one.

- The parameter is out of valid range. Very often, this is due to wrong unit selection.

Note: Check the valid range and current unit of the command parameter (see command description).
Example: The system is currently set to 'Meters' for length units, but the user enters 5000 (5000 mm) instead of 5.

- ES_RS_WrongParameter1
- ES_RS_WrongParameter2
- ES_RS_WrongParameter3
- ES_RS_WrongParameter4
- ES_RS_WrongParameter5
- ES_RS_WrongParameter6
- ES_RS_WrongParameter7
- ES_RS_WrongParameter8
- ES_RS_WrongParameter9
- ES_RS_WrongParameter10
- ES_RS_WrongParameter11
- ES_RS_WrongParameter12
- ES_RS_WrongParameter13
- ES_RS_WrongParameter14
- ES_RS_WrongParameter15
- ES_RS_WrongParameter16

  Meaning: Applies to commands with more than one parameter. The symbol specifies which one of the parameters is wrong.

- ES_RS_Parameter1OutOfRangeOK
- ES_RS_Parameter1OutOfRangeNOK

- ES_RS_Parameter2OutOfRangeOK
- ES_RS_Parameter2OutOfRangeNOK
- ES_RS_Parameter3OutOfRangeOK
- ES_RS_Parameter3OutOfRangeNOK
- ES_RS_Parameter4OutOfRangeOK
- ES_RS_Parameter4OutOfRangeNOK
- ES_RS_Parameter5OutOfRangeOK
- ES_RS_Parameter5OutOfRangeNOK
- ES_RS_Parameter6OutOfRangeOK
- ES_RS_Parameter6OutOfRangeNOK
  Meaning: OutOfRangeOK (warning) – The value of the specified parameter was out of the recommended range (but within the valid range) and accepted. The command was executed.
  OutOfRangeNOK (error) – The value of the specified parameter was not within the valid range and was not accepted. The command was not executed.
  These errors/warnings typically apply to atmospheric values such as temperature and pressure. The system can still perform the requested action, but the result will not be within specifications.
  In case of OutOfRangeOK, the user should be aware that the system might not deliver highest accuracy.
- ES_RS_WrongCurrentReflector
  Meaning: An invalid reflector was set (e.g. if the parameter of command *SetReflector* applies to a non-existing reflector ID or to an ID of an existing but inaccurate reflector.
  Note: This is usually a programming error in the application. The application should not allow the user to set an invalid reflector. The application should query the IDs of valid

reflectors with the command *GetReflectors* and then offer these as possible parameters for the *SetReflector* command.

- ES_RS_NoCircleCenterFound
  Meaning: This error occurs only in the continuous measurement mode, *CircleCenterMode*. The calculation of the circle center failed.
  Note: The measurements represent either a very small sector of the circle and/or describe a circle not within the required accuracy, which is not sufficient for calculation. The Circle Center Mode parameters may not have been set properly.
  See command 'SetCircleCenterModeParams'.
- ES_RS_NoSphereCenterFound
  Meaning: Similar to ES_RS_NoCircleCenterFound.
  Note: The measurements represent a very small sector of the sphere. For good results, at least half of the sphere should be covered by measurements. The Sphere Center Mode parameters may not have been set properly
  See command 'SetSphereCenterModeParams'.
- ES_RS_NoTPFound
  Meaning: There is no communication between the tracker controller and the tracker server. Either the connection is broken or the tracker controller did not boot and connect properly. Often this error occurs if the application tries to access the tracker server before the boot process is finished or if the boot process failed for some reason.
  For emScon version 1.5 and higher, it is recommended to await the *ES_SSC_ServerStarted* event before trying to issue a command.

Note: This problem can occur with use of an External Tracker Server (cable unplugged/damaged, plugged to wrong connector). This problem is minimized for LT Controller plus/base since both the tracker server and controller are integrated in one unit.

- ES_RS_NoWeathermonitorFound
  Meaning: A command or polling mechanism could not access an external weather station. The weather station is not present/connected/switched on.
  Note: If there is a weather station connected, check the cable and make sure the power is switched on. If no weather station is connected, set the SystemStatusFlag *HasWeatherMonitor* to zero. (Command *SetSystemStatus*). The flag must be ≠ 0, in order to access the weather station.
- ES_RS_NoLastMeasuredPoint
  Meaning: This error occurs after a command *GoLastMeasuredPoint*, when no stationary point has been measured since last system boot. There is no last measured point to go to.
  Note: Ensure that the user or the application does not call *GoLastMeasuredPoint*, if no stationary point has been measured since last system boot.
- ES_RS_NoVideoCamera
  Meaning: A command could not access the Overview Camera. This error can only occur if no Overview Camera is attached to the system.
  Note: If no camera is connected, set the SystemStatusFlag *HasVideoCamera* to zero. (Command *SetSystemStatus*). The application should not call camera related commands, if there is no camera attached.

There exist different types of overview cameras that differ in internal parameters (focus distance, CCD chip size). Older emScon versions were not able to detect whether an overview camera was mounted or not, not to speak of type recognition (indeed it was the overview camera hardware that did not support type recognition). For that reason, the flag 'HasVideoCamera' was originally introduced. Thus, the user had to 'tell' the system when an overview camera was mounted. Newer EmScon versions (2.0 and up) are able to detect the camera type automatically. Hence, this flag theoretically has become obsolete. However, currently the camera type is recognized **only when the 'hHasVideoCamera' flag is enabled**.
If your system is equipped with an overview camera, it is highly recommended to always having this flag checked (default is unchecked). Otherwise, the system may not detect the correct camera type and use wrong (default) parameters.
However, wrong parameters do not cause any fatal failures. The only effect will be that the 'Find Reflector' feature by clicking to the live video image by mouse pointer will move the tracker inaccurately (typically, the tracker will move double or half the amount of the 'clicked' distance).

- ES_RS_NoAdm
  Meaning: A command could not access the absolute distance meter of the tracker. This error should only occur if a tracker is not equipped with an ADM (i.e. LT/AT- series only).
  Note: If this error occurs for LTD/AT trackers, this probably indicates a hardware failure.(Refer to Leica service).

- ES_RS_NoNivel
  Meaning: A command could not access the external Leica 'Nivel' inclination sensor. Either it is not present or not correctly connected.
  Note: If there is a 'Nivel' connected, check the cable. If no 'Nivel' is present, set the SystemStatusFlag *HasNivel* to zero (Command *SetSystemStatus*). The flag must be ≠ 0, in order to access the 'Nivel'.
- ES_RS_WrongTPFirmware
  Meaning: The installed Firmware on the Tracker controller does not match the actual hardware.
  Note: Upgrade the firmware (Refer to Leica service)
- ES_RS_DataBaseNotFound
  Meaning: No database could be found on the tracker server.
  Note: There are no compensation parameters found for the attached sensor. Send the respective parameter files to the emScon server using the transfer tool.
- ES_RS_LicenseExpired
  Meaning: The Copy- Protection Dongle has expired (Probably due to a demo dongle?).
  Note: Request for a dongle Field- upgrade at Leica or get a new dongle.
- ES_RS_UsageConflict
  Meaning: Some system modes disable other commands, because they do not make sense in this context. For example, if the system is equipped with a weather station and is set up to automatically monitor the temperature, pressure and humidity, the system will prevent a manual setting of these values.
  The command *SetEnvironmentParams* will issue an error ES_RS_UsageConflict.
  The command *GetEnvironmentParams* will

work and deliver the actual values measured by the monitor. If the weather station mode is set to 'read and recalculate Refraction', then the same applies to the command *SetRefractionParams*. It will issue a ES_RS_UsageConflict, since setting the refraction index manually would conflict the automatic mechanism and would be overwritten upon the next weather station read cycle (~ 20 seconds).
Note: The application should not call SetEnvironmentParams and/or SetRefractionParams, if these values are automatically updated by the weather station, as per system settings.

- ES_RS_Unknown
  Meaning: An unknown error occurred. Should never occur as a response to a command.
- ES_RS_NoDistanceSet
  Meaning: The interferometer has no valid reference distance. Measuring is not possible in this condition.
  Note: Trackers with ADM may attach to a stable reflector anywhere. Use *GoPosition* or, if close to a reflector, *FindReflector*. If 'Keep last position is enabled', the system tries to re-establish the distance automatically as soon as a reflector can be tracked. For trackers without a ADM:
  - Place the reflector in the Birdbath. Do a GoBirdbath.
  - Move reflector to the measuring position without interrupting the beam.
- ES_RS_NoTrackerConnected
  Meaning: The connection between controller and tracker is broken.
  Note: Check all cables between controller and tracker.

- ES_RS_TrackerNotInitialized
  Meaning: The tracker is not initialized.
  Note: Execute the *Initialize* command. Set the environmental parameters (manually/weather station) before initialization.
  See also chapter 'Initial Steps'
- ES_RS_ModuleNotStarted
- ES_RS_ModuleTimedOut
- ES_RS_ErrorReadingModuleDb
- ES_RS_ErrorWritingModuleDb
  Meaning: These errors indicate a software installation problem on the emScon server.
  Note: Reinstall emScon software.
- ES_RS_NotInCameraPosition
  Meaning: Application tried to grab a video image from the Overview Camera, when the tracker was not in camera position.
  Note: Issue an *ActivateCameraView* command first.
- ES_RS_TPHasServiceFirmware
  Meaning: The server has loaded service firmware. This firmware is not suitable for ordinary tracker usage. This error cannot occur under normal conditions.
  Note: Refer to Leica service.
- ES_RS_TPExternalControl
  Meaning: The controller is running under external (e.g. AXYZ) control.
  Note: Reboot the tracker processor.
- ES_RS_NoSuchCompensation
  Meaning: The ID of a non-existent Compensation was passed to the *SetCompensation* command.
  Note: Use the *GetCompensations* command to get a list of valid Compensations.

- ES_RS_MeteoDataOutOfRange
  Meaning: The current environmental parameters (Temperature, Pressure, Humidity) are out of range.
  Note: Use *SetEnvironmtalParams* command to set these parameters correctly. If a weather station is attached, check for proper functioning.
  A Meteo station (Leica AT station or Thommen station) must be connected to the tracker system and switched-on before booting emScon. Incorrect environmental data may be produced, if the weather station is connected/switched-on later than that. For the Thommen station, connecting the combined Temperature/Pressure device is optional. However, if missing, the other (small) Temperature device must be present (applies to Thommen only - the AT station contains an integrated air temperature sensor). If no humidity device is available, a default value of 70% is assumed (Thommen only - AT station contains an integrated humidity sensor). Note: Other than for temperature and pressure, the influence of the humidity to the refraction index is marginal. See also
  ES_RS_NoTemperatureFromWM,
  ES_RS_NoPressureFromWM,
  and ES_RS_NoHumidityFromWM.
- ES_RS_InCompensationMode
  Meaning: The server is set to Compensation Mode. This is the case when the Compensation Application is active. During this state, all TPI commands are locked.
  Note: Quit the Compensation Application (Web App).
  Remark: In rare situations - for example after a crash of the Compensation Application - it may happen that the system remains in

compensation mode and the server can neither be accessed by the TPI nor by the Web Application. In this case, the tracker server needs to be rebooted.
For further details see remark at chapter 'Application Initial Steps' / 'Essential Steps'.

- ES_RS_InternalProcessActive
  Meaning: The server is still busy with a command.
  Note: The application must wait until the previous command has finished, before issuing a new command (asynchronous behavior).
- ES_RS_NoCopyProtectionDongleFound
  Meaning: The copy protection dongle is missing.
  Note: Make sure the dongle is connected at the correct port.
- ES_RS_ModuleNotActivated
  Meaning: The copy protection dongle does not qualify to use the specified module.
  Note: Refer to Leica representative to get a dongle field- upgrade.
- ES_RS_ModuleWrongVersion
  Meaning: The copy protection dongle does not qualify to use the specified module version.
  Note: Refer to Leica representative to get a dongle field- upgrade.
- ES_RS_DemoDongleExpired
  Meaning: The dongle is not activated or has expired.
  Note: Refer to a Leica representative. A field upgrade might be provided.
- ES_RS_ParameterImportFromProbeFailed
  Meaning: Importing of a probe compensation failed.
  Note: Make sure Probe has information in its

memory. Also check for potential version conflict.

- ES_RS_ParameterExportToProbeFailed
  Meaning: Exporting of a probe compensation failed.
  Note: Check for potential version conflict.
- ES_RS_TrkCompMeasCameraMismatch
  Meaning: The selected Tracker Compensation was not made with a T-Cam mounted. This compensation must not be used with a Tracker wit T-Cam mounted.
  Note: Select a different compensation.
- ES_RS_NoMeasurementCamera
  Meaning: No T-Cam is available.
  Note: Mount the T-Cam.
- ES_RS_NoActiveMeasurementCamera
  Meaning: The mounted T-Cam does not match the one stored in the database.
  Note: Make sure mounted T-Cam matches the camera information stored in the database.
- ES_RS_NoMeasurementCamerasInDb
  Meaning: No T-Cam is defined in database.
  Note: Provide camera information in database.
- ES_RS_NoCameraToTrackerCompSet
  Meaning: No T-Cam to tracker compensation is activated.
  Note: use the 'SetTCamToTrackerCompensation' command to activate a compensation.
- ES_RS_NoCameraToTrackerCompInDb
  Meaning: No T-Cam to Tracker compensation is available in database.
  Note: Perform a T-Cam to Tracker compensation.
- ES_RS_WrongActiveCameraToTracker
  CompInDb

Meaning: T-Cam to Tracker compensation does not match the mounted camera.
Note: Use the correct camera, or provide a compensation.

- ES_RS_NoMeasurementProbe
  Meaning: No probe can be 'seen' by the camera.
  Note: Move the probe to the camera's viewing space.
- ES_RS_NoActiveMeasurementProbe
  Meaning: The detected probe cannot be set as active.
  Note: Make sure probe communication is OK (cable problem?)
- ES_RS_NoMeasurementProbesInDb
  Meaning: No Probes are available in database.
  Note: Import probe information.
- ES_RS_NoMeasurementProbeCompSet
  Meaning: No probe compensation is activated.
  Note: use the 'SetProbeCompensation' command to activate a compensation.
- ES_RS_NoMeasurementProbeCompInDb
  Meaning: No probe compensation can be found in database.
  Note: Import or provide a probe compensation.
- ES_RS_WrongActiveMeasurementProbe CompInDb
  Meaning: The probe seen by the camera does not match the information in database.
  Note: Replace the probe by the matching one, or provide database information suitable to active probe.
- ES_RS_CommunicationWithMeasurement ProbeFailed
  Meaning: Possibly a hardware failure. The

probe should be detected automatically.
Note: Relocate the probe to try again. Try with a cable connection if using a cordless probe. Refer to Leica service if problem still remains.

- ES_RS_NoMeasurementTip
Meaning: No Tip is mounted at the probe.
Note: Mount a tip.
- ES_RS_NoActiveMeasurementTip
Meaning: The detected Tip cannot be set as active.
Note: Make sure probe communication is OK (cable problem?)
- ES_RS_NoMeasurementTipsInDb
Meaning: No Tips can be found in database.
Note: Provide tip definition.
- ES_RS_NoMeasurementTipCompInDb
Meaning: No Tip compensation can be found in database.
Note: Import or provide a tip compensation.
- ES_RS_ProblemReadingCompensationDb
Meaning: Compensations could not be read from database.
Note: Access to the database has failed. This error should not occur under normal conditions.
- ES_RS_ProblemSettingTriggerSource
Meaning: Trigger source parameters could not be set.
Note: Probably a hardware problem, or no trigger board available with current system.
- ES_RS_NoMeasurementTipCompSet
Meaning: Tip compensation missing.
Note: A Tip / Tip Assembly must be compensated and activated before it can be used for measuring.
- ES_RS_ProblemStoringCameraToTracker FactorySet

Meaning: The factory parameters of the current camera could not be replicated in the database.
Note: This error should not occur under normal conditions.

- ES_RS_ProblemWithCameraInternal Calibration
  Meaning: There is something wrong with the internal camera calibration.
  Note: This error should not occur under normal conditions. The camera probably needs to be repaired.
- ES_RS_CommunicationWithMeasurement CameraFailed
  Meaning: Possibly a hardware failure. The mounted camera should be detected automatically.
  Note: Remove the Camera and mount again. If still a problem, refer to Leica service.
- ES_RS_ProblemStoringProbeFactorySet
  Meaning: The Factory parameters of the current probe could not be stored in the database.
  Note: This error should not occur under normal conditions.
- ES_RS_NoDataToImport
  Meaning: Import Data failed since no data to import was found.
- ES_RS_ProblemStoringTipAssembly
  Meaning: Tip assembly could not be stored.
  Note: This error should not occur under normal conditions.
- ES_RS_6DModeNotAllowed
  Meaning: Trying to execute a 6DoF related command with a 3D measuring system, or system is set to 3D Mode.
  Note: Make sure the system supports 6DoF (i.e. has a camera mounted) and that one of

the Probe (6DoF) measurement modes is selected.

- ES_RS_Bad6DResult
  Meaning: The 6D coordinates delivered with this packet are not complete or even wrong (maybe zero). This situation can occur because of a bad rotation status or because not enough LED's were visible during a 'long time'. In other words: the system was not able to measure as many single measurements as specified during the specified measurement-time. An application must treat such a result as an error.
- ES_RS_NoHumidityFromWM
  Meaning: No humidity value could be queried from the weather monitor.
  If a Thommen station, there is probably no (external) humidity sensor connected to the weather station. This is a legal condition. A default value of 70% is assumed in this case (Note: The influence of the Humidity to the refraction index is marginal).
  The Leica AT meteo station contains a humidity sensor as an integral part. It should always succeed to deliver a humidity value. NoHumidityFromWM would probably mean defective meteo hardware.
- ES_RS_NoTemperatureFromWM
  Meaning: No temperature value could be queried from the Weather monitor. None of the two Temperature devices is probably connected to the Thommen Weather Station. This is a fatal error since the Temperature is required for the calculation of the refraction index. At least one of the Temperature devices must be attached to the Thommen Weather monitor. If both are connected, the temperature of the combined Temperature/Humidity device has priority.

The Leica AT meteo station contains a TEMP1 sensor as an integral part. It should always succeed to deliver an (air-) temperature value.
NoTemperatureFromWM for an AT station would probably mean defective hardware.

- ES_RS_NoPressureFromWM
  Meaning: No pressure value could be queried from the Weather monitor. Since the pressure device is an integral, non-removable part of both, Thommen and AT meteo station, this error probably indicates defective hardware.
  This is a fatal error since the Pressure is required for the calculation of the refraction index.
- ES_RS_6DMeasurementFace2NotAllowed
  Meaning: The system is in Face II while trying to do a 6D measurement.
  The system does not allow performing 6D measurements while in Face II. Change to Face I first.
- ES_RS_NoTriggerBoard
  Meaning: A trigger- board specific command was executed, although the system is not equipped with a trigger board.
  See 'Tracker Trigger Interface' Appendix for a more detailed description of trigger- issues.
- ES_RS_InvalidInputData
  Meaning: At least one of the input-parameters of the executed command is not valid. This error mostly applies if a coordinate triple is given in the wrong CS-type (for example if X,Y,Z passed where H,V,D expected). This error is similar to 'ES_RS_WrongParameter...', but less specific (since neither known which parameter, nor whether only one is wrong or several)

- ES_RS_NoMeasurementShankCompSet
Meaning: If we are in 'Shank' mode, measurements without shank compensation are not allowed
- ES_RS_NoValidADMCompensation
Meaning: The issued command is not available without having a valid ADM compensation; import or perform a mechanical tracker compensation
- ES_RS_PressureSensorProblem
Meaning: The meteo station reported a discrepancy in terms of a too big difference from the 2 internal sensors. This only applies to new AT meteo station- types.
- ES_RS_MeasurementStatusNotReady
Meaning: Tried to trigger a measurement while measurement status was not (yet) ready.

Remark: Error Range 100..9999 is reserved for Controller/Sensor Firmware errors (as listed in Appendices C and D), hence the gap between error #99 and #10001.

ES_MeasMode

This enumeration type names the currently implemented measurement modes. Used as a parameter for the *ES_C_SetMeasurementMode* command.

```
enum ES_MeasMode
{
    ES_MM_Stationary,
    ES_MM_ContinuousTime,
    ES_MM_ContinuousDistance,
    ES_MM_Grid,
    ES_MM_SphereCenter,
    ES_MM_CircleCenter,
    ES_MM_6DStationary,
    ES_MM_6DContinuousTime,
    ES_MM_6DContinuousDistance,
    ES_MM_6DGrid,
    ES_MM_6DSphereCenter,
    ES_MM_6DCircleCenter,
};
```

- ES_MM_Stationary
Stationary measurement mode. Also known as 'Single Point' measurement, where the

target is stationary.
A stationary measurement is an average value of many tracker measurements. The parameters for a stationary measurement, number of measurements and the time span can be controlled with the *ES_C_SetStationaryModeParams* command.

- ES_MM_ContinuousTime
  Continuous measurement mode with a time interval. a measurement is triggered after the time interval. The behavior of a continuous measurement can be controlled with the *ES_C_SetContinuousTimeModeParams* command.
- ES_MM_ContinuousDistance
  Continuous Measurement mode with a distance interval. A measurement is triggered after the distance interval. The behavior of a Continuous Distance measurement can be controlled with the *ES_C_SetContinuousDistanceModeParams* command.
- ES_MM_Grid
  Continuous Measurement Mode by grid interval. A measurement is triggered after the grid interval. The behavior of a grid measurement can be controlled with the *ES_C_SetGridModeParams* command.
- ES_MM_SphereCenter
  Measurement mode to indirectly measure a sphere center point. This is achieved by a continuous measurement scan over the sphere surface. The behavior for a Sphere Center measurement can be controlled with the ES_C_SetSphereCenterModeParams command.
- ES_MM_CircleCenter
  Circle measurement similar to

ES_MM_SphereCenter. The behavior for a Circle Center measurement can be controlled with the *ES_C_SetCircleCenterModeParams* command.

- ES_MM_6DStationary

  The Probe (6DoF) relative of ES_MM_Stationary mode. See description there.

- ES_MM_6DContinuousTime
  The Probe (6DoF) relative of ES_MM_ContinuousTime mode. See description there.

- ES_MM_6DContinuousDistance
  The Probe (6DoF) relative of ES_MM_ContinuousDistance mode. See description there.

- ES_MM_6DGrid
  The Probe (6DoF) relative of ES_MM_ Grid mode. See description there.

- ES_MM_6DSphereCenter
  The Probe (6DoF) relative of ES_MM_SphereCenter mode. See description there.

- ES_MM_6DCircleCenter
  The Probe (6DoF) relative of ES_MM_CircleCenter mode. See description there.

ES_MeasurementStatus

Additional status information to be delivered with each single measurement of a continuous measurement stream.
Measurements with a status other than ES_MS_AllOK should be treated with care.

```
enum ES_MeasurementStatus
{
    ES_MS_AllOK,
    ES_MS_SpeedWarning,
    ES_MS_SpeedExeeded,
    ES_MS_PrismError,
    ES_MS_TriggerTimeViolation,
};
```

- ES_MS_AllOK
  Measurement was carried out within specified target speed (movement).
- ES_MS_SpeedWarning
  Measurement was taken, when target was moving with a speed above warning threshold.
- ES_MS_SpeedExeeded
  Measurement was taken when target was moving with a speed above limit.
- ES_MS_PrismError
  Measurement could not be taken due to a prism error. Reflection is probably too weak.
- ES_MS_ TriggerTimeViolation
  Those measurements marked with 'TriggerTimeViolation' in a (trigger controlled) stream could not be taken in exact coincidence with the trigger pulse. This situation can occur if the trigger pulse rate is very close to the maximum measurement rate.
  If it is even beyond the maximum measurement rate, probably all of the measurements will be marked with 'TriggerTimeViolation'.

ES_TargetType

This enumeration type names the known target types (prism types). It is used as one of the *ES_C_SetSystemSettings* command parameters.

```
enum ES_TargetType
{
    ES_TT_Unknown,
    ES_TT_CornerCube,
    ES_TT_CatsEye,
    ES_TT_GlassPrism,
    ES_TT_RFIPrism,
};
```

- ES_TT_Unknown
  The target type is unknown.
- ES_TT_CornerCube
  The target is a corner-cube reflector.
- ES_TT_CatsEye
  The target is a cats eye reflector.
- ES_TT_GlassPrism
  The target is a glass prism reflector.
- ES_TT_RFIPrism
  The target is an RFI (Reflector for fixed installations) reflector.

ES_TrackerTemperatureRange

The ambient temperature range for the laser tracker.

```
enum ES_TrackerTemperatureRange
{
   ES_TR_Low,
   ES_TR_Medium,
   ES_TR_High,
   ES_TR_Automatic,
};
```

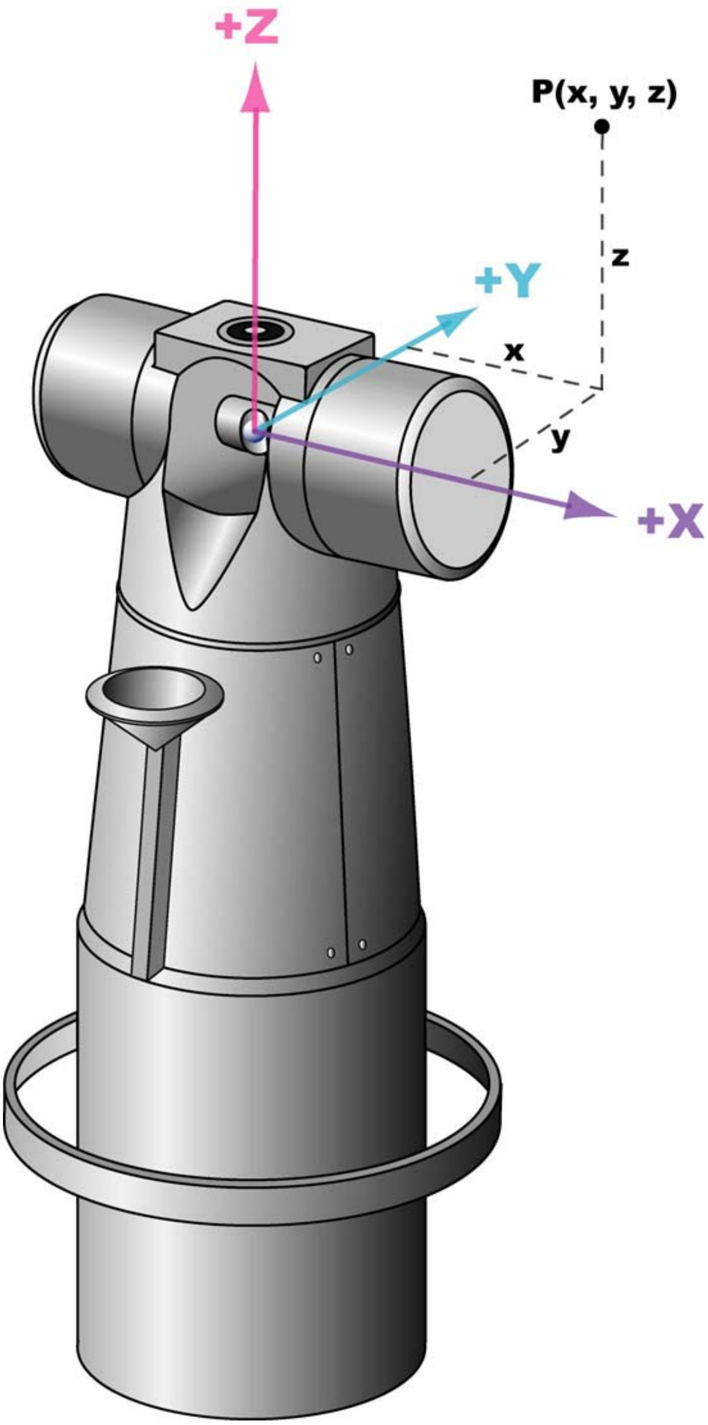
- ES_TR_Low
  Ambient temperatures between 5 and 20 °C.
- ES_TR_Medium
  Ambient temperatures between 10 and 30 °C.
- ES_TR_High
  Ambient temperatures between 20 and 40 °C.
- ES_TR_Automatic
  This value applies to new AT series trackers only. AT trackers no longer require manual selection of temperature range. Their only valid setting is ES_TR_Automatic (which is set by default). Other settings will be rejected with a 'wrong parameter' error.
  On the other hand, ES_TR_Automatic will be rejected for older, non-AT tracker types.

ES_CoordinateSystemType

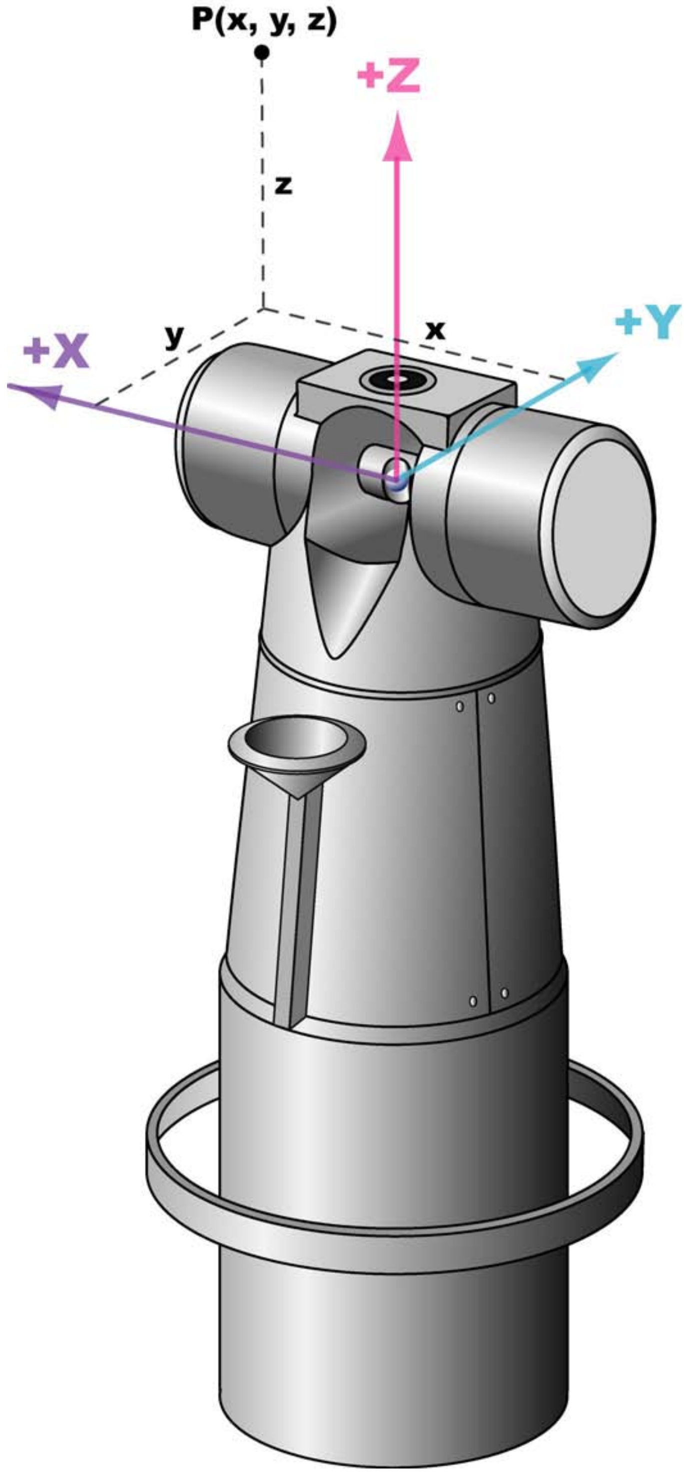
Coordinate system types supported by the TPI:

```
enum ES_CoordinateSystemType
{
    ES_CS_RHR,
    ES_CS_LHRX,
    ES_CS_LHRY,
    ES_CS_LHRZ,
    ES_CS_CCW,
    ES_CS_CCC,
    ES_CS_SCW,
    ES_CS_SCC
};
```

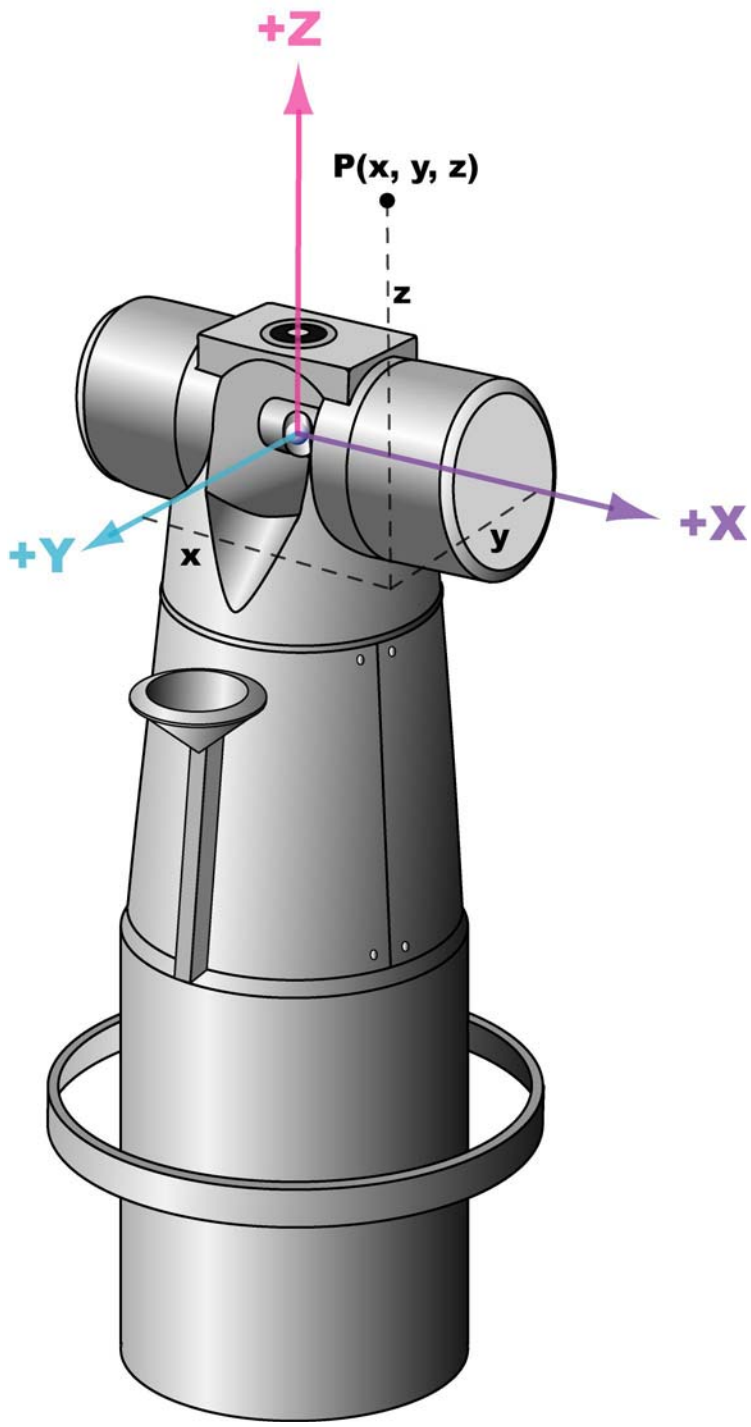
- ES_CS_RHR
  Right-Handed Rectangular (default type)



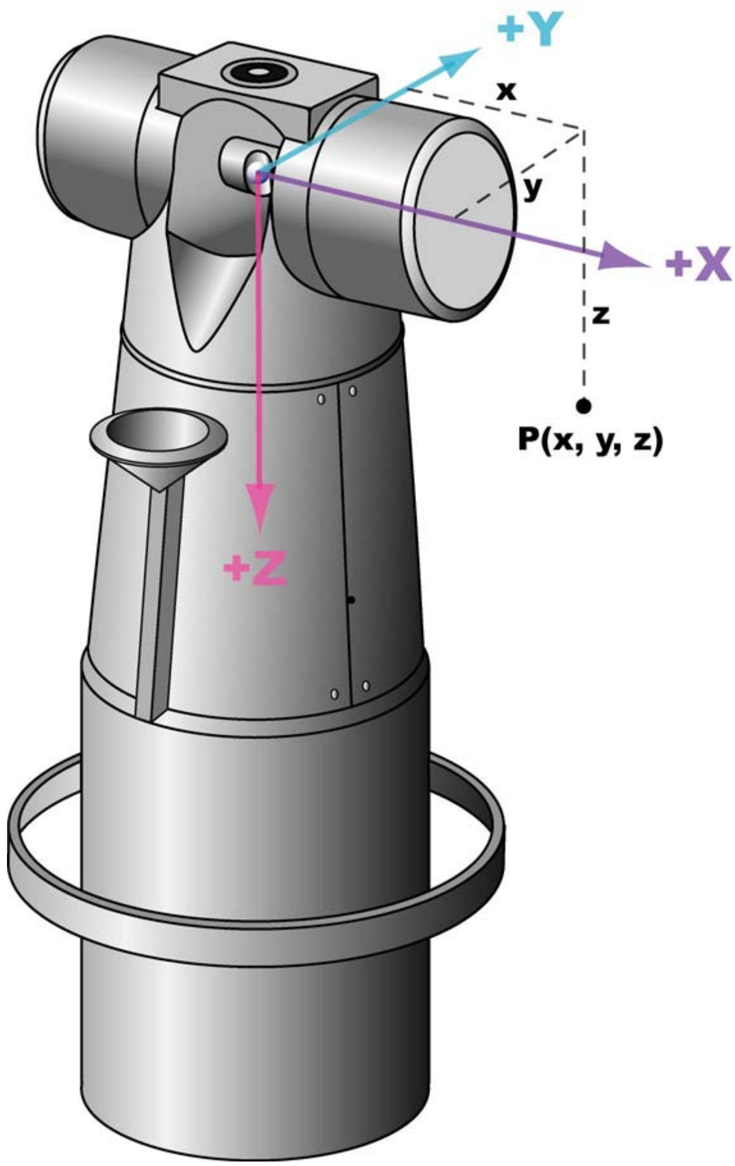
- ES_CS_LHRX
  Left-Handed Rectangular. Achieved by changing the sign of the X-axis.



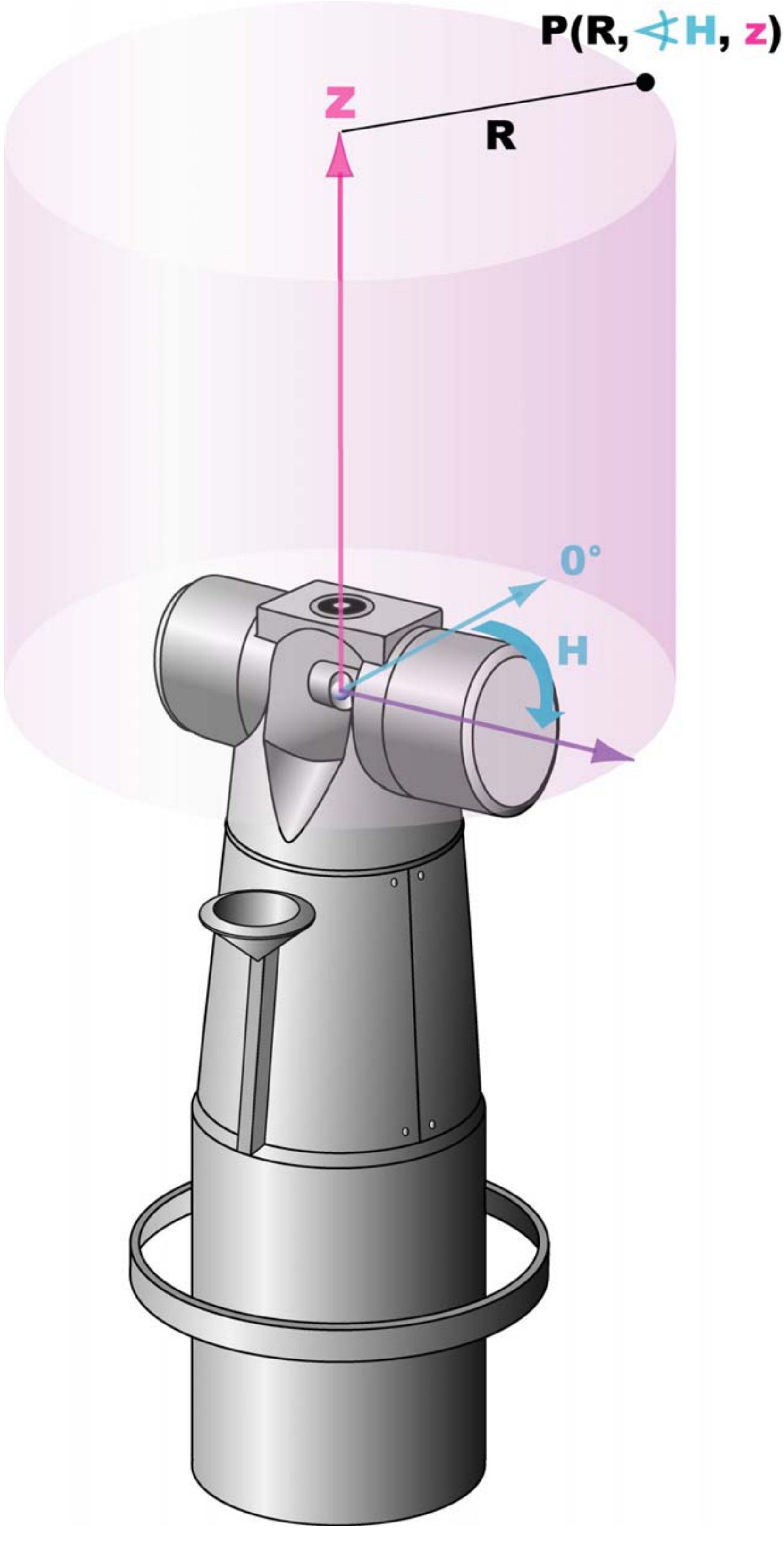
- ES_CS_LHRY
  Left-Handed Rectangular. Achieved by changing the sign of the Y-axis.



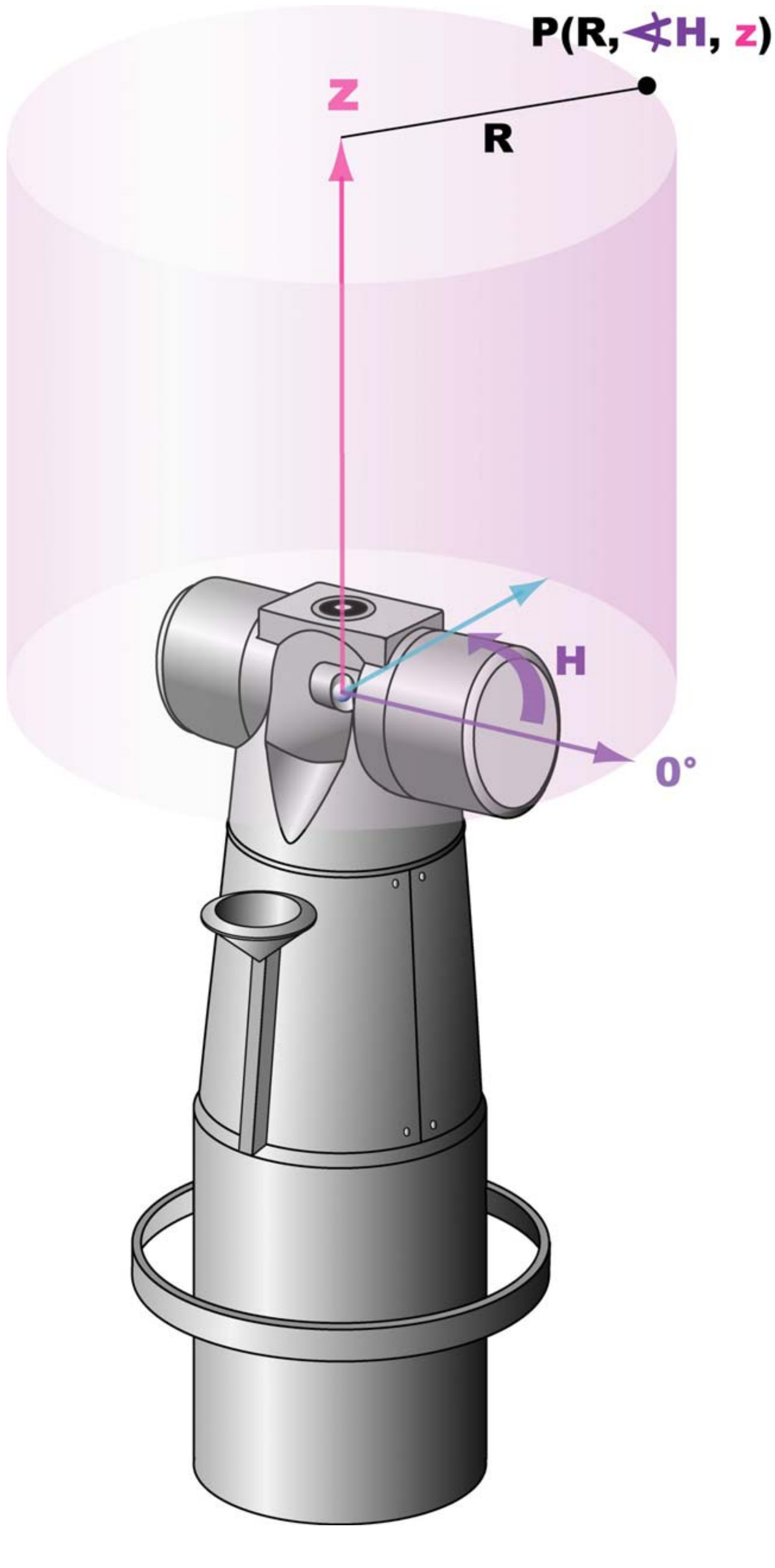
- ES_CS_LHRZ
  Left-Handed Rectangular. Achieved by changing the sign of the Z-axis.



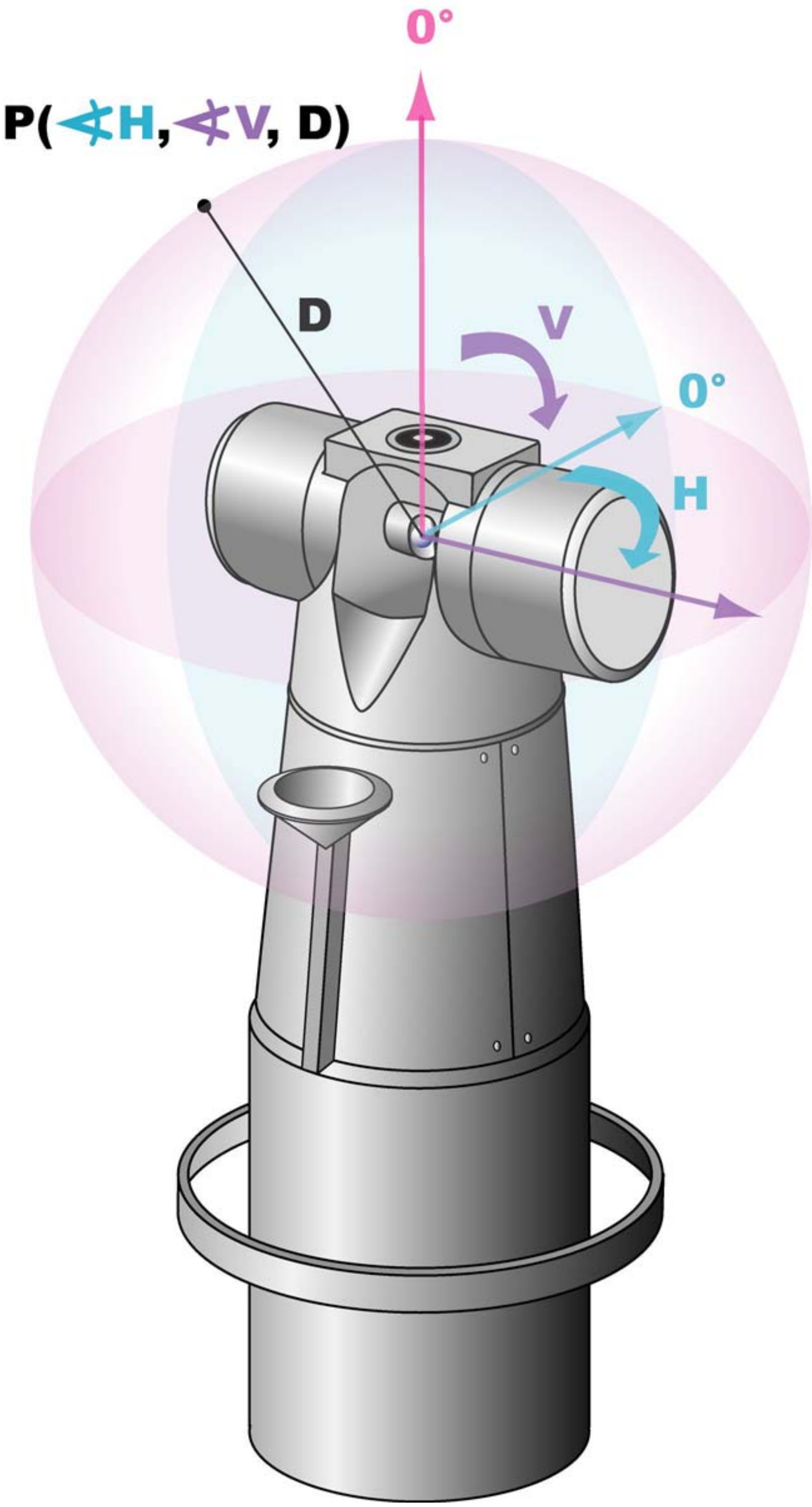
- ES_CS_CCW
  Cylindrical Clockwise system.



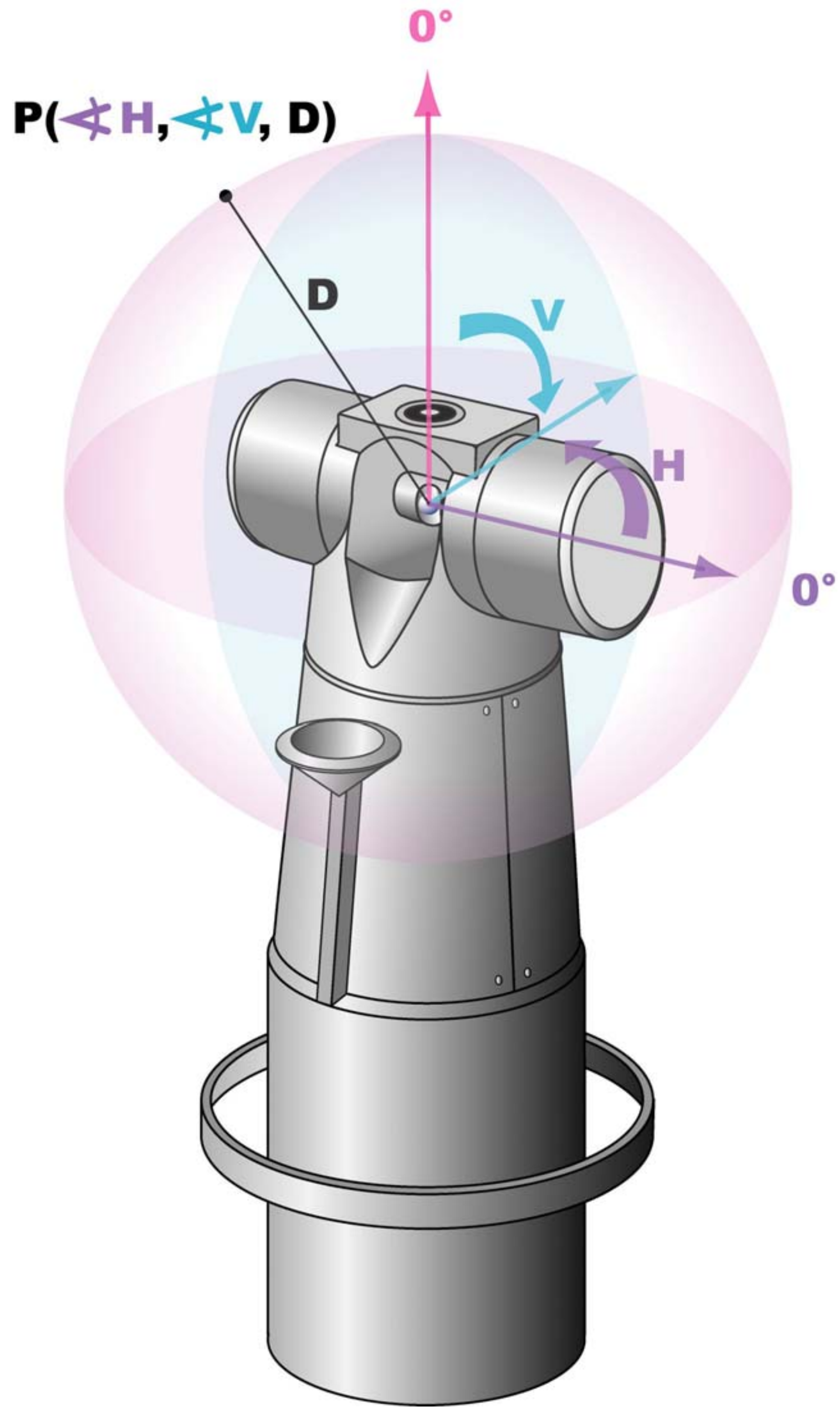
- ES_CS_CCC
  Cylindrical Counter-Clockwise system.



- ES_CS_SCW
  Spherical Clockwise system.

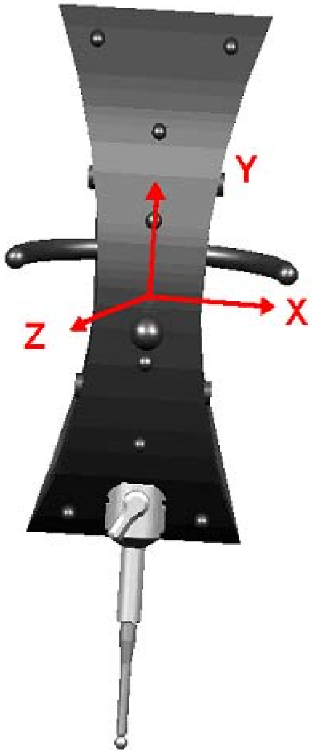


- ES_CS_SCC
  Spherical Counter-Clockwise system.

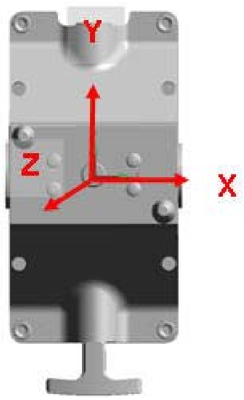


Addendum: Probe Coordinate Systems

T-Probe:



T-Mac:



These Pictures relate to RHR CS- Type.

Further details about Probe Coordinate Systems see Chapter 9: Mathematics (Chapter 9.3 in particular)

ES_LengthUnit

Length units supported by the TPI. This enumeration type is used as a parameter for *ES_C_SetUnits*/*ES_C_GetUnits*.

```
enum ES_LengthUnit
{
    ES_LU_Meter,
    ES_LU_Millimeter,
    ES_LU_Micron,
    ES_LU_Foot,
    ES_LU_Yard,
    ES_LU_Inch
};
```

ES_AngleUnit

Angle units supported by TPI. This enumeration type is used as a parameter for *ES_C_SetUnits*/*ES_C_GetUnits*.

```
enum ES_AngleUnit
{
    ES_AU_Radian,
    ES_AU_Degree,
    ES_AU_Gon
};
```

ES_TemperatureUnit

Temperature units supported by TPI. This enumeration type is used as a parameter for *ES_C_SetUnits*/*ES_C_GetUnits*.

```
enum ES_TemperatureUnit
{
    ES_TU_Celsius,
    ES_TU_Fahrenheit
};
```

ES_PressureUnit

Pressure units supported by the TPI. This enumeration type is used as a parameter for *ES_C_SetUnits*/*ES_C_GetUnits*.

```
enum ES_PressureUnit
{
   ES_PU_Mbar,    //default
   ES_PU_HPascal, //same as MBar
   ES_PU_KPascal,
   ES_PU_MmHg,
   ES_PU_Psi,
   ES_PU_InH2O,
   ES_PU_InHg,
};
```

- ES_PU_Mbar
  Millibar
- ES_PU_Hpascal
  HectoPascal (= Millibar)

- ES_PU_Kpascal
  KiloPascal
- ES_PU_MmHg
  Millimeter Mercury
- ES_PU_Ps
  Pounds per Inch
- ES_PU_InH2O
  Inch Water Height
- ES_PU_InHg
  Inch Mercury

ES_HumidityUnit

Humidity units supported by the TPI. This enumeration type is used as parameter for *ES_C_SetUnits*/*ES_C_GetUnits*.

```
enum ES_HumidityUnit
{
    ES_HU_RH
};
```

- ES_HU_RH
  Relative humidity, which is expressed in percentage.

ES_TrackerStatus

This enumeration type names the possible tracker states. It is used as the *ES_C_GetTrackerStatus* command parameter. The Tracker Status is related to the LED indicator on the tracker head.

```
enum ES_TrackerStatus
{
    ES_TS_NotReady,
    ES_TS_Busy,
    ES_TS_Ready,
    ES_TS_6DstatusInvalid,
};
```

- ES_TS_NotReady
  Tracker not ready; currently not attached to a target.
- ES_TS_Busy
  Tracker is currently measuring.
- ES_TS_Ready
  Tracker attached to a target and is ready to measure.

- ES_TS_6DStatusInvalid
  6D status of T-Probe measurement is not valid

ES_ADMStatus

Additional information about the ADM of the laser tracker. This enumeration type is used as a parameter for *ES_C_GetSystemStatus*.

```
enum ES_ADMStatus
{
    ES_AS_NoADM,
    ES_AS_ADMCommFailed,
    ES_AS_ADMReady,
    ES_AS_ADMBusy,
    ES_AS_HWError,
    ES_AS_SecurityLockActive,
    ES_AS_NotCompensated,
};
```

- ES_AS_NoADM
  Tracker not equipped with an ADM.
- ES_AS_ADMCommFailed
  Communication with ADM failed.
- ES_AS_ADMReady
  ADM is ready to measure.
- ES_AS_ADMBusy
  ADM is busy (performing a measurement).
- ES_AS_HWError
  Unspecified hardware error
- ES_AS_SecurityLockActive
  ADM has been locked for security because maximal allowed laser intensity has exceeded. Try to recover with powering off/on the controller. If problem persists, refer to Leica service.
- ES_AS_NotCompensated
  The ADM is not compensated and, if at all, may deliver inaccurate distances.

ES_NivelStatus

Additional information about the Leica 'Nivel' sensor connected to the laser tracker. This enumeration type is used as a result parameter for *ES_C_StartNivelMeasurement*.

Note: Nivel - Sensors of type 230 (newer models) have a smaller (highest accuracy) range of +/-1.1 mrad. The highest accuracy range of older models (Type Nivel20) is +/-1.5 mrad. Values that apply to Nivel 230 types are shown in brackets [] in the description below.

```
enum ES_NivelStatus
{
    ES_NS_AllOK,
    ES_NS_OutOfRangeOK,
    ES_NS_OutOfRangeNOK,
    ES_NS_NoNivel,
};
```

- ES_NS_NoNivel
  No 'Nivel' inclination sensor found/connected to tracker.
- ES_NS_AllOK
  'Nivel' measurement OK. The range of the measurement rx/ry values is within +/- 1.5 [1.1] millirad. Applications should only rely on measurement- values marked with ES_NS_AllOK.
- ES_NS_OutOfRangeOK
  Result within measurement range, but warning threshold exceeded. This warning applies when the range of at least one measurement value is within +/- 1.5 [1.1] and 2.0 millirad.
  Since it is not recommended to use these values, emScon maps them to a constant value of +/- 2.0 mrad. In other words, only the sign is reliable under this condition!
- ES_NS_OutOfRangeNOK
  No measurement could be taken; out of range. This error applies when at least one measurement value exceeds +/- 2.0 millirad.

These tolerance- thresholds 1.5 [1.1] /2.0 millirad are invariable characteristics of the 'Nivel' hardware. Please refer to the Nivel 20 Instruction Manual, Page 7.

ES_NivelPosition

Positions during orient to gravity procedure. This enumeration type is used as a parameter for *ES_C_GoNivelPosition* command.

```
enum ES_NivelPosition
{
    ES_NP_Pos1,
    ES_NP_Pos2,
    ES_NP_Pos3,
    ES_NP_Pos4,
};
```

- ES_NP_Pos1
  Tracker head at Nivel position 1 (90 degrees).
- ES_NP_Pos2
  Tracker head at Nivel position 2 (180 degrees).
- ES_NP_Pos3
  Tracker head at Nivel position 3 (270 degrees).
- ES_NP_Pos4
  Tracker head at Nivel position 4 (360 degrees).

ES_WeatherMonitorStatus

Specifies status of the weather monitor. This enumeration type is used as a parameter for *ES_C_SetSystemSettings* and *ES_C_GetSystemStatus* commands. The Tracker server maintains one single set of current environmental parameters – temperature, pressure and humidity. The command *ES_C_GetEnvironmentParams* queries current parameters. Parameters are set with explicit/implicit methods.

```
enum ES_WeatherMonitorStatus
{
   ES_WMS_NotConnected,
   ES_WMS_ReadOnly,
   ES_WMS_ReadAndCalculateRefractions,
};
```

- ES_WMS_NotConnected
  There is no weather monitor connected to the system, or it is switched off. The application must use ES_C_SetEnvironmentParams to set the

environment parameters (explicit method). SetEnvironmentParams also updates the refraction parameters. Therefore, it is not necessary to use 'ES_C_SetRefractionParams'. If ES_C_SetRefractionParams is called anyway, the refraction parameters are updated with the values provided, however, the next call to ES_C_SetEnvironmentParams will overwrite these values again.

- ES_WMS_ReadOnly
  While in this mode, if weather monitor is connected and correctly working, the system automatically reads the environmental values periodically (~ 20 seconds) from the monitor and internally updates the current environment parameters (implicit method). Error events repeatedly occur if no values can be read (weather monitor switched off, or cable connection broken).
  The 'ES_C_GetEnvironmentParams' command can be used to retrieve the current values (Note: this command does not immediately trigger a measurement from the weather monitor – it just returns the emScon- internally buffered meteo values, i.e. those last read from the WM), while the command 'ES_C_SetEnvironmentParams' is not available in this mode (Returns with an 'usage conflict' error).
  Refraction parameters are not influenced by the periodical update of environmental parameters. To change refraction values, an explicit 'ES_C_SetRefractionParams' is required. The 'ES_WMS_ReadOnly' mode is therefore suitable if the environmental

values come from the WM, but the application wants to use its own formula to calculate refraction parameters from these values. The mode of operation is hence as follows:

- ES_C_GetEnvironmentParams: delivers values last read from weather monitor.

- Calculate ADM and IFM refraction indices with application-specific formula.

- Set the calculated refraction parameters with ES_C_SetRefractionParams.

This mode is therefore rarely used. The normal mode of operation is to use 'ES_WMS_ReadAndCalculateRefractions' (see below).

- ES_WMS_ReadAndCalculateRefractions
  This is the normal mode of operation if using a weather monitor. It acts the same as the 'ES_WMS_ReadOnly' mode, but in addition, the current refraction parameters are automatically recalculated and updated. The 'ES_C_GetEnvironmentParams' and 'ES_C_GetRefractionParams' commands can be used to retrieve the current values, while the 'ES_C_SetEnvironmentParams' and 'ES_C_SetRefractionParams' both are not available in this mode (would return with an 'usage conflict' error).

Attention: The weather monitor should be switched-on before starting the emScon server. The weather monitor requires some initialization-time after switching on. If values are queried during this initialization phase, wrong values may be returned and the weather monitor remains in indifferent state. This is due to a problem of the weather monitor hardware. It is recommended to remove the battery from the weather monitor and always enable its power supply before, or at the same time, the emScon server gets booted.

New behavior with emScon 3.0:

With emScon 3.0, there is an automatic recognition of any attached meteo station and the system will automatically set related flags to a most common and reasonable state.

See chapter **Automatic External Device Recognition** (under Section 2.4) for more details.

ES_RegionType

This enumeration type is used as a parameter for regions .

```
enum ES_RegionType
{
    ES_RT_Sphere,
    ES_RT_Box,
};
```

- ES_RT_Sphere
  Region type is a sphere.
- ES_RT_Box
  Region Type is a box.

ES_TrackerProcessorStatus

The sequence of this enum is important. It shows the state of the tracker processor during startup of the Tracker Server. The value issued describes the status of the startup procedure.

- The tracker can only be booted if there is a connection to emScon.

- It can have a valid compensation only if it is booted.

- It can be initialized only if it has a valid compensation.

- The tracker is ready only if it is initialized.

This enumeration type is used as a parameter of *ES_C_GetSystemStatus*.

```
enum ES_TrackerProcessorStatus
{
    ES_TPS_NoTPFound,
    ES_TPS_TPFound,
    ES_TPS_NBOpen,
    ES_TPS_Booted,
    ES_TPS_CompensationSet,
    ES_TPS_Initialized,
};
```

- *ES_TPS_NoTPFound*
  No Tracker Processor could be recognized.
- *ES_TPS_TPFound*
  Tracker Processor is recognized, but connection from processor to tracker failed.
- *ES_TPS_NBOpen*
  Connection from processor to tracker is established, but booting failed.
- *ES_TPS_Booted*
  Tracker Processor booted, but there is no valid compensation.
- *ES_TPS_CompensationSet*
  Compensation set available, tracker not yet initialized.
- *ES_TPS_Initialized*
  Initialization was OK; tracker is ready.

ES_LaserProcessorStatus

Additional information about the laser processor. This enumeration type is used as a parameter for *ES_C_GetSystemStatus*.

```
enum ES_LaserProcessorStatus
{
    ES_LPS_LCPCommFailed,
    ES_LPS_LCPNotAvail,
    ES_LPS_LaserHeatingUp,
    ES_LPS_LaserReady,
    ES_LPS_UnableToStabilize,
    ES_LPS_LaserOff
};
```

- *ES_LPS_LCPCommFailed*
  Communication to laser processor failed.

This indicates a hardware problem. Report to Leica service representative.

- *ES_LPS_LCPNotAvail*
  The Laser processor is not available. This indicates a hardware problem. Report to Leica service representative.
- *ES_LPS_LaserHeatingUp*
  Laser is warming up. This is the normal case after switching-on the laser / controller (takes about 20 minutes).
- *ES_LPS_LaserReady*
  Laser is ready. From now on, the tracker can be used, but first needs to be initialized. See chapter 'Application Initial Steps'.
  Note: There is an alternative of repeatedly polling with 'ES_C_GetSystemStatus' to figure out whether the laser is ready. As soon as the laser is ready, emScon issues a so- called ‘SystemStatusChange’ event. This is a packet of the type 'ES_DT_SystemStatusChange', containing a status parameter. In case of laser ready, this parameter is 'ES_SSC_LaserWarmedUp'.
- *ES_LPS_UnableToStabilize*
  Laser not able to stabilize. This probably indicates a rapidly changing (up and down) of the environment temperature or a wrong active Temperature Range. Make sure the tracker is used in an environment with stable temperature. This rarely happens. Usually the laser just takes a longer warm up phase if environment temperature is not that stable.
- *ES_LPS_LaserOff*
  The Laser is switched off. Use ‘ES_SwitchLaser’ to switch laser on.

ES_SystemStatusChange

Specifies status change types. This enumeration type is used as a parameter for *ES_DT_SystemStatusChange* notifications.

```
enum ES_SystemStatusChange
{
   ES_SSC_DistanceSet,
   ES_SSC_LaserWarmedUp,
   ES_SSC_EnvironmentParamsChanged,
   ES_SSC_RefractionParamsChanged,
   ES_SSC_SearchParamsChanged,
   ES_SSC_AdmParamsChanged,
   ES_SSC_UnitsChanged,
   ES_SSC_ReflectorChanged,
   ES_SSC_SystemSettingsChanged,
   ES_SSC_TemperatureRangeChanged,
   ES_SSC_CameraParamsChanged,
   ES_SSC_CompensationChanged,
   ES_SSC_CoordinateSystemTypeChanged,
   ES_SSC_BoxRegionParamsChanged,
   ES_SSC_SphereRegionParamsChanged,
   ES_SSC_StationOrientationParamsChanged,
   ES_SSC_TransformationParamsChanged,
   ES_SSC_MeasurementModeChanged,
   ES_SSC_StationaryModeParamsChanged,
   ES_SSC_ContinuousTimeModeParamsChanged,
   ES_SSC_ContinuousDistanceModeParamsChanged,
   ES_SSC_GridModeParamsChanged,
   ES_SSC_CircleCenterModeParamsChanged,
   ES_SSC_SphereCenterModeParamsChanged,
   ES_SSC_StatisticModeChanged,
   ES_SSC_MeasStatus_NotReady,
   ES_SSC_MeasStatus_Busy,
   ES_SSC_MeasStatus_Ready,
   ES_SSC_MeasurementCountReached,
   ES_SSC_TriggerSourceChanged,
   ES_SSC_IsFace1,
   ES_SSC_IsFace2,
   ES_SSC_ExternalControlActive,
   ES_SSC_ServiceSoftwareActive,
   ES_SSC_MeasurementCameraChanged,
   ES_SSC_MeasurementCameraModeChanged,
   ES_SSC_ProbeChanged,
   ES_SSC_TipChanged,
   ES_SSC_TCamToTrackerCompensationChanged,
   ES_SSC_ProbeCompensationChanged,
   ES_SSC_TipToProbeCompensationChanged,
   ES_SSC_ExternTriggerParamsChanged,
   ES_SSC_TCamToTrackerCompensationDeleted,
   ES_SSC_MeasurementProbeCompensationDeleted,
   ES_SSC_MeasurementTipCompensationDeleted,
   ES_SSC_ManyMechanicalCompensationsInDB,
   ES_SSC_MeasStatus_6DstatusInvalid,
   ES_SSC_MeasurementProbeButtonDown,
   ES_SSC_MeasurementProbeButtonUp,
   ES_SSC_ExternalTriggerEvent,
   ES_SSC_ExternalTriggerStartEvent,
   ES_SSC_ExternalTriggerStopEvent,
   ES_SSC_ObjectTemperatureChanged,
   ES_SSC_OverviewCameraChanged,
   ES_SSC_NivelSensorChanged,
   ES_SSC_ProbeButton1Down,
   ES_SSC_ProbeButton1Up,
   ES_SSC_ProbeButton1DoubleClick, // not supported
   ES_SSC_ProbeButton2Down,
   ES_SSC_ProbeButton2Up,
   ES_SSC_ProbeButton2DoubleClick, // not supported
   ES_SSC_ProbeButton3Down,
   ES_SSC_ProbeButton3Up,
   ES_SSC_ProbeButton3DoubleClick, // not supported
   ES_SSC_ProbeButton4Down,
   ES_SSC_ProbeButton4Up,
   ES_SSC_ProbeButton4DoubleClick, // not supported
   ES_SSC_QuickReleaseOpend,
   ES_SSC_QuickReleaseClosed,
   ES_SSC_LaserReachingLimit,
   ES_SSC_LaserNotStabilized,
   ES_SSC_CompensationModeStart,
   ES_SSC_CompensationModeEnd,
   ES_SSC_EmsysFilesImported,
   ES_SSC_CopyProtectionRemoved,
   ES_SSC_TPConnectionClosing,
   ES_SSC_ServerClosing,
   ES_SSC_ServerStarted,
};
```

- *ES_SSC_DistanceSet*
  Precondition is that the system is equipped with an ADM and is set to

‘KeepLastPosition’ (one of the parameters controlled by Set/GetSystemSettings). This event is fired as soon as the beam is (re-) locked on to the target and an ADM measurement has been performed (a few seconds after the target has been placed to a stable position while beam attached). From now on, measurements can be continued. This mode is very convenient since it is not necessary to go back to the BirdBath after a beam break.
For Probe (6DoF) measurements, the ‘KeepLastPosition’ flag MUST always be set as true!
The 'ES_SCC_DistanceSet' event is not fired when the system flag '*Keep Last Position'* is not set.

- *ES_SSC_LaserWarmedUp*
  This event is fired once the tracker is warmed up (after system / laser start, about 20 minutes after the laser was switched on). Also see description of enum 'ES_LaserProcessorStatus'. The laser processor status (warmed up or not) can also be queried in an active way (polling) by using 'ES_C_GetSystemStatus'.
- *ES_SSC_XXX_Changed*
  These events are fired whenever there is a change of one of the system settings (Parameters, Modes, Regions, Compensations) or Hardware (those detected automatically, such as TCam, Probe, Tip).
- *ES_SSC_MeasStatus_NotReady*
- *ES_SSC_MeasStatus_Busy*
- *ES_SSC_MeasStatus_Ready*
  This event informs about a Measurement Status change (Ready, Busy, Not Ready). Apart from evaluating these events, the

measurement status can also be asked actively with the command 'ES_C_GetTrackerStatus'. This information is typically used for user- interface purpose to implement a 'traffic-light' with green (ready) / yellow (busy measuring) /red (target lost or missing compensation) colors.

- *ES_SSC_MeasStatus_6DStatusInvalid*
  Same comments as above. But only applies to probe measurements. Tracking is still OK, but the tilt of the probe is out of range so the TCam cannot reliably determine the rotation parameters. The rotation angles are not accurate and thus, the tip- coordinates not reliable. The recommended UI- color to assign to this status is blue (Used in BUI/ Compensation module).
- *ES_SSC_MeasurementCountReached*
  Stop a continuous measurement, when the max. number of measurements are reached.
- *ES_SSC_IsFace1*
  This event is fired whenever the tracker changes to Face I.
- *ES_SSC_IsFace2*
  This event is fired whenever the tracker changes to Face II.
- *ES_SSC_ExternalControlActive*
  This event is fired whenever the tracker server enters external control (e.g. Axyz). While under external control, control through TPI commands are blocked.
- *ES_SSC_ServiceSoftwareActive*
  This event is fired whenever the tracker server runs with service software. While running service software, control through TPI commands is limited.

- *ES_SSC_TcamToTrackerCompensation Deleted*
- *ES_SSC_MeasurementProbeCompensation Deleted*
- *ES_SSC_MeasurementTipCompensation Deleted*

  Above three events inform about compensation deletion.

- *ES_SSC_ManyMechanicalCompensations InDB*

  The recommended maximal number of mechanical compensations has been reached. Please delete some older compensations.

- *ES_SSC_MeasurementProbeButtonDown*
  This event is fired whenever one of the probe buttons (measurement trigger) is pressed.
  Exception: The system parameter 'ES_SP_ProbeConfig_Button' is set to 'ES_PCB_4ButtonMode'.
- *ES_SSC_MeasurementProbeButtonUp*
  This event is fired whenever the previously pressed probe button is released.
  Exception: The system parameter 'ES_SP_ProbeConfig_Button' is set to 'ES_PCB_4ButtonMode'.
- *ES_SSC_ExternalTriggerEvent*
  This event is fired whenever an external Trigger Pulse occurs.
- *ES_SSC_ExternalTriggerStartEvent*
  This event is fired whenever an external Trigger Start Pulse (trigger signal rising flank) occurs.
- *ES_SSC_ExternalTriggerStopEvent*
  This event is fired whenever an external

Trigger Stop Pulse (trigger signal falling flank) occurs.

- *ES_SSC_ObjectTemperatureChanged*

  This event is fired when the object temperature has changed more than the tolerance value (since the last time this event was fired). The object temperature tolerance value is a System Parameter and must be set as 'ES_SP_D_ObjectTemperatureTolerance', by using the 'SetDoubleSystemParamter' command).
  See also description of 'ES_C_GetObjectTemperature' command. The hardware configuration issues described there also apply here.

- *ES_SSC_OverviewCameraChanged*

  This event is fired when an overview camera either gets removed or mounted to a tracker. An application then can use the 'GetOverviewCameraInfo' command to get further information. Note: older hardware may not support this feature.

- *ES_SSC_NivelSensorChanged*

  This event is fired when a 'Nivel' (inclination Sensor) either gets removed or mounted to a tracker. Note: older hardware may not support this feature.

- *ES_SSC_ProbeButton1Down*
- *ES_SSC_ProbeButton1Up*
- *ES_SSC_ProbeButton2Down*
- *ES_SSC_ProbeButton2Up*
- *ES_SSC_ProbeButton3Down*
- *ES_SSC_ProbeButton3Up*
- *ES_SSC_ProbeButton4Down*
- *ES_SSC_ProbeButton4Up*

The Probe button interface has been improved with emScon V2.3 in terms than each one of the 4 buttons can be addressed individually. This feature is disabled by default in order to keep compatibility with existing applications. To enable, set the system parameter 'ES_SP_ProbeConfig_Button' to 'ES_PCB_4ButtonMode' by using the 'SetLongSystemParameter' command.
The application will then get individual events for each button as listed above instead of the ordinary MeasurementProbeButtonDown/Up events.

- *ES_SSC_ProbeButton1DoubleClick*
- *ES_SSC_ProbeButton2DoubleClick*
- *ES_SSC_ProbeButton3DoubleClick*
- *ES_SSC_ProbeButton4DoubleClick*
  Double Clicks are not supported with current Probe Firmware revision.
- *ES_SSC_QuickReleaseOpend*
  Indicates an opening of the quick release. This event only applies to new AT series trackers.
- *ES_SSC_QuickReleaseClosed*
  Indicates closing of quick release.
  This event only applies to new AT series trackers.
- *ES_SSC_LaserReachingLimit*
  Indicates the laser is about to reach the limit of a temperature range. If this event is ignored, a LaserNotStabilized event may follow soon. This will then require to pause a few minutes with measuring until the laser is ready again. Alternatively, you may perform an initialize upon a 'LaserReachingLimit' event.
  See also enum

'ES_TrackerTemperatureRange'.
This event only applies to new AT series trackers.

- *ES_SSC_LaserNotStabilized*
  This event is issued when the laser has (automatically) changed temperature range (which should have preceeded by a 'LaserReachingLimit' event). Must wait a few minutes until laser is ready again. Alternatively, an 'Initialize' command can be issued (recommended).
  See also See also enum 'ES_TrackerTemperatureRange'.
  This event only applies to new AT series trackers.
- *E_SSC_CompensationModeStart*

  This event is fired when the system enters compensation mode. While the system is in compensation mode, ordinary commands are blocked and will return with a 'System is in compensation mode' error. Setting the compensation mode is not a public TPI command and therefore not under control of the application programmer. However, if the compensation BUI is running or launched besides an application, it might be useful to the application to know when the system is in / enters / leaves compensation mode.
  This is an advanced programming issue.
- *ES_SSC_CompensationModeEnd*

  This event is fired when the system leaves compensation mode. All ordinary TPI commands are available again. This is an advanced programming issue.
- *ES_SSC_EmsysFilesImported*
  This event is fired when a data- import has completed (For example sending

compensation data (.emsys files) to the server on using the transfer- client tool).

- *ES_SSC_CopyProtectionRemoved*
  This event is fired if the copy protection device (dongle) is removed. System control through TPI commands is locked.
- *ES_SSC_TPConnectionClosing*
  This event is fired if the server connection gets lost. Server control through TPI commands is no longer possible. Server probably needs a reboot.
- *ES_SSC_ServerClosing*
  This event is fired if the server software terminates gracefully while the connection is still established. Upon a server crash, this event cannot be expected.
- *ES_SSC_ServerStarted,*
  This event is fired if the server is has re-started (supposed the connection was still established).

ES_StatisticMode

Specifies the current statistical mode. This enumeration type is used as a parameter for the *ES_C_SetStatisticMode* command.

```
enum ES_StatisticMode
{
   ES_SM_Standard,
   ES_SM_Extended
};
```

- *ES_SM_Standard*
  This is the default. Single- and Multi-measurement results are provided with reduced statistical information (without covariance values). That is, the data structures SingleMeasResultT and MultiMeasResultT are used and are compatible with the structures used in earlier emScon versions.

- *ES_SM_Extended*
  Single- and Multi- measurement results are provided with enhanced statistical information (including covariance values). While this mode is activated, the data structures SingleMeasResult2T and MultiMeasResult2T are used. The only difference is that these '2'- versions contain extended (statistical) information. Applications passing measurements to the 'CallTransformation' command should use the '2'- variants since the transformation routine requires these extended statistics. To maintain compatibility with earlier versions, Single/MultiMeasResultT have not been extended with additional parameters. Newer application should always use the Extended mode and therefore use all the '2'-version structures / handlers.

ES_StillImageFileType

Specifies the format of the still image. This enumeration type is used as a parameter for the *ES_C_GetStillImage* command.

```
enum ES_StillImageFileType
{
   ES_SI_Bitmap,
   ES_SI_Jpeg
};
```

- *ES_SI_Bitmap*
  The image arrives in Bitmap format
- ES_SI_Jpeg
  The image arrives in Jpeg format.
  This format is not supported.

ES_TransResultType

Specifies the type of the Transformation Parameters. Depending on this setting, the transformation routine will provide the 7 result parameters in ‘inverse’ order. This enumeration type is used as a parameter for the

ES_C_Set/GetTransformationInputParams command.

```
enum ES_TransResultType
{
   ES_TR_AsTransformation,
   ES_TR_AsOrientation
};
```

- *ES_TR_AsTransformation*
  The 7 parameters are provided to be used for a transformation from local to object (nominal) coordinate system.
- *ES_TR_AsOrientation*
  The 7 parameters are provided to be used as orientation parameters (*ES_C_SetOrientationParameters*).

ES_TrackerProcessorType

Specifies the controller type of the Tracker Processor in use (SMART, Embedded [LTController plus/base] etc.). ATC900 applies to new controller for AT series trackers.

```
enum ES_TrackerProcessorType
{
    ES_TT_Undefined,
    ES_TT_SMART310,
    ES_TT_LT_Controller,
    ES_TT_EmbeddedController,
    ES_TT_EmbeddedController600,
    ES_TT_ATC900,
};
```

ES_TPMicroProcessorType

Specifies the microprocessor type of the Tracker Processor in use (i486, 686 etc.).

```
enum ES_TPMicroProcessorType
{
   ES_TPM_Undefined,
   ES_TPM_i486,
   ES_TPM_686
};
```

ES_LTSensorType

Specifies the type of sensors that are defined (LT300, LTD800, AT901-LR etc.).

```
enum ES_LTSensorType
{
    ES_LTS_Undefined,
    ES_LTS_SMARTOptodyne,
    ES_LTS_SMARTLeica,
    ES_LTS_LT_D_500,
    ES_LTS_LT300,
    ES_LTS_LT301,
    ES_LTS_LT_D_800,
    ES_LTS_LT_D_700,
    ES_LTS_LT_D_600,
    ES_LTS_LT_D_640,
    ES_LTS_LT_D_706,
    ES_LTS_LT_D_709,
    ES_LTS_LT_D_840,
    ES_LTS_AT901_B,
    ES_LTS_AT901_MR,
    ES_LTS_AT901_LR,
    ES_LTS_NoSensor,
};
```

ES_DisplayCoordinateConversionType

Specifies the conversion of the coordinate system, either base to current or vice versa. Do not use this type. It is related to the 'ConvertDisplayCoordinates' command (not supported)

```
enum ES_DisplayCoordinateConversionType
{
   ES_DCC_BaseToCurrent,
   ES_DCC_CurrentToBase,
};
```

ES_TriggerStatus

Enumeration type to describe Status of Trigger Button at T-Probe

```
enum ES_TriggerStatus
{
    ES_TS_TriggerNotPressed,
    ES_TS_TriggerPressed,
};
```

- ES_TS_TriggerNotPressed,
  The measurement trigger button at the T-Probe is currently released
- ES_TS_TriggerPressed,
  The measurement trigger button at the T-Probe is currently pressed

ES_MeasurementTipStatus

Enumeration type to describe Status of Measurement Tip at T-Probe

```
enum ES_MeasurementTipStatus
{
    ES_PTS_TipOK,
    ES_PTS_UnknownTip,
    ES_PTS_MultipleTipsAttached
};
```

- ES_PTS_TipOK
  A tip (adapter) is present and is working correctly
- ES_PTS_UnknownTip
  There is no tip (adapter) attached or the currently attached tip cannot be recognized
- ES_PTS_MultipleTipsAttached
  There are multiple Tips attached

ES_TriggerSource

Specifies the source for the measurement trigger. This enumeration type is used as a parameter for the ES_C_Set/GetTriggerSource commands.
See 'Tracker Trigger Interface' Appendix for a more detailed description of trigger- issues.

```
enum ES_TriggerSource
{
    ES_TS_Undefined,
    ES_TS_Internal_Application,
    ES_TS_External,
    ES_TS_External_EventMessage,
};
```

- ES_TS_Undefined
  The trigger source is undefined.

- ES_TS_Internal_Application
  The application acts as trigger source. Mainly used for emScon internal modes.

- ES_TS_External
  The trigger source is external. The 'trigger port' of the controller is used for trigger signal input. A regular clock signal is usually used with this mode.

- ES_TS_External_EventMessage
  The trigger source is external. The trigger port of the controller is used for trigger

signal input. The trigger signal occurs on a specific event such as (manual) button press, robot elevation limit and so on. There is no distinction between start/stop. The application defines the behavior (for example whether the reaction is the same for every event, or whether there is a toggle behavior).
An 'ExternalTriggerEvent' status change event is issued on each trigger event.

ES_TrackerFace

Specifies the Tracker Face. This enumeration type is used as a parameter for the ES_C_GetFace command.

```
enum ES_TrackerFace
{
    ES_TF_Unknown,
    ES_TF_Face1,
    ES_TF_Face2
};
```

- TF_Unknown
  Tracker face could not be determined. Should not occur under normal conditions.

- ES_TF_Face1
  The tracker is in face I position.

- ES_TF_Face2
  The tracker is in face II position.

ES_MeasurementCameraMode

Specifies the source for the measurement camera mode. This enumeration type is used as a parameter for the Set/GetMeasurementCameraMode command.

```
enum ES_MeasurementCameraMode
{
    ES_MCM_Measure,
    ES_MCM_Overview,
};
```

- ES_MCM_Measure
  Measurement camera (T-Cam) is in measurement mode.

- ES_MCM_Overview
  Measurement camera (T-Cam) is in overview mode and can be addressed by e.g. GetStillImage.

ES_MeasurementCameraType

Specifies the measurement camera type. This enumeration type is used as a parameter for the GetMeasurementCameraInfo command.

```
enum ES_MeasurementCameraType
{
   ES_MC_None,
   ES_MC_TCam700,
   ES_MC_TCam800,
   ES_MC_TCam706,
   ES_MC_TCam709,
   ES_MC_TCam_MR,
   ES_MC_TCam_LR,
};
```

- ES_MC_None
  Type could not be determined. Should not occur under normal conditions.

- ES_MC_TCam700
  ….
  ES_MC_TCam_LR
  T-Cam is of indicated type

ES_ProbeType

Specifies the measurement probe type. This enumeration type is used as a parameter for the GetMeasurementProbeInfo command.

```
enum ES_ProbeType
{
    ES_PT_None,
    ES_PT_Reflector,
    ES_PT_TProbe,
    ES_PT_TScan,
    ES_PT_MachineControlProbe,
    ES_PT_TCamToTrackerTool,
    ES_PT_ZoomArtifactTool,
};
```

- ES_PT_None
  Type could not be determined. Should not occur under normal conditions.

- ES_PT_Reflector
  The ‘probe’ is a reflector. No 6DoF measurements are possible

- ES_PT_TProbe
  Probe is a standard T-Probe

- ES_PT_TScan
  Probe is a T-Scan

- ES_PT_MachineControlProbe
  Probe is of type ‚Machine Control Probe’

- ES_PT_TCamToTrackerTool,
  'Probe’ is the T-Cam to tracker compensation tool.

- ES_PT_ZoomArtifactTool,
  'Probe’ is the T-Cam to tracker compensation tool.

ES_ProbeConnectionType

Specifies the measurement probe type. This enumeration type is used as a parameter for the GetMeasurementProbeInfo command.

```
enum ES_ProbeConnectionType
{
    ES_PCT_None,
    ES_PCT_CableController,
    ES_PCT_CableSensor,
    ES_PCT_IRLaser,
    ES_PCT_IRWideAngle,
};
```

- ES_PCT_None
  No connection could be determined

- ES_PCT_CableController
  Connection is through cable to controller

- ES_PCT_CableSensor
  Connection is through cable to sensor (skipping the controller)

- ES_PCT_IRLaser
  There is a wireless connection (through Infrared Laser)

- ES_PCT_IRWideAngle
  There is a wireless connection (through Infrared wide angle sensor)

ES_ProbeButtonType

Specifies the measurement probe measurement button (trigger). This enumeration type is used as a parameter for the GetMeasurementProbeInfo command.

```
enum ES_ProbeButtonType
{
    ES_PBT_None,
    ES_PBT_Measurement,
    ES_PBT_4Button,
};
```

- ES_PBT_None
  The probe is not equipped with a trigger button.

- ES_PBT_Measurement
  The probe is equipped with one or several trigger buttons. If more than one (usually 4), all buttons have the same functionality - usually used to trigger a measurement (hence the name)

- ES_PBT_4Button
  The probe is equipped with 4 Buttons. Each one of these may cause an individual trigger event. Note that this is not the default behaviour of a 4Button probe. This mode must be explicitly enabled. See ES_ProbeConfigButton. Only newer probes with appropriate firmware support this mode.

ES_TipType

Specifies the measurement tip type. This enumeration type is used as a parameter for the GetTipAdapters command. Note: There exist alternate terms for 'Tip'. Some talk of 'Stylus'.

```
enum ES_TipType
{
    ES_TT_None,
    ES_TT_Fixed,
    ES_TT_Scanner,
    ES_TT_TouchTrigger,
};
```

- ES_TT_None
  Tip type is undefined or could not be determined.

- ES_TT_Fixed
  Tip tip-type is a fixed standard tip.

- ES_TT_Scanner
  Tip 'tip' type is a scanner. I.e. a 'virtual tip'.

- ES_TT_TouchTrigger
  Tip tip-type is equipped with a touch-trigger.

ES_ClockTransition

Specifies the trigger clock transition. This enumeration type is used as a parameter for the Get/SetExternTriggerParams command (ExternTriggerParamsT sub-structure)

```
enum ES_ClockTransition
{
   ES_CT_Positive,
   ES_CT_Negative,
};
```

- ES_CT_Negative
  The negative clock transition triggers the event

- ES_CT_Positive
  The positive clock transition triggers the event

ES_TriggerMode

Specifies the trigger mode. This enumeration type is used as a parameter for the Get/SetExternTriggerParams command (ExternTriggerParamsT sub-structure).
See 'Tracker Trigger Interface' Appendix for a more detailed description of trigger- issues.

```
enum ES_TriggerMode
{
    ES_TM_EventTrigger,
    ES_TM_ContinuousExternalClockWithStartStop,
    ES_TM_InternalClockWithExternalStartStop,
};
```

- ES_TM_EventTrigger
  The measurement is triggered by an event trigger (button, touch- trigger)

- ES_TM_ContinuousExternalClockWithStartStop
  The measurement (start/stop) is triggered by an external clock.

- ES_TM_InternalClockWithExternalStartStop
  The measurement is triggered by the internal clock, with external start/stop.

ES_TriggerStartSignal

Specifies the level of the trigger start signal. This enumeration type is used as a parameter for the Get/SetExternTriggerParams command (ExternTriggerParamsT sub-structure).
See 'Tracker Trigger Interface' Appendix for a more detailed description of trigger- issues.

```
enum ES_TriggerStartSignal
{
   ES_TSS_High,
   ES_TSS_Low,
};
```

- ES_TSS_Low
  The trigger start signal is of low level.

- ES_TSS_High
  The trigger start signal is of high level.

ES_SystemParameter

Specifies the value to be addressed by the ES_C_Set/GetLongSystemParameter command.

```
enum ES_SystemParameter
{
    ES_SP_KeepLastPositionFlag,
    ES_SP_WeatherMonitorSetting,
    ES_SP_ShowAll6DMeasurements,
    ES_SP_LaserPointerCaptureBeam,
    ES_SP_DisplayReflectorPosition,
    ES_SP_ProbeConfig_Button,
    ES_SP_ProbeConfig_ButtonEvent,
    ES_SP_ProbeConfig_Tip,
    ES_SP_ProbeConfig_SoundVolume,
    ES_SP_ProbeConfig_PowerOffTime,
    ES_SP_QuickReleaseStatus,
    ES_SP_TcpCommandQueueSize,
    ES_SP_SystemMax6DDataRate,
    ES_SP_D_TemperatureThreshold,
    ES_SP_D_PressureThreshold,
    ES_SP_D_HumidityThreshold,
    ES_SP_D_SystemLongest3DDistanceIFM,
    ES_SP_D_SystemLongest3DDistanceADM,
    ES_SP_D_SystemLongest6DDistance,
};
```

- ES_SP_KeepLastPositionFlag
  Param value: 0 = OFF; 1 = ON.
  Important: Enabling the 'KeepLastPosition' flag is compulsory for 6D Measurement Modes. Otherwise the Probe will not be recognized (If beam catched at zero position).
  Alternatively, this setting also can be controlled through the SetSystemSettings command.
- ES_SP_WeatherMonitorSetting
  Parameter value: see ES_WeatherMonitorStatus.
  Alternatively, this setting also can be controlled through the SetSystemSettings command.
- ES_SP_ShowAll6DMeasurements
  Parameter value: 0 = Only show data if 6D rotation status is OK (default); 1 = Show always.
- ES_SP_LaserPointerCaptureBeam
  Allows to control the behavior of the 'PointLaser' command if the beam is being sent very close to a reflector. In this situation, it is not always desired that the laser beam locks on to the reflector.
  Parameter value: 0 = Beam catch OFF; 1 = Beam catch ON (default).

- ES_SP_DisplayReflectorPosition
  Parameter value: 0 = Disable Reflector Position Tracking (default); 1 = Enable Tracking. This setting also can be controlled through the SetSystemSettings command.
- ES_SP_ProbeConfig_Button
  Configures the behavior of the probe-buttons. Parameter values: see enum ES_ProbeConfigButton
- ES_SP_ProbeConfig_ButtonEvent
  Enables/disables events throwing on using the probe buttons. Parameter values: see enum ES_ProbeButtonEvent
- ES_SP_ProbeConfig_Tip
  Configure whether 6Dof measurements are allowed without a mounted Tip or not.
  Parameter values: enum ES_ProbeConfigTip
- ES_SP_ProbeConfig_SoundVolume
  Parameter values: volume as long, 0: No sound, 0..7 sound volume selected: 0 off, 1 (soft) – 7 (loud)
- ES_SP_ProbeConfig_PowerOffTime
  Time until probe automatically shuts off (if idle).
  Parameter values: time in minutes. valid range: 2..255.
- ES_SP_QuickReleaseStatus
  Indicates open/close status of Quick Release. Parameter values: see enum ES_QuickReleaseStatus
- ES_SP_TcpCommandQueueSize
  A value between 0 ... 10 can be set as command buffer- depth. Default is 0, i.e. command buffering is switched off.
- ES_SP_SystemMax6DDataRate.
  Cannot be set. Only 'Get..' supported. The

maximum measuring rate supported in 6DoF mode.

- ES_SP_D_TemperatureThreshold
  The Set/Get**Double**SystemParamter command must be used to handle this parameter. The value specifies the Temperature- threshold upon which, if reached, a 'ES_SSC_EnvironmentParamsChanged' (for Air- Temperature) and/or (if applies) a 'ES_SSC_ObjectTemperatureChanged' (for Object temperature) is thrown.
  Default threshold for temperature is 0.1 degree Celsius and is common for both, Air- and Object- temperature.
- ES_SP_D_PressureThreshold
  The Set/Get**Double**SystemParamter command must be used to handle this parameter. The value specifies the Pressure- threshold upon which, if reached, a 'ES_SSC_EnvironmentParamsChanged' is thrown.
  Default threshold for pressure is 1.0 hPa.
- ES_SP_D_HumidityThreshold
  The Set/Get**Double**SystemParamter command must be used to handle this parameter. The value specifies the Humidity- threshold upon which, if reached, a 'ES_SSC_EnvironmentParamsChanged' is thrown.
  Default threshold for pressure is 1.0 %.
- ES_SP_D_SystemLongest3DDistanceIFM
  Cannot be set. Only 'Get..' supported. Returns the longest distance (double parameter value) the interferometer is able to measure (which depends on tracker type).

- ES_SP_D_SystemLongest3DDistanceADM
  Cannot be set. Only 'Get..' supported.
  Returns the longest distance (double parameter value) the Absolute Distance Meter (ADM) is able to measure (which depends on tracker type).
- ES_SP_D_SystemLongest6DDistance
  Cannot be set. Only 'Get..' supported.
  Returns the longest distance (double parameter value) the system is able to measure in 6DoF mode (which depends on the combination of Tracker and TCam type).

Note: Some settings, for example 'LaserPointerCaptureBeam', 'ES_SP_TcpCommandQueueSize and 'ShowAll6Dmeasurements' are non-persistent settings.
They fall back to the default value in case of server reboot. If applies, an application must always set these values upon startup.

ES_ProbeConfigButton

Parameter values for ES_C_Set/GetLongSystemParameter command in case of 'ES_SP_ProbeConfig_Tip' parameter type. Allows to configure the behavior of the probe buttons.

```
enum ES_ProbeConfigButton
{
    ES_PCB_SingleClick,
    ES_PCB_StartStop,
    ES_PCB_4ButtonMode,
};
```

- ES_PCB_SingleClick:
  A single button click causes a 'ES_SSC_MeasurementProbeButtonDown' event. Typically used in an application to trigger a 'StartMeasurement'.
  Remark: This mode has somehow become

obsolete. An application can always use 'ES_PCB_StartStop' and then only evaluate either the Down- or the Up- Event or both. For that reason, the equivalent to 'ES_PCB_SingleClick' is no longer available in 4Button mode.

- ES_PCB_StartStop:
  A first button- click causes a 'ES_SSC_MeasurementProbeButtonDown ' event, releasing the button causes a 'ES_SSC_MeasurementProbeButtonUp' event. Typically used to perform a continuous measurement while the Button is being hold down (i.e. Start the measurement upon pressing the button and stop it on releasing button).

- ES_PCB_4ButtonMode:
  This mode has been introduced with emScon V2.3. It allows addressing each one of the 4 probe buttons individually. Behaves like ES_PCB_StartStop, but individually for each one of the four buttons.
  In addition, 'double- click' events have been defined for future issues. However, these are not supported so far (V3.0).
  Consequently, the following events are issued:
  ES_SSC_ProbeButton[1..4]Down,
  ES_SSC_ProbeButton[1..4]Up
  See enum 'ES_SystemStatusChange'. The events
  ES_SSC_MeasurementProbeButtonDown and ES_SSC_MeasurementProbeButtonUp are void in 4Button mode.
  Only newer probes with appropriate firmware support this mode.
  See also ES_ProbeButtonType.
  Double-click events are not yet available

with emScon versions V3.0.

ES_ProbeConfigTip

Parameter values for ES_C_Set/GetLongSystemParameter command in case of ES_SP_ProbeConfig_Tip parameter type.

```
enum ES_ProbeConfigTip
{
    ES_PCT_OnlyWithTip,
    ES_PCT_NoTipAllowed,
    ES_PCT_OnlyWithShankCompensation,
};
```

- ES_PCT_OnlyWithTip:
  Probe requires a Tip attached to allow measuring.
- ES_PCT_NoTipAllowed:
  No tip required (Scanner- probes). System allows measuring without a tip.
- ES_PCT_OnlyWithShankCompensation:
  If 'ProbeConfigTip' is set to this value, a valid shank- compensation must exist. Otherwise the system will not get ready ('green') for measuring.
  This setting thus can be used by an application to force a shank- compensation, if applies.
  Note: If a shank compensation exists for a particular tip, but 'ES_PCT_OnlyWithShankCompensation' is not set, the measurements will nevertheless be corrected by the shank compensation values!
  This setting does therefore not mean to enable/disable an (existing) shank compensation! It is just thought as a 'security- switch' for applications that must have valid shank compensations in order to block measurements if the shank compensation is missing!

ES_ProbeButtonEvent

Parameter values for the ES_C_Set/GetLongSystemParameter command in case of ES_SP_ProbeConfig_ButtonEvent parameter type.

```
enum ES_ProbeButtonEvent
{
    ES_PBE_DisableEvents,
    ES_PBE_EnableEvents,
};
```

- ES_PBE_DisableEvents:
  no button events are sent
- ES_PBE_EnableEvents:
  server sends button events

ES_QuickReleaseStatus

Parameter values for the ES_C_GetLongSystemParameter command in case of ES_SP_QuickReleaseStatus parameter type.

```
enum ES_QuickReleaseStatus
{
    ES_QRS_Closed,
    ES_QRS_Open,
};
```

- ES_QRS_Closed:
  Quick release is closed (OK to continue with tracker operations)
- ES_QRS_Open:
  Quick release is open (Must first close in order to continue with tracker operations)

ES_MeasurementStatusInfo

The values of this enum can be used to identify/mask each individual bit of the long parameter delivered by the command ES_C_GetMeasurementStatusInfo. Hence the power of 2 of every value. The meaning of the values should be self-explaining according to their symbol-names.
See description of command

ES_C_GetMeasurementStatusInfo for further information.

```
enum ES_MeasurementStatusInfo
{
    ES_MSI_Unknown = 0,
    ES_MSI_TrackerFound = 1,
    ES_MSI_TrackerCompensationFound = 2,
    ES_MSI_ADMFound = 4,
    ES_MSI_ADMCompensationFound = 8,
    ES_MSI_MeasurementCameraFound = 16,
    ES_MSI_InternalCameraParamsOK = 32,
    ES_MSI_CameraToTrackerParamsFound = 64,
    ES_MSI_MeasurementProbeFound = 128,
    ES_MSI_ProbeParamsFound = 256,
    ES_MSI_MeasurementTipFound = 512,
    ES_MSI_TipParamsFound = 1024,
    ES_MSI_ReflectorFound = 2048,
    ES_MSI_InFace1 = 4096,
    ES_MSI_ShankParamsFound = 8192,
};
```

ES_ClearCommandQueueType

This type is used as input- parameter for the 'ClearCommandQueue' command. See struct ClearCommandQueueCT. Clearing command buffers is only an issue when the ES_SP_TcpCommandQueueSize system parameter is set > 0 and usually only if a fatal error has happened upon which we want to stop the command execution immediately.
This is an advanced programming feature.

```
enum ES_ClearCommandQueueType
{
    ES_CCQ_ClearOwnOnly,
    ES_CCQ_ClearAll,
};
```

- ES_CCQ_ClearOwnOnly:
  Clear only those commands from the queue that were placed by the owning application. Do not remove commands that have been placed by other clients. This is an issue if several clients are connected to the server at a time.
- ES_CCQ_ClearAll:
  Clear all pending commands, regardless which application placed them.

ES_OverviewCameraType

This enum is part of the result of a 'GetOverviewCameraInfo' command. See struct

GetOverviewCameraInfoRT. It shows the type of the mounted overview camera.

```
enum ES_OverviewCameraType
{
    ES_OCT_Unknown,
    ES_OCT_Classic,
    ES_OCT_TCam_Integrated, // overview camera in TCam stand
};
```

- ES_OCT_Unknown:
  None or a non- recognizable Overview Camera is mounted.
- ES_OCT_Classic
  A classic 'standalone' Overview Camera is mounted on the tracker.
- ES_OCT_TCam_Intergrated
  A T-Cam with integrated Overview Camera is installed. Note: This is a hardware option - Not all T-Cams have an integrated overview camera.

ES_TriggerCardType

This enum is part of the result of a 'GetTriggerBoardInfo' command. See struct GetTriggerBoardInfRT. It shows the type of the mounted trigger board.

```
enum ES_TriggerCardType
{
    ES_TCT_None,
    ES_TCT_SingleTracker,
};
```

- ES_TCT_None
  The system is not equipped with a Trigger Board.
- ES_TCT_SingleTracker
  The system is equipped with a single Tracker Trigger Board.

Multi- Tracker Boards are not yet supported.

ES_ADMType

Specifies the type of the Absolute Distance Meter.

```
enum ES_ADMType
{
    ES_AMT_Unknown,
    ES_AMT_LeicaADM,
    ES_AMT_LeicaAIFM,
};
```

- ES_AMT_Unknown
  The type is unknown or cannot be determined.
- ES_AMT_ LeicaADM
  The ADM is a Leica type ADM.
- ES_AMT_ LeicaAIFM
  The tracker is equipped with an 'absolute interferometer' ADM type.

ES_TrkAccuracyModel

Specifies the accuracy model of the tracker.

```
enum ES_TrkAccuracyModel
{
    ES_TAM_Unknown,
    ES_TAM_2005,
};
```

- ES_TAM_Unknown
  The accuracy model cannot be determined. This is mostly due to old firmware.
- ES_TAM_2005
  The accuracy model represents the revision from 2005.

ES_NivelType

Specifies the type of the 'Nivel' inclination sensor. Note that the 'range of most precise measurement' of the Nivel 230 is smaller [1.1 mrad] than the one of the Nivel 20 [1.5 mrad]. Details see Nivel hardware Manuals.

```
enum ES_NivelType
{
    ES_NT_Unknown,
    ES_NT_Nivel20,
    ES_NT_Nivel230,
};
```

- ES_NT_Unknown
  The 'Nivel' type is unknown or cannot be determined.

- ES_NT_Nivel20
  The type is a 'classic' Nivel20 inclination sensor.
- ES_NT_Nivel230
  The type is of a new Nivel230 (released 2005)

ES_TipToProbeCompensationType

Specifies the type of the TipToProbe Compensation. See command 'GetTipToProbeCompensations2' where this parameter is delivered.

```
enum ES_TipToProbeCompensationType
{
    ES_TCT_Unknown,
    ES_TCT_TipOnly,
    ES_TCT_ShankEnabled,
};
```

- ES_TCT_Unknown
  The type of the TipToProbe compensation could not be determined.
- ES_TCT_TipOnly
  There exists only a Tip compensation
- ES_TCT_ShankEnabled
  A Tip and a Shank compensation exists. Note: The option 'Shank compensation only' (i.e. without Tip compensation) is not possible.

3.4 Data Structures

This section describes all data structures defined in *ES_C_API_Def.h*. The data structures describe the 'layout' of the data packets (byte arrays) to be transmitted over the TCP/IP network. The structures are required to construct and send data packets, to mask incoming data packets in order to recognize their type and to interpret their contents.

Note the 4-Byte alignment prerequisite for the Tracker Server and the client. See #pragma pack (push, 4) in file *ES_C_API_Def.h*. The 'pragma pack' is a Microsoft specific C-language extension. A 4-Byte alignment may be different for other C/C++ compilers. No change of layout (# of bytes and alignment for each member) is permitted, during translation of these structures to other languages.

There is a short general description for each type. Not all members are described in detail. Data members are often self- explanatory, while enumeration-type members have been described under Enumeration Types. Struct variable descriptions are provided only where necessary.

Parameters are always in current units and coordinate system / CS-type (where applicable) – unless specified otherwise.

3.4.1 Basic Data Structures

This section describes those data structures that are not directly exchanged as packets. They are used as sub-structures to compose the real 'Packet' data types.

PacketHeaderT

```
struct PacketHeaderT
{
   long             lPacketSize;
   enum ES_DataType  type;
};
```

This basic structure is a part of all data blocks transmitted over the TCP/IP network. The *lPacketSize* has been introduced for programmer's convenience. The value of the data structure contains the size (in Bytes) of received packets.
New for emScon V2.0 and up:
The *lPacketSize* value is no longer ignored. It is compulsory to correctly initialize this value. Otherwise, command calls will mostly fail. Note that due to this change, existing V1.2 / V1.5 emScon C- clients, who did not initialize these length variables, may fail with emScon servers newer than V2.0. Such client applications need to be fixed at source level.

C- programmers may use the *sizeof()* operator to determine the size of data structures.

ReturnDataT

```
struct ReturnDataT
{
   struct PacketHeaderT    packetHeader;
   enum ES_ResultStatus    status;
};
```

This basic structure is part of all result data blocks. It comprises a *PacketHeaderT* and a *ES_ResultStatus*.
Note: the variable 'status' cannot only take values of the enum 'ES_ResultStatus'. In addition, it may take any hardware/controller error as listed in the Appendix of this manual.

BasicCommandCT

```
struct BasicCommandCT
{
   struct PacketHeaderT    packetHeader;
   enum ES_Command         command;
};
```

This is a generic structure used to derive all other command types from. It serves as a general basis for sending commands.

BasicCommandRT

```
struct BasicCommandRT
{
    struct PacketHeaderT    packetHeader;
    enum ES_Command         command;
    enum ES_ResultStatus    status;
};
```

This is a generic structure used to derive all other result types from. It serves as a general basis for receiving commands.
Instead of using 'typedef' for all basic command types / result types (commands that do not take additional parameters or do not return date), two data structure containing only *BasicCommandCT* / *BasicCommandRT* member have been introduced. This approach enables naming consistency, with respect to struct nesting depth.
See also chapter 'Non- Parameter Command/Return Types'.
Note: the variable 'status' cannot only take values of the enum 'ES_ResultStatus'. In addition, it may take any hardware/controller error as listed in the Appendix of this manual.

MeasValueT

```
struct MeasValueT
{
   enum ES_MeasurementStatus   status;
   long                        lTime1;
   long                        lTime2;
   double                      dVal1;
   double                      dVal2;
   double                      dVal3;
};
```

This struct describes a single measurement of a continuous 3D measurement stream. *Time1* indicates seconds expired since a measurement start. *Time2* indicates microseconds expired within the last second. The total elapsed time in microseconds is:

T [ms] = 10e6 * lTime1 + lTime2

Attention: The value of T in the formula above becomes huge within only a few minutes! If your application implements this formula, you must use caution to avoid an overflow of T. Either use a 64bit Integer or protect the resulting

value for not to exceed MaxInt (depends on your platform).

Example:
If T was an ordinary 32 bit (unsigned) long value, its max value is 2^32 = 4'294'967'296.
This value (in microseconds) evaluates to ~ 4295 seconds. In other words, without any measures, after a continuous measurement period of about 1.2 hours the, value of T will overflow and probably cause a crash of your application. (Even worse with a signed value where the overflow will happen after ~ 0.6 hours)

Position values Val1..Val3 are in current units / CS-type and according to applied orientation / transformation parameters.

MeasValue2T

```
struct MeasValue2T
{
   enum ES_MeasurementStatus     status;
   long                          lTime1;
   long                          lTime2;
   double                        dVal1;
   double                        dVal2;
   double                        dVal3;
   double                        dAprioriStdDev1;
   double                        dAprioriStdDev2;
   double                        dAprioriStdDev3;
   double                        dAprioriStdDevTotal;
   double                        dAprioriCovar12;
   double                        dAprioriCovar13;
   double                        dAprioriCovar23;
};
```

This struct describes a single measurement of a continuous 3D measurement stream in case the statistical mode is set to ‘extended’. Principally the same as MeasValueT, but with statistic information in addition. Position values and statistic parameters are in current units / CS-type and according to applied orientation / transformation parameters.

See command '*SetStatisticMode'* and description of struct '*MeasValueT'* above, for details.

ProbeMeasValueT

```
struct ProbeMeasValueT

{
    enum ES_MeasurementStatus     status;
    enum ES_TriggerStatus         triggerStatus;
    long                          lRotationStatus;
    long                          lTime1;
    long                          lTime2;
    double                        dPosition1;
    double                        dPosition2;
    double                        dPosition3;
    double                        dStdDevPosition1;
    double                        dStdDevPosition2;
    double                        dStdDevPosition3;
    double                        dStdDevPositionTotal;
    double                        dCovarPosition12;
    double                        dCovarPosition13;
    double                        dCovarPosition23;
    double                        dQuaternion0;
    double                        dQuaternion1;
    double                        dQuaternion2;
    double                        dQuaternion3;
    double                        dRotationAngleX;
    double                        dRotationAngleY;
    double                        dRotationAngleZ;
    double                        dStdDevRotationAngleX;
    double                        dStdDevRotationAngleY;
    double                        dStdDevRotationAngleZ;
    double                        dStdDevRotationAngleTotal;
    double                        dCovarRotationAngleXY;
    double                        dCovarRotationAngleXZ;
    double                        dCovarRotationAngleYZ;
};
```

This struct describes a single measurement (6 degrees of freedom) in a 6DoF continuous measurement stream. *Time1* indicates seconds expired since a measurement start. *Time2* indicates microseconds expired within the last second. The total elapsed time in microseconds is:

T [ms] = 10e6 * lTime1 + lTime2

Attention: The value of T in the formula above becomes huge within only a few minutes! If your application implements this formula, you must use caution to avoid an overflow of T. Either use a 64bit Integer or protect the resulting value for not to exceed MaxInt (depends on your platform).

Example: See MeasValueT

Position values, angular values and statistic parameters are in current units / CS-type and according to applied orientation / transformation parameters.

The position values relate to the center of the tip ruby sphere.
Rotation angles are always represented in the interval between -PI and PI.

The following helper- structs ease the interpretation of the Rotation- Status:

RotationStatus

Note: If the SystemParameter flag 'ES_SP_ShowAll6DMeasurements' is set to 'False' (which is default), then only measurements with Rotation Status OK will arrive. Interpreting the Rotation Status only becomes an issue if the 'ShowAll6DMeasurements' is enabled (By using the 'SetLongSystemParameter' command).
The following union can be used to easily interpret the rotation status: Assign the returned value (a long) to URotationStatus.l, then interpret the Error6D and optionally other fields. Note that the fields are only valid if Status6D bit is set.
The evaluation of rotation status in detail is subject of advanced programming. Usually it is sufficient just to check for ‘Error6D’ being 0 (success) or 1 (error) (while ‘Status6D’ is 1).

```
struct RotationStatus
{
    unsigned Status6D:1;        // 0 => no rotation status; 1 =>
                                // rotation status valid
    unsigned Error6D:1;         // 1 => ERROR in rotation status
    unsigned NotEnoughLED:1;
    unsigned RMSToHigh:1;
    unsigned AngleOutOfRange:1;   // Hz or Vt (see RotStatus
                                  // values)
    unsigned Frozen6DValues:1;    // 6D values are not updated !
    unsigned DistanceOutOfRange:1;// dist too short or too long
    unsigned Reserved1:1;         // always 0
    unsigned RotStatLeftRight:3;  // see documentation
    unsigned RotStatUpDown:3;     // see documentation
    unsigned GoodGauge:2;         // 0 => All bad; 1 => 33% good
                                  // 2 => 66% good ...
    unsigned Face2:1;             // 0 => Face1; 1 => Face2
    unsigned Reserved2:15;        // always 0
};

union URotationStatus
{
    long                        l;
    struct RotationStatus       rotStat;
};
```

StationaryModeDataT

```
struct StationaryModeDataT
{
   long    lMeasTime;
   ES_BOOL bUseADM; // Caution: has no effect in 6D mode !
};
```

Used as parameters for the *Set/GetStationaryModeParams* commands. The measurement time parameter must lie between 500 ms [2500 ms if *useADM* is *true*] and 100'000 ms (0.5 [2.5] – 100 seconds).
The *useADM* flag is *false* by default. If this flag is set to *true*, an ADM measurement is always performed prior to the stationary measurement (which is based on the IFM). This usually does not make sense and will also slow down the measurement process significantly.
Only in exceptional cases, this flag may be set to *true*. (For example if the beam always remains attached to the same reflector and there is a major time- gap between measurements (several minutes or hours).

Note: the *useADM* flag has no effect for 6DoF measurement modes and will be ignored for these modes, regardless whether true or false.

ContinuousTimeModeDataT

```
struct ContinuousTimeModeDataT
{
   long              lTimeSeparation;
   long              lNumberOfPoints;
   ES_BOOL           bUseRegion;
   enum ES_RegionType  regionType;
};
```

Used as parameters for the *Set/GetContinuousTimeModeParams* commands. A *lNumberOfPoints* value of zero means 'infinite' (in this case, the measurement must be stopped explicitly with a StopMeasurement command). Time separation is in milliseconds and can vary between 1..99999 ms.

ContinuousDistanceModeDataT

```
struct ContinuousDistanceModeDataT
{
   double            dSpatialDistance;
   long              lNumberOfPoints;
   ES_BOOL           bUseRegion;
   enum ES_RegionType  regionType;
};
```

Used as parameters for the *Set/GetContinuousDistanceModeParams* commands. A *lNumberOfPoints* value of zero means 'infinite' (must be stopped explicitly). Rather than based on a time- separation criteria, a distance criteria is used. It is in current length- unit. Note: One single measurement will be preformed upon StartMeasurement. Further measurements are not taken until the reflector is being moved.
A region can be applied to limit the 'sensitive' measurement space. See commands SetBox- / SetSphereRegionParams for region definition.

SphereCenterModeDataT

```
struct SphereCenterModeDataT
{
   double  dSpatialDistance;
   long    lNumberOfPoints;
   ES_BOOL bFixRadius;
   double  dRadius;
};
```

Used as parameters for the *Set/GetSphereCenterModeParams* commands. A *lNumberOfPoints* value of zero means 'infinite' (must be stopped explicitly).
Spatial distance and Radius are in current length-

unit. The radius can be left variable (to be calculated by the fit- routine), or fixed, if it is known.
Same trigger criteria as with Continuous distance mode.

CircleCenterModeDataT

```
struct CircleCenterModeDataT
{
   double  dSpatialDistance;
   long    lNumberOfPoints;
   ES_BOOL bFixRadius;
   double  dRadius;
};
```

Used for parameters *Set/GetCircleCenterModeParams* commands. A *lNumberOfPoints* value of zero means 'infinite' (must be stopped explicitly).
Radius is in current length- unit.
Spatial distance and Radius are in current length-unit. The radius can be left variable (to be calculated by the fit- routine), or fixed, if it is known.
Same trigger criteria as with Continuous distance mode.

GridModeDataT

```
struct GridModeDataT
{
   double              dVal1;
   double              dVal2;
   double              dVal3;
   long                lNumberOfPoints;
   ES_BOOL             bUseRegion;
   enum ES_RegionType  regionType;
};
```

Used as parameters for the *Set/GetGridModeParams* commands. The 3 values describe the grid size in the CS. Position values are in current units / CS-type. A *lNumberOfPoints* value of zero means 'infinite' (must be stopped explicitly).
A region can be applied to limit the 'sensitive' measurement space. See commands 'SetBox- / SetSphereRegionParams' for region definition.

SearchParamsDataT

```
struct SearchParamsDataT
{
   double   dSearchRadius;
   double   lTimeOut;
};
```

Used for parameters of *Set/GetSearchParams* commands.
The search process is aborted upon one or the other of the two criteria is reached.
TimeOut is in milliseconds. There is a minimum value of 10’000 ms (10 Seconds) and a maximum of 240'000 ms (4 minutes).
SearchRadius is in current units. The timeout parameter will interrupt the search if it takes too long due to a too big search radius (if no reflector found within the specified time). The Search Radius in current length units and must lie between 0 and 0.5 meters. The default value is 0.04 meters. (Caution with small or even zero radius and / or small timeOut: Too small value may cause the search process to fail.
Note: the maximum radius value was 1.0 m in emScon versions prior to version 2.0 and has been reduced to 0.5 m for newer versions!
Large search radii result in extended search times, unless time is limited to a reasonable value.
Typical values are 0.05 m for the radius and 30’000 ms for timeout.

AdmParamsDataT

```
struct AdmParamsDataT
{
   double   dTargetStabilityTolerance;
   double   lRetryTimeFrame;
   double   lNumberOfRetrys;
};
```

Used for parameters for the *Set/GetAdmParams* commands. *RetryTimeFrame* is in milliseconds in the range between 500 and 5000.
TargetStabilityTolerance is a distance parameter and is in current length- units.
TargetStabilityTolerance must lie between 0.005 and 0.1 Millimeter. Leave this value as low as

possible! (Default is 0.005).

The *SetAdmParams* command should be used with caution. Only change these parameters if working in an unstable environment (vibrations). Lowering the stability tolerance results in loss of precision!

SystemSettingsDataT

```
struct SystemSettingsDataT
{
   enum ES_WeatherMonitorStatus   weatherMonitor;
   ES_BOOL                        bApplyTransformationParams;
   ES_BOOL                       bApplyStationOrientationParams;
   ES_BOOL                        bKeepLastPosition;
   ES_BOOL                        bSendUnsolicitedMessages;
   ES_BOOL                        bSendReflectorPositionData;
   ES_BOOL                        bTryMeasurementMode;
   ES_BOOL                        bHasNivel;
   ES_BOOL                        bHasVideoCamera;
};
```

Used for parameters of *Set/Get SystemSettings* commands. The system settings are a collection of various 'properties' to control certain behavior of the emScon system :

- *WeatherMonitorStatus*
  Indicates the WM status. See description on enum *ES_WeatherMonitorStatus*
  New behavior with emScon 3.0:
  With emScon 3.0, there is an automatic recognition of any attached meteo station. See chapter **Automatic External Device Recognition** (under Section 2.4) for more details.

- *bApplyTransformationParams*
  If this flag is set to *false*, the System does not transform the measurements into a user-specified coordinate system. If set to *true,* transformation as per transformation parameters is applied. If set to *false*, the default transformation will be used {0, 0, 0, 0, 0, 0, 1}, regardless of the current values set with SetTransformationParams command. Transformations also apply to the positioning commands (such as GoPosition) and to part of the Input/Output filters (Box, Sphere)

- *bApplyStationOrientationParams*
  If this flag is set to *true*, the System uses the given orientation parameters. If set to *false*, the default station orientation will be used {0, 0, 0, 0, 0, 0}, regardless of the current values set with the SetStationOrientationParams command. Orientations also apply to the positioning commands (such as GoPosition).
- *bKeepLastPosition*
  If this flag is set to *true* and the laser beam is broken, it does not leave the current position. This allows to 'catch' the beam again, then placing the reflector to a stable position. The ADM then tries to perform a measurement and – if success- sets the measured distance as the new interferometer distance. From then on, it is possible to recover measuring without having to go back to the BirdBath on beam broken events.
  If the flag is set to *false*, the beam is disabled (mirror points down). If an Overview Camera is installed, the sensor drives into the camera position.
  Important: Enabling the 'KeepLastPosition' flag is compulsory for 6D Measurement Modes. Otherwise the Probe will not be recognized (If beam catched at zero position).
- *bSendUnsolicitedMessages*
  If this flag is set to *true*, the system sends all error messages as they occur. This flag should always be true. Otherwise neither error events nor system status- change events will be issued. These events should be suppressed only in real special situations.
- *bSendReflectorPositionData*
  If this flag is set to *true* and a reflector / Probe is locked on by the tracker, the system sends the current reflector position (max. 3 measurements per second). These are issued

even when no continuous measurement is in progress. They can be used to view the Reflector/probe movement on applications with graphic representation of reflector movement. Do not regard the position values as accurate measurements. They are of limited accuracy!
See structs 'ReflectorPosResultT' and 'ProbePosResultT' for details.

- *bTryMeasurementMode*
  If this flag is set to *true*, the system delivers all results in the try mode. This is a Leica internal feature and therefore undocumented. It can be ignored by application programmers. The effect is just that – if set to true – the value is 'echoed' with each measurement.

- *bHasNivel*
  A hardware Configuration issue. This flag tells the system that a Leica 'Nivel' inclination sensor is attached. Measurements with the sensor are now possible. **Behavior up to emScon V2.4:** The system cannot automatically detect whether a 'Nivel' sensor is attached. Hence you must tell it the system by enabling this flag.
  New behavior with emScon 3.0:
  With emScon 3.0, there is an automatic recognition of any attached inclination sensor.
  See chapter **Automatic External Device Recognition** (under Section 2.4) for more details.

- *bHasVideoCamera*
  A hardware Configuration issue. This flag tells the system, that an Overview Camera is present.
  The following description mainly applies to former emScon 2.4 and older systems. For

the new emScon 3.0 behavior see remark at the end of this section.
If your system is equipped with an overview camera, it is recommended to always having checked this flag (even when the camera is temporarily removed). Otherwise, leave it always unchecked (= default).
In the meantime there exist different types of overview cameras that differ in internal parameters (focus distance, CCD chip size). Older emScon versions were not able to detect whether an overview camera was mounted or not, not to speak of type recognition (indeed it was the overview camera hardware that did not support type recognition). For that reason, the flag 'HasVideoCamera' was originally introduced. Thus, the user had to 'tell' the system when an overview camera was mounted. Newer EmScon versions (2.0 and up) are able to detect the camera type automatically. Hence, this flag theoretically has become obsolete. However, currently the camera type is recognized **only when the 'hHasVideoCamera' flag is enabled**.
If your system is equipped with an overview camera, it is highly recommended to always having this flag checked (default is unchecked). Otherwise, the system may not detect the correct camera type and use wrong (default) parameters.
However, wrong parameters do not cause any fatal failures. The only effect will be that the 'Find Reflector' feature by clicking to the live video image by mouse pointer will move the tracker inaccurately (typically, the tracker will move double or half the amount of the 'clicked' distance).
New behavior with emScon 3.0:
With emScon 3.0, there is an automatic

recognition of any present overview camera. See chapter **Automatic External Device Recognition** (under Section 2.4) for more details.

SystemUnitsDataT

```
struct SystemUnitsDataT
{
   enum ES_LengthUnit          lenUnitType;
   enum ES_AngleUnit           angUnitType;
   enum ES_TemperatureUnit     tempUnitType;
   enum ES_PressureUnit        pressUnitType;
   enum ES_HumidityUnit        humUnitType;
};
```

Used for parameters of *Set/GetUnits* commands. See related enums – they explain themselves.

EnvironmentDataT

```
struct EnvironmentDataT
{
   double    dTemperature;
   double    dPressure;
   double    dHumidity;
};
```

Used for parameters of *Set/GetEnvironmentParams* commands. The *SetEnvironmentParams* command mainly applies when no weather monitor is available, or when disabled by the *bUseWeatherMonitor* setting. Otherwise, these parameters are updated implicitly and the current values can be retrieved with the *GetEnvironmentParams*. See also description of enum 'ES_WeatherMonitorStatus'.

See chapter 'Working Conditions'.

RefractionDataT

```
struct RefractionDataT
{
   double dIfmRefractionIndex;
   double dAdmRefractionIndex;
};
```

Used for parameters of *Set/GetRefractionParams* commands. See also description of enum 'ES_WeatherMonitorStatus'.
This is a command for advanced and special usage. It should only be used in combination with the WeatherMonitorStatus mode 'ES_WMS_ReadOnly'. See description there.

Normal application should not explicitly set refraction parameters. They are set indirectly by using the *SetEnvironmentParams* command (if no weather monitor available), or by selecting the mode 'ES_WMS_ReadAndCalculateRefractions' (if a WM is connected).

Under certain conditions, the refraction parameters are updated (set) implicitly on setting new environment parameters. See description of enum 'ES_WeatherMonitorStatus'.

See chapter 'Working Conditions'.

StationOrientationDataT

```
struct StationOrientationDataT
{
   double    dVal1;
   double    dVal2;
   double    dVal3;
   double    dRot1;
   double    dRot2;
   double    dRot3;
};
```

Used as parameters for *Set/GetStationOrientationParams* commands. Values are in current units and CS-type. These settings can be enabled/disabled through the system flag *bUseStationOrientationParams*.

TransformationDataT

```
struct TransformationDataT
{
   double    dVal1;
   double    dVal2;
   double    dVal3;
   double    dRot1;
   double    dRot2;
   double    dRot3;
   double    dScale;
};
```

Used as parameters for *Set/GetTransformationParams* commands. Values are in current units and CS-type. These settings can be enabled/disabled through the system flag *bUseLocalTransformationMode*.

BoxRegionDataT

```
struct BoxRegionDataT
{
   double    dP1Val1;
   double    dP1Val2;
   double    dP1Val3;
   double    dP2Val1;
   double    dP2Val2;
   double    dP2Val3;
};
```

Used for parameters of *Set/GetBoxRegionParams* commands. The parameters describe two diagonal points of a box.
Values are in current units and CS-type (but not according to active transformation settings).
These settings only apply if the *bUseRegion* flag in the appropriate continuous measurement structure is enabled, together with the 'Box' region type.

SphereRegionDataT

```
struct SphereRegionDataT
{
   double    dVal1;
   double    dVal2;
   double    dVal3;
   double    dRadius;
};
```

Used for parameters of *Set/GetSphereRegionParams* commands. The parameters describe center point and radius of a sphere.
Values are in current units and (apart from Radius) in current CS-type and according to applied transformation settings.
These settings only apply if the *bUseRegion* flag in the appropriate continuous measurement structure is enabled, together with 'Sphere' region type.

ESVersionNumberT

```
struct ESVersionNumberT
{
   int   iMajorVersionNumber;
   int   iMinorVersionNumber;
   int   iBuildNumber;
};
```

Used for one of the parameters of the *GetSystemStatus* command. Contains version info of the currently installed tracker server software.

TransformationInputDataT

```
struct TransformationInputDataT
{
   enum ES_TransResultType    resultType;
   double                     dTransVal1;
   double                     dTransVal2;
   double                     dTransVal3;
   double                     dRotVal1;
   double                     dRotVal2;
   double                     dRotVal3;
   double                     dScale;
   double                     dTransStdVal1;
   double                     dTransStdVal2;
   double                     dTransStdVal3;
   double                     dRotStdVal1;
   double                     dRotStdVal2;
   double                     dRotStdVal3;
   double                     dScaleStd;
};
```

Used for parameters of the *Set/GetTransformationInputParams* command.
Used in order to specify (Fixing, Weighting) transformation result values.
Values are in current units and (apart from Radius) in current CS-type (No transformation applies).

For details see Section 9.2 .

For the StdDev parameters, use values as specified in chapter 'Constants'.

TransformationPointT

```
struct TransformationPointT
{
   double                  dVal1;
   double                  dVal2;
   double                  dVal3;
   double                  dStd1;
   double                  dStd2;
   double                  dStd3;
   double                  dCov12;
   double                  dCov13;
   double                  dCov23;
};
```

It is used as a sub- structure for the *AddNominal/AddActualTransformationPoint* commands.
Values are in current units and CS-type and according to applied transformation settings only in case of actual points. Nominal points are not influenced by transformation settings.
For details see Section 9.2 .

For the StdDev parameters, use values as specified in chapter 'Constants'.

CameraParamsDataT

```
struct CameraParamsDataT
{
   int   iContrast;
   int   iBrightness;
   int   iSaturation;
};
```

Used for parameters of the *Set/GetCameraParams* command. Values of Contrast/Brightness range from 0 to 256.

Saturation is currently not used and must be set to zero.

3.4.2 Packet Data Structures

These data types describe the real data blocks exchanged over the TCP/IP network between the Tracker Server and the application PC. There are 9 main types of packets (see enum '*ES_DataType'*). The structures of *ES_DT_Command*- type packets differ for different commands.

All packet types contain (directly or through another sub-structure such as *ReturnDataT*, *BasicCommandCT* or *BasicCommandRT*) a sub-structure of type *PacketHeaderT* with the size and type of the packet.

- Command type packets (apart from a certain number of parameters), always contain an *ES_Command* command type parameter.
- Return type packets, command, error and measurements always contain a status parameter.

ErrorResponseT

```
struct ErrorResponseT
{
   struct PacketHeaderT  packetHeader;
   enum ES_Command       command;
   enum ES_ResultStatus  status;
};
```

This receive-only structure *ES_DT_Error* packet type describes the packet size and type. It contains a standard packet header and a return

status, *ES_ResultStatus*, or a hardware/controller error number.
Note: the variable 'status' cannot only take values of the enum 'ES_ResultStatus'. In addition, it may take any hardware/controller error as listed in the Appendices of this manual.

The 'command' parameter is often set to *ES_C_Unknown* since errors are often occur 'unsolicited', that is, they are not a reaction to a command. Consider a 'beam broken' error. Such an event can happen at any time and is obviously not caused by a command.
The command parameter is set to *ES_C_Unknown* unless the error was caused by particular command.

SingleMeasResultT

```
struct SingleMeasResultT
{
   struct ReturnDataT      packetInfo;
   enum ES_MeasMode        measMode;
   ES_BOOL                 bIsTryMode;
   double                  dVal1;
   double                  dVal2;
   double                  dVal3;
   double                  dStd1;
   double                  dStd2;
   double                  dStd3;
   double                  dStdTotal;
   double                  dPointingError1;
   double                  dPointingError2;
   double                  dPointingError3;
   double                  dAprioriStd1;
   double                  dAprioriStd2;
   double                  dAprioriStd3;
   double                  dAprioriStdTotal;
   double                  dTemperature;
   double                  dPressure;
   double                  dHumidity;
};
```

This receive-only structure describes the *ES_DT_SingleMeasResult* packet type. Apart from the standard *ReturnDataT* structure, it contains data specific to a single tracker 3D measurement. In addition to the 3 coordinate values, there is statistical information such as standard deviations (a posteriori and a priori) and pointing errors. The environmental values are those currently valid to the system (either those explicitly set by SetEnvironmentParams, or those last implicitly updated by the weather monitor).

The flag *bIsTryMode* is set if system is in 'Try Mode'. This is not relevant for common users.
The format of measurements, statistical information and environmental values depend on current units. Measurements and statistical information in addition are according current CS-type and applied orientation / transformation parameters.

SingleMeasResult2T

```
struct SingleMeasResult2T
{
   struct ReturnDataT      packetInfo;
   enum ES_MeasMode        measMode;
   ES_BOOL                 bIsTryMode;
   double                  dVal1;
   double                  dVal2;
   double                  dVal3;
   double                  dStdDev1;
   double                  dStdDev2;
   double                  dStdDev3;
   double                  dStdDevTotal;
   double                  dCovar12;
   double                  dCovar13;
   double                  dCovar23;
   double                  dPointingErrorH;
   double                  dPointingErrorV;
   double                  dPointingErrorD;
   double                  dAprioriStdDev1;
   double                  dAprioriStdDev2;
   double                  dAprioriStdDev3;
   double                  dAprioriStdDevTotal;
   double                  dAprioriCovar12;
   double                  dAprioriCovar13;
   double                  dAprioriCovar23;
   double                  dTemperature;
   double                  dPressure;
   double                  dHumidity;
};
```

This receive-only structure describes the *ES_DT_SingleMeasResult2* packet type in case of extended statistical mode. Use this variant if points to be used as input for the Transformation routine.
The flag *bIsTryMode* is set, if system is in 'Try Mode'. This is not relevant for common users.
See also command '*SetStatisticMode'*.
The format of measurements, statistical information and environmental values depend on current units. Measurements and statistical information in addition are according current CS-type and applied orientation / transformation parameters.

MultiMeasResultT

```
struct MultiMeasResultT
{
   struct ReturnDataT      packetInfo;
   long                    lNumberOfResults;
   enum ES_MeasMode        measMode;
   ES_BOOL                 bIsTryMode;
   double                  dTemperature;
   double                  dPressure;
   double                  dHumidity;
   struct MeasValueT       data[1];
};
```

This receive-only structure describes the *ES_DT_MultiMeasResult* packet type, where a continuous stream of packets is received during a continuous measurement.
A packet consists of the single measurement and an array of *MeasValueT* parameters attached to it. The *MultiMeasResultT* structure only contains (covers) the first element of this array (a 'pointer' to the array). The *lNumberOfResults* parameter identifies the number of array elements, and the remaining elements can be iterated from *data [0] … data [lNumberOfResults - 1]*.

C-Arrays are always zero-based!

This structure only covers the header of a multi-measurement packet. Measurement mode and environmental parameters are common for the body (measurement array). The flag *bIsTryMode* is set if system is in *Try Mode*. This is not relevant for common users.
The format of measurements, statistical information and environmental values depend on current units. Measurements and statistical information in addition are according current CS-type and applied orientation / transformation parameters.

MultiMeasResult2T

```
struct MultiMeasResult2T
{
   struct ReturnDataT      packetInfo;
   long                    lNumberOfResults;
   enum ES_MeasMode        measMode;
   ES_BOOL                 bIsTryMode;
   double                  dTemperature;
   double                  dPressure;
   double                  dHumidity;
   struct MeasValue2T      data[1];
};
```

The same as *MultiMeasResultT* (see above), but received in case the statistical mode is set to 'extended'.
See also command '*SetStatisticMode*'.

ProbeStationaryResultT

```
struct ProbeStationaryResultT
{
    struct ReturnDataT            packetInfo;
    enum ES_MeasMode              measMode;
    ES_BOOL                       bIsTryMode;
    enum ES_TriggerStatus         triggerStatus;
    long                          lRotationStatus;
    long                          iInternalProbeId;
    int                           iFieldNumber;
    enum ES_MeasurementTipStatus  tipStatus;
    long                          iInternalTipAdapterId;
    long                          iTipAdapterInterface;
    double                        dPosition1;
    double                        dPosition2;
    double                        dPosition3;
    double                        dStdDevPosition1;
    double                        dStdDevPosition2;
    double                        dStdDevPosition3;
    double                        dStdDevPositionTotal;
    double                        dCovarPosition12;
    double                        dCovarPosition13;
    double                        dCovarPosition23;
    double                        dAprioriStdDevPosition1;
    double                        dAprioriStdDevPosition2;
    double                        dAprioriStdDevPosition3;
    double                        dAprioriStdDevPositionTotal;
    double                        dAprioriCovarPosition12;
    double                        dAprioriCovarPosition13;
    double                        dAprioriCovarPosition23;
    double                        dQuaternion0;
    double                        dQuaternion1;
    double                        dQuaternion2;
    double                        dQuaternion3;
    double                        dRotationAngleX;
    double                        dRotationAngleY;
    double                        dRotationAngleZ;
    double                        dStdDevRotationAngleX;
    double                        dStdDevRotationAngleY;
    double                        dStdDevRotationAngleZ;
    double                        dStdDevRotationAngleTotal;
    double                        dCovarRotationAngleXY;
    double                        dCovarRotationAngleXZ;
    double                        dCovarRotationAngleYZ;
    double                        dAprioriStdDevRotationAngleX;
    double                        dAprioriStdDevRotationAngleY;
    double                        dAprioriStdDevRotationAngleZ;
    double                     dAprioriStdDevRotationAngleTotal;
    double                        dAprioriCovarRotationAngleXY;
    double                        dAprioriCovarRotationAngleXZ;
    double                        dAprioriCovarRotationAngleYZ;
    double                        dTemperature;
    double                        dPressure;
    double                        dHumidity;
};
```

This receive-only structure describes the *ES_DT_Single6DMeasResult* packet type.

This structure is used to transmit the result of a 6D stationary measurement. The result depends on current length and angle units, the coordinate system type, orientation and transformation parameters applied.

It contains:

- Status Information
- Adapter where Tip mounted including its accuracy
- Probe position. The position values relate to the center of the tip ruby sphere.
- Probe orientation in two different representations:
    - Quaternion or
    - Rotation Angles including their accuracy
- Environmental Data

Rotation angles are always represented in the interval between -PI and PI.

Details about RotationStatus: see chapter 'Rotation Status' just following the chapter 'ProbeMeasValueT'

Applies only to 6DoF systems.

ProbeContinuousResultT

```
struct ProbeContinuousResultT

{
    struct ReturnDataT            packetInfo;
    long                          lNumberOfResults;
    enum ES_MeasMode              measMode;
    ES_BOOL                       bIsTryMode;
    int                           iInternalProbeId;
    int                           iFieldNumber;
    enum ES_MeasurementTipStatus  tipStatus;
    int                           iInternalTipAdapterId;
    int                           iTipAdapterInterface;
    double                        dTemperature;
    double                        dPressure;
    double                        dHumidity;
    struct ProbeMeasValueT        data[1];
};
```

This receive-only structure describes the *ES_DT_ContinuousProbeMeasResult* packet type. The only difference to an *ES_DT_ MultiMeasResult* is the array element types. Applies only to 6DoF systems.

NivelResultT

```
struct NivelResultT
{
   struct ReturnDataT      packetInfo;
   enum ES_NivelStatus     nivelStatus;
   double                  dXTilt;
   double                  dYTilt;
   double                  dNivelTemperature;
};
```

This receive-only structure describes the *ES_DT_NivelResult* packet type, which includes the *ReturnDataT* structure and contains data specific to a 'Nivel' measurement.

Refer to chapter 'ES_NivelStatus' in chapter 3.3.2 (enumeration types) for details about supported measurement ranges.

The format of measurement and environmental values do **NOT** depend on current unit settings. 'Nivel' results always arrive in native 'Nivel' format – milliradiant for X/Y tilt and Celsius for temperature.

ReflectorPosResultT

```
struct ReflectorPosResultT
{
   struct ReturnDataT      packetInfo;
   double                  dVal1;
   double                  dVal2;
   double                  dVal3;
};
```

This receive-only structure describes the *ES_DT_ReflectorPosResult* packet type. These are received whenever the tracker is locked onto a reflector (3 measurements per second). The receipt of these 'measurement'- types can be switched on/off with the systems flag *bSendReflectorPositionData*. Values are in current units / CS-type and according to applied orientation / transformation parameters.

ProbePosResultT

```
struct ProbePosResultT
{
    struct ReturnDataT              packetInfo;
    long                            lRotationStatus;
    enum ES_MeasurementTipStatus    tipStatus;
    long                            iInternalTipAdapterId;
    long                            iTipAdapterInterface;
    double                          dPosition1;
    double                          dPosition2;
    double                          dPosition3;
    double                          dQuaternion0;
    double                          dQuaternion1;
    double                          dQuaternion2;
    double                          dQuaternion3;
    double                          dRotationAngleX;
    double                          dRotationAngleY;
    double                          dRotationAngleZ;
};
```

The 'Probe' relative to ReflectorPosResult. Values are in current units / CS-type and according to applied orientation / transformation parameters. There are some status values in addition.
Rotation angles are always represented in the interval between -PI and PI.
The position values relate to the center of the tip ruby sphere.
Details about RotationStatus: see chapter 'Rotation Status' just following the chapter 'ProbeMeasValueT'

SystemStatusChangeT

```
struct SystemStatusChangeT
{
   struct ReturnDataT         packetHeader;
   enum ES_SystemStatusChange systemStatusChange;
};
```

This receive-only structure describes the *ES_DT_SystemStatusChange* packet type. These are received when the system status has changed.

See enum 'ES_SystemStatusChange' for supported notification types.

ExternTriggerParamsT

```
struct ExternTriggerParamsT
{
   enum ES_ClockTransition    clockTransition;
   enum ES_TriggerMode        triggerMode;
   enum ES_TriggerStartSignal startSignal;
   long lMinimalTimeDelay;
};
```

Parameters 1..3: See description of appropriate enumeration types.

lMinimalTimeDelay: The time delay between trigger event and measurement.

Non- Parameter Command/Return Types

Lists all non- parameter command structures. They are derived from the *BasicCommandCT* (command-types; client to Server) and the *BasicCommandRT* (return-types; Server to client).

```
struct InitializeCT
{
   struct BasicCommandCT   packetInfo;
};

struct InitializeRT
{
   struct BasicCommandRT   packetInfo;
};

struct ReleaseMotorsCT
{
   struct BasicCommandCT   packetInfo;
};

struct ReleaseMotorsRT
{
   struct BasicCommandRT   packetInfo;
};

struct ActivateCameraViewCT
{
   struct BasicCommandCT   packetInfo;
};

struct ActivateCameraViewRT
{
   struct BasicCommandRT   packetInfo;
};

struct ParkCT
{
   struct BasicCommandCT   packetInfo;
};

struct ParkRT
{
   struct BasicCommandRT   packetInfo;
};

struct GoBirdBathCT
{
   struct BasicCommandCT   packetInfo;
};

struct GoBirdBathRT
{
   struct BasicCommandRT   packetInfo;
};

struct GoLastMeasuredPointCT
{
   struct BasicCommandCT   packetInfo;
};

struct GoLastMeasuredPointRT
{
   struct BasicCommandRT   packetInfo;
};

struct ChangeFaceCT
{
   struct BasicCommandCT   packetInfo;
};

struct ChangeFaceRT
{
   struct BasicCommandRT   packetInfo;
};

struct StartNivelMeasurementCT
{
   struct BasicCommandCT   packetInfo;
};

struct StartNivelMeasurementRT
{
   struct BasicCommandRT   packetInfo;
};

struct StartMeasurementCT
{
   struct BasicCommandCT   packetInfo;
};

struct StartMeasurementRT
{
   struct BasicCommandRT   packetInfo;
```

```
};

struct StopMeasurementCT
{
   struct BasicCommandCT   packetInfo;
};

struct StopMeasurementRT
{
   struct BasicCommandRT   packetInfo;
};

struct ExitApplicationCT
{
   struct BasicCommandCT   packetInfo;
};

struct ExitApplicationRT
{
   struct BasicCommandRT   packetInfo;
};

struct ClearTransformationNominalPointListCT
{
   struct BasicCommandCT   packetInfo;
};

struct ClearTransformationNominalPointListRT
{
   struct BasicCommandRT   packetInfo;
};

struct ClearTransformationActualPointListCT
{
   struct BasicCommandCT   packetInfo;
};

struct ClearTransformationActualPointListRT
{
   struct BasicCommandRT   packetInfo;
};

struct ClearDrivePointListCT
{
   struct BasicCommandCT   packetInfo;
};

struct ClearDrivePointListRT
{
   struct BasicCommandRT      packetInfo;
};
```

SwitchLaserCT/RT

Command structures for switching the laser on/off. The laser should only be switched off during long breaks (overnight), while the controller is not shut down. Switching laser on again will take about 20 minute to stabilize!

```
struct SwitchLaserCT
{
   struct BasicCommandCT   packetInfo;
   ES_BOOL                 bIsOn;
};

struct SwitchLaserRT
{
   struct BasicCommandRT   packetInfo;
};
```

FindReflectorCT/RT

Command structures for invoking a 'Find Reflector' sequence. d*ApproxDistance* should be specified in order to apply search radius dependent on the distance from the tracker. Approx distance is in current length units.

```
struct FindReflectorCT
{
   struct BasicCommandCT   packetInfo;
   double                  dApproxDistance;
};

struct FindReflectorRT
{
   struct BasicCommandRT   packetInfo;
};
```

The search time depends on the search radius and timeout set by the SetSearchParams command. Large search radii result in extended search times unless limited by a reasonable SearchTimeout. See ‘SetSearchParams’ for details. The real search radius in addition depends on the specified approx distance. An approx. distance, which is 50% off the actual value, will also influence the search radius by 50%. The system cannot directly work with the radius. It calculates horizontal and vertical angles for the tracker from the specified search radius and approximate Distance.
Although no range limitation for the approx distance applies in theory, there is a practical limitation given by tracker working space: 100 mm < approxDist <= 50000 mm. Note: the minimum value is 101 mm, not 100 mm!

See also SearchParamsDataT.

Set/GetCoordinateSystemTypeCT/RT

Command structures for setting/getting the current coordinate system type. The current CS-type acts – like current units (and transformation / orientation parameters) – as a input/output 'Filter' to all coordinate-type related parameters.

```
struct SetCoordinateSystemTypeCT
{
   struct BasicCommandCT            packetInfo;
   enum ES_CoordinateSystemType     coordSysType;
};

struct SetCoordinateSystemTypeRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetCoordinateSystemTypeCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetCoordinateSystemTypeRT
{
   struct BasicCommandRT            packetInfo;
   enum ES_CoordinateSystemType     coordSysType;
};
```

See enum 'ES_CoordinateSystemType' for details.

Set/GetMeasurementModeCT/RT

Command structures for setting/getting the current measurement mode.

```
struct SetMeasurementModeCT
{
   struct BasicCommandCT   packetInfo;
   enum ES_MeasMode        measMode;
};

struct SetMeasurementModeRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetMeasurementModeCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetMeasurementModeRT
{
   struct BasicCommandRT   packetInfo;
   enum ES_MeasMode        measMode;
};
```

See enum 'ES_MeasMode' for details.

Set/GetTemperatureRangeCT/RT

Command structures for setting/getting the active laser tracker temperature range. A value different than 'ES_TR_Medium' (default) should be selected only if special environmental conditions apply.

```
struct SetTemperatureRangeCT
{
   struct BasicCommandCT            packetInfo;
   enum ES_TrackerTemperatureRange  temperatureRange;
};

struct SetTemperatureRangeRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetTemperatureRangeCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetTemperatureRangeRT
{
   struct BasicCommandRT            packetInfo;
   enum ES_TrackerTemperatureRange  temperatureRange;
};
```

See enum 'ES_TrackerTemperatureRange' for details.

Set/GetStationaryModeParamsCT/RT

Command structures for setting/getting the parameters for the Stationary Measurement mode.

```
struct SetStationaryModeParamsCT
{
   struct BasicCommandCT   packetInfo;
   struct StationaryModeDataT  stationaryModeData;
};

struct SetStationaryModeParamsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetStationaryModeParamsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetStationaryModeParamsRT
{
   struct BasicCommandRT         packetInfo;
   struct StationaryModeDataT    stationaryModeData;
};
```

See struct 'StationaryModeDataT' for details.

Set/GetContinuousTimeModeParamsCT/RT

Command structures for setting/getting the parameters for the Continuous Time Measurement mode.

```
struct SetContinuousTimeModeParamsCT
{
   struct BasicCommandCT            packetInfo;
   struct ContinuousTimeModeDataT   continuousTimeModeData;
};

struct SetContinuousTimeModeParamsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetContinuousTimeModeParamsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetContinuousTimeModeParamsRT
{
   struct BasicCommandRT            packetInfo;
   struct ContinuousTimeModeDataT   continuousTimeModeData;
};
```

See struct 'ContinuousTimeModeDataT' for details.

Set/GetContinuousDistanceModeParamsCT/RT

Command structures for setting/getting the parameters for the Continuous Distance Measurement Mode.

```
struct SetContinuousDistanceModeParamsCT
{
   struct BasicCommandCT               packetInfo;
   struct ContinuousDistanceModeDataT
                        continuousDistanceModeData;
};

struct SetContinuousDistanceModeParamsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetContinuousDistanceModeParamsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetContinuousDistanceModeParamsRT
{
   struct BasicCommandRT               packetInfo;
   struct ContinuousDistanceModeDataT
                        continuousDistanceModeData;
};
```

See struct 'ContinuousDistanceModeDataT' for details.

Set/GetSphereCenterModeParamsCT/RT

Command structures for setting/getting the parameters for the Sphere Center Measurement mode.

```
struct SetSphereCenterModeParamsCT
{
   struct BasicCommandCT           packetInfo;
   struct SphereCenterModeDataT    sphereCenterModeData;
};

struct SetSphereCenterModeParamsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetSphereCenterModeParamsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetSphereCenterModeParamsRT
{
   struct BasicCommandRT           packetInfo;
   struct SphereCenterModeDataT    sphereCenterModeData;
};
```

Se struct 'SphereCenterModeDataT' for details.

Set/GetCircleCenterModeParamsCT/RT

Command structures for setting/getting the parameters for the Circle Center Measurement Mode.

```
struct SetCircleCenterModeParamsCT
{
   struct BasicCommandCT           packetInfo;
   struct CircleCenterModeDataT    circleCenterModeData;
};

struct SetCircleCenterModeParamsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetCircleCenterModeParamsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetCircleCenterModeParamsRT
{
   struct BasicCommandRT           packetInfo;
   struct CircleCenterModeDataT    circleCenterModeData;
};
```

See struct 'CircleCenterModeDataT' for details.

Set/GetGridModeParamsCT/RT

Command structures for setting/getting the parameters for the Grid Measurement mode.

```
struct SetGridModeParamsCT
{
   struct BasicCommandCT   packetInfo;
   struct GridModeDataT    gridModeData;
};

struct SetGridModeParamsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetGridModeParamsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetGridModeParamsRT
{
   struct BasicCommandRT   packetInfo;
   struct GridModeDataT    gridModeData;
};
```

See struct 'GridModeDataT' for details.

Set/GetSystemSettingsCT/RT

Command structures for setting/getting the system settings parameters.

```
struct SetSystemSettingsCT
{
   struct BasicCommandCT         packetInfo;
   struct SystemSettingsDataT    systemSettings;
};

struct SetSystemSettingsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetSystemSettingsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetSystemSettingsRT
{
   struct BasicCommandRT         packetInfo;
   struct SystemSettingsDataT    systemSettings;
};
```

See struct 'SystemSettingsDataT' for details.

Set/GetUnitsCT/RT

Command structures for setting/getting the units' settings. The current units act – like current CS-type (and transformation / orientation parameters) – as a input/output 'Filter' to all Length/Angular/Meteo-type parameters.

```
struct SetUnitsCT
{
   struct BasicCommandCT   packetInfo;
   struct SystemUnitsDataT unitsSettings;
};

struct SetUnitsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetUnitsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetUnitsRT
{
   struct BasicCommandRT   packetInfo;
   struct SystemUnitsDataT unitsSettings;
};
```

See struct 'SystemUnitsDataT' for details.

GetSystemStatusCT/RT

Command structures for getting the system status.

```
struct GetSystemStatusCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetSystemStatusRT
{
   struct BasicCommandRT            packetInfo;
   enum ES_ResultStatus             lastResultStatus;
   enum ES_TrackerProcessorStatus   trackerProcessorStatus;
   enum ES_LaserProcessorStatus     laserStatus;
   enum ES_ADMStatus                admStatus;
   struct ESVersionNumber           esVersionNumber;
   enum ES_WeatherMonitorStatus     weatherMonitor;
   long                             lFlagsValue;
   long                             lTrackerSerialNumber;
};
```

See description of related enumeration types for details.

The *lFlagsValue* member contains some additional status information about the tracker/tracker processor, for advanced programming.

The description of the n_{th} bit of the *lFlagsValue* (start with least significant bit):

Bit	Description
Bit 1	Reflector was found
Bit 2	Interferometer locked
Bit 3	Positioning complete
Bit 4	Tracker initialized
Bit 5	Calibration set
Bit 6	Tracker parked

Bit	Description
Bit 7	Motor switch is on
Bit 8	Encoder angle error
Bit 9	Sleep condition set
Bit 10	Motor power active

GetTrackerStatusCT/RT

```
struct GetTrackerStatusCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetTrackerStatusRT
{
   struct BasicCommandRT   packetInfo;
   enum ES_TrackerStatus   trackerStatus;
};
```

Command structures for getting the tracker status.

See enum 'ES_TrackerStatus' for details.

Set/GetReflector(s)CT/RT

Command structures for getting/setting the current reflector by its numerical ID.

```
struct SetReflectorCT
{
   struct BasicCommandCT   packetInfo;
   int                     iInternalReflectorId;
};

struct SetReflectorRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetReflectorCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetReflectorRT
{
   struct BasicCommandRT      packetInfo;
   int                        iInternalReflectorId;
};

struct GetReflectorsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetReflectorsRT
{
   struct BasicCommandRT      packetInfo;
   int                        iTotalReflectors;
   int                        iInternalReflectorId;
   enum ES_TargetType         targetType;
   double                     dSurfaceOffset;
   short                      cReflectorName[32];
};
```

The *GetReflectors* command retrieves all reflectors defined in the Tracker Server. The answer consists of as many answer packets as reflector types, defined in the server database. These resolve the relation between reflector name (string) and reflector ID (numerical). Each packet, in addition (a redundancy), contains the total number of reflectors, i.e. the total number of packets to be expected (only for programmer's convenience). Other properties are the *targetType* and the *surfaceOffset*. Surface offset is in current length units.

The reflector name is in Unicode format - *short cReflectorName[32]* declaration. It can consist of a maximum of 32 characters.

Each tracker- compensation has its own set of reflector- definitions! However, the mapping between reflector-name and ID remains the same throughout all available tracker-compensations!

Example: A T-Cam is mounted on the tracker; hence, the active tracker compensation is one that was performed with a mounted camera. Assume this tracker - compensation has definitions for three valid reflectors as follows:

Name	ID
CCR-75mm	7
CCR-1.5in	2
TBR-0.5in	5

Now, the T-Cam is removed, and hence another tracker- compensation becomes active (one that was performed without a mounted T-Cam). Let's assume that this compensation has only two reflector definitions: CCR-1.5in and TBR-0.5in. **Conveniently, the mapping between name and ID remained the same** as it was in the previous compensation:

Name	ID
CCR-1.5in	2
TBR-0.5in	5

If reflector ID 7 was the active one at the time the camera was removed, you will now get a 'wrong current reflector' error message on executing reflector- dependent commands. Thus, the application must first set one of the now available IDs 2 or 3 with the 'SetReflector' command.

The fact that the relation between reflector ID and Name remains the same throughout all tracker-compensations may be convenient to application programmers since there is no need to re-query all reflector mappings upon a tracker compensation change.

Set/GetSearchParamsCT/RT

```
struct SetSearchParamsCT
{
   struct BasicCommandCT      packetInfo;
   struct SearchParamsDataT   searchParams;
};

struct SetSearchParamsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetSearchParamsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetSearchParamsRT
{
   struct BasicCommandRT      packetInfo;
   struct SearchParamsDataT   searchParams;
};
```

Command structures for setting/getting the reflector search parameter values.

The search time depends on the search radius. Large search radii may result in extended search times unless limited by a reasonable SearchTimout.

See struct 'SearchParamsDataT' for details.

Set/GetAdmParamsCT/RT

```
struct SetAdmParamsCT
{
   struct BasicCommandCT   packetInfo;
   struct AdmParamsDataT   admParams;
};

struct SetAdmParamsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetAdmParamsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetAdmParamsRT
{
   struct BasicCommandRT   packetInfo;
   struct AdmParamsDataT   admParams;
};
```

Command structures for setting/getting the reflector search parameter values.

See struct 'AdmParamsDataT' for details.

Set/GetEnvironmentParamsCT/RT

```
struct SetEnvironmentParamsCT
{
   struct BasicCommandCT   packetInfo;
   struct EnvironmentDataT environmentData;
};

struct SetEnvironmentParamsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetEnvironmentParamsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetEnvironmentParamsRT
{
   struct BasicCommandRT   packetInfo;
   struct EnvironmentDataT environmentData;
};
```

Command structures for setting/getting the environmental parameter values.

Environmental values are updated automatically at regular intervals, if the weather monitor is on, connected and the WeatherMonitorStatus (of SystemSettings) is one of ES_WMS_ReadOnly or ES_WMS_ReadAndCalculateRefractions.

See struct 'EnvironmentDataT' for details.

Set/GetStationOrientationParamsCT/RT

```
struct SetStationOrientationParamsCT
{
   struct BasicCommandCT           packetInfo;
   struct StationOrientationDataT   stationOrientation;
};

struct SetStationOrientationParamsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetStationOrientationParamsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetStationOrientationParamsRT
{
   struct BasicCommandRT           packetInfo;
   struct StationOrientationDataT   stationOrientation;
};
```

Command structures for setting/getting the station orientation parameters. These settings act – like current units and current CS-type – as a input/output 'Filter' to all coordinate-type related parameters.

See struct 'StationOrientationDataT' for details.

Set/GetTransformationParamsCT/RT

```
struct SetTransformationParamsCT
{
   struct BasicCommandCT        packetInfo;
   struct TransformationDataT    transformationData;
};

struct SetTransformationParamsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetTransformationParamsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetTransformationParamsRT
{
   struct BasicCommandRT        packetInfo;
   struct TransformationDataT    transformationData;
};
```

Command structures for setting/getting the transformation parameters. These settings act – like current units and current CS-type – as a input/output 'Filter' to all coordinate-type related parameters.

See struct 'TransformationDataT' for details.

Set/GetBoxRegionParamsCT/RT

```
struct SetBoxRegionParamsCT
{
   struct BasicCommandCT   packetInfo;
   struct BoxRegionDataT   boxRegionData;
};

struct SetBoxRegionParamsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetBoxRegionParamsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetBoxRegionParamsRT
{
   struct BasicCommandRT   packetInfo;
   struct BoxRegionDataT   boxRegionData;
};
```

Command structures for setting/getting the Box Region parameters.

See struct 'BoxRegionDataT' for details.

Set/GetSphereRegionParamsCT/RT

```
struct SetSphereRegionParamsCT
{
   struct BasicCommandCT      packetInfo;
   struct SphereRegionDataT   sphereRegionData;
};

struct SetSphereRegionParamsRT
{
   struct BasicCommandRT   packetInfo;
};

struct GetSphereRegionParamsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetSphereRegionParamsRT
{
   struct BasicCommandRT      packetInfo;
   struct SphereRegionDataT   sphereRegionData;
};
```

Command structures for setting/getting the sphere region parameters.

See struct 'SphereRegionDataT' for details.

GoPositionCT/RT

```
struct GoPositionCT
{
   struct BasicCommandCT   packetInfo;
   double                  dVal1;
   double                  dVal2;
   double                  dVal3;
   ES_BOOL                 bUseADM;
};

struct GoPositionRT
{
   struct BasicCommandRT   packetInfo;
};
```

These are structures for invoking the *GoPosition* command. Values are in current units / CS-type

and according to applied orientation / transformation parameters. When *bUseADM* is set, which is the normal case for this command, an ADM measurement is performed and the IFM distance is set to this new value. If ADM flag is not set, the IFM distance is calculated from the supplied coordinates and is set as the valid one. To be used with caution!
The useADM flag should always be set for trackers equipped with an ADM.
No range limitations apply to these parameters in theory, but there is a practical limitation given by tracker working volume.
GoPosition can be seen as a combination of commands 'PointLaser', followed by a 'FindReflector'.

The search time depends on the search radius. Large search radii may result in extended search times. A typical value is 0.05 m. An approx. distance entry is required only for the FindReflector command. UseADM should normally be true for this command.

GoPositionHVDCT/RT

Structures for invoking the *GoPositionHVD* command. Same as *GoPosition* with the input parameters in a spherical (tracker-) coordinate system type, irrespective of the current CS-type. Values are in current units.
Range limitations apply with respect to the tracker elevation limits. The *useADM* flag should always be set for trackers equipped with an ADM.
If ADM flag is not set, the provided distance is taken as new IFM distance. To be used with caution!

```
struct GoPositionHVDCT
{
   struct BasicCommandCT   packetInfo;
   double                  dHzAngle;
   double                  dVtAngle;
   double                  dDistance;
   ES_BOOL                 bUseADM;
};

struct GoPositionHVDRT
{
   struct BasicCommandRT   packetInfo;
};
```

The search time depends on the search radius. Large search radii result in extended search times unless limited by a reasonable SearchTimeout. A typical value is 0.05 m.
'UseADM' should normally be true for this command.

See also command 'SetSearchParams'.

PositionRelativeHVCT/RT

Structures for invoking the *PositionRelativeHV* command. The input parameters are angles in the current units. The angles are prefixed with +/- (clockwise is + and anti clockwise is -), to specify the direction of movement. In contrast to the MoveHV command, PositionRelative means a one-time movement.

```
struct PositionRelativeHVCT
{
   struct BasicCommandCT   packetInfo;
   double                  dHzVal;
   double                  dVtVal;
};

struct PositionRelativeHVRT
{
   struct BasicCommandRT   packetInfo;
};
```

PointLaserCT/RT

Structures for invoking the *PointLaser* command. The input parameters are in current units / CS-type and according to applied orientation / transformation parameters.

```
struct PointLaserCT
{
   struct BasicCommandCT   packetInfo;
   double                  dVal1;
   double                  dVal2;
   double                  dVal3;
};

struct PointLaserRT
{
   struct BasicCommandRT   packetInfo;
};
```

PointLaserHVDCT/RT

Structures for invoking the *PointLaserHVD* command. Same as *PointLaser* with the input parameters in a spherical coordinate system type, irrespective of the selected CS. Values are in current units.

```
struct PointLaserHVDCT
{
   struct BasicCommandCT   packetInfo;
   double                  dHzAngle;
   double                  dVtAngle;
   double                  dDistance;
};

struct PointLaserHVDRT
{
   struct BasicCommandRT   packetInfo;
};
```

MoveHVCT/RT

Structures for invoking the *MoveHV* command. The input parameters are vertical/horizontal speed values between 1% and 100% of the maximum speed of the tracker.

Use 0 value(s) to stop a previously started movement. MoveHV can be called repeatedly with varying speed values in order to change moving speed. No stop is required in- between. In contrast to the PositionRelative command, MoveHV does not mean a one-time movement. The MoveHV command rather means 'Start movement'.

```
struct MoveHVCT
{
   struct BasicCommandCT   packetInfo;
   int                     iHzSpeed;
   int                     iVtSpeed;
};

struct MoveHVRT
{
   struct BasicCommandRT   packetInfo;
};
```

The speed parameters are prefixed with +/- (clockwise is + and anti clockwise is -), to specify the direction of movement.

GoNivelPositionCT/RT

```
struct GoNivelPositionCT
{
   struct BasicCommandCT   packetInfo;
   enum ES_NivelPosition   nivelPosition;
};

struct GoNivelPositionRT
{
   struct BasicCommandRT   packetInfo;
};
```

Structures for invoking the *GoNivelPosition* command in the orient to gravity procedure. The input parameters are the pre-defined 'Nivel' positions (1 to 4). This command is mainly used for the 'Orient to Gravity' command. It is rarely used by applications unless an own orient to Gravity procedure is implemented.

The tracker head moves at a slow speed to minimize affecting the 'Nivel' sensor.

LookForTargetCT/RT

Structures for invoking the *LookForTarget* command. The input parameters are in the selected CS-type / units. The output parameters are always angles related to the tracker coordinate system in the current angle unit settings.

This command is mainly used for LT- series of trackers (without ADM). For LTD/AT trackers, rather use 'GoPosition' instead.

```
struct LookForTargetCT
{
    struct BasicCommandCT   packetInfo;
    double                  dVal1;
    double                  dVal2;
    double                  dVal3;
    double                  dSearchRadius;
};

struct LookForTargetRT
{
    struct BasicCommandRT   packetInfo;
    double                  dHzAngle;
    double                  VtAngle;
};
```

The search time depends on the search radius. Large search radii result in extended search times. A typical value is 0.05 m; The default value is 0.04 m.

GetDirectionCT/RT

Structures for invoking the *GetDirection* command. The output parameters are always angles related to the tracker coordinate system in the current angle unit settings.
This command is mainly useful for LT- series of trackers (in combination with LookForTarget).

```
struct GetDirectionCT
{
    struct BasicCommandCT   packetInfo;
};

struct GetDirectionRT
{
    struct BasicCommandRT  packetInfo;
    double                 dHzAngle;
    double                 dVtAngle;
};
```

Set/GetStatisticModeCT/RT

Command structures for setting/getting the statistic mode. Depending on the mode, stationary and/or continuous 3D measurement packets will contain more or less statistical information. Note that different data packets for the measurement apply depending on which mode is used.

See enum 'ES_StatisticMode' description for details.

```
struct SetStatisticModeCT
{
   struct   BasicCommandCT      packetInfo;
   enum     ES_StatisticMode    stationaryMeasurements;
   enum     ES_StatisticMode    continuousMeasurements;
};

struct SetStatisticModeRT
{
   struct   BasicCommandRT      packetInfo;
};

struct GetStatisticModeCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetStatisticModeRT
{
   struct BasicCommandRT        packetInfo;
   enum     ES_StatisticMode    stationaryMeasurements;
   enum     ES_StatisticMode    continuousMeasurements;
};
```

Changing the statistical mode is for advanced purposes only. Default statistical mode is 'Standard' and ensures compatibility to earlier versions.

Set/GetCameraParamsCT/RT

Command structures for setting/getting the Camera parameters.
See also description of struct 'CameraParamsDataT'.

```
struct SetCameraParamsCT
{
   struct BasicCommandCT         packetInfo;
   struct CameraParamsDataT      cameraParams;
};

struct SetCameraParamsRT
{
   struct BasicCommandRT         packetInfo;
};


struct GetCameraParamsCT
{
   struct BasicCommandCT         packetInfo;
};

struct GetCameraParamsRT
{
   struct BasicCommandRT         packetInfo;
   struct CameraParamsDataT      cameraParams;
};
```

AddDrivePointCT/RT

Command to add a point to the Drive Point List to be used by the Intermediate Compensation process. See chapter ' Intermediate Compensation ' in main chapter 8 for details.

```
struct AddDrivePointCT
{
   struct BasicCommandCT   packetInfo;
   int                     iInternalReflectorId;
   double                  dVal1;
   double                  dVal2;
   double                  dVal3;
};

struct AddDrivePointRT
{
   struct BasicCommandRT      packetInfo;
};
```

CallOrientToGravityCT/RT

Command structures for executing an ‘Orient To Gravity’ process (including reception of results).

Results are in current angle units. Typically, the value dOmega and dPhi are set as dRot1 and dRot2 parameters of StationOrientationDataT, to be passed with the SetStationOrientationParams command.

See special chapter 'Orient to Gravity procedure' in chapter 8.

```
struct CallOrientToGravityCT
{
   struct BasicCommandCT   packetInfo;
};

struct CallOrientToGravityRT
{
   struct BasicCommandRT      packetInfo;
   double                     dOmega;
   double                     dPhi;
};
```

Error codes

A return status other than *ES_RS_AllOK (0)* means that the command could not be completed. In addition to the values defined in *ES_ResultStatus*, the *CallOrientToGravity* command answer status can evaluate to one of the following values:

Code	Description
20010	An unknown error occurred (F)
20011	Socket initialization failed (F)
20012	OLE/COM initialization failed (F)
20013	Reading resource string failed (F)
20014	Error on sending data
20015	Error on receiving data
20016	No answer within reasonable time
20017	Error on saving results to database (F)
20018	Too many retries due to unstable Nivel liquid
20019	Invalid count of samples specified(min 2, max 10)
20020	There was an unexpected command answer
20021	(Some) Nivel results out of valid range
20022	No Nivel connected, or Nivel flagged off
20023	/POS270 or /POS90 expected as command line argument (F)
20024	Process terminated from outside

Errors marked with (F) are unanticipated fatalities.

CallIntermediateCompensationCT/RT

Command structures for executing an 'Intermediate Compensation' sequence (including reception of quality result parameters). TotalRMS and maxDev are angular values and are in current angle units.
For details see special chapter 'Intermediate Compensation procedure' in chapter 8.

```
struct CallIntermediateCompensationCT
{
   struct BasicCommandCT   packetInfo;
};

struct CallIntermediateCompensationRT
{
   struct BasicCommandRT      packetInfo;
   double                     dTotalRMS;
   double                     dMaxDev;
   long                       lWarningFlags;
};
```

Error codes

A return status other than *ES_RS_AllOK (0)* means that the command could not be completed. In addition to the values defined in *ES_ResultStatus*, the *CallIntermediateCompensation* command answer status can evaluate to one of the following values.

Code	Description
23011	EmScon database open failure (F)
23012	EmScon database read failure (F)
23013	EmScon database write failure (F)
23014	No points to measure in database
23015	Creation of compensation failed
23016	Saving / Updating of compensation failed
23017	Reading Drive-Point failed
23018	An 'In-work' compensation already exists
23019	Failed to delete 'In-work' compensation (F)
23020	Measurement timeout expired
23021	Getting tracker parameters failed
23022	Setting tracker parameters failed

23023	Timeout in Positioning (no reflector within searched range?)
23030	There was a command answer other than OK (Unknown error)
23031	Sending data via TCP/IP failed (F)
23032	Error on receiving data (communication error) (F)
23033	Process terminated from outside
23501	At least one of the 3 calculated mechanical parameters is not in range specified.
23502	Too few (less than 2) measurements available. Calculation cannot be performed. Either not enough driving points, or not all could be found and/or measured.
23503	Minimum vertical angle difference not met
23998	An unsolicited error occurred (F)
23999	Unknown error (F)

Errors marked with (F) are unanticipated fatalities.

Warning flags

Warning flags are available upon a successful compensation (Status ES_RS_AllOK [= 0]). The parameter *lWarningFlags* is a 32-bit value. If the value is zero (none of the bits set), then the intermediate compensation process completed with no warnings. Otherwise, each raised bit means a particular warning. There can be more than one warning at a time.

Currently, the following warnings are possible:

Bit 1 (0x1)	AverageVerticalTwoFaceErrorIsTooHigh: Tracker service (from Leica Geosystems personnel) is required because the vertical index is constantly > 1 Gon. There is currently no way for the user to reset the approximate index.

Bit 2 (0x2)	AtLeastOneVerticalTwoFaceErrorIsTooHigh: If Bit 1 not raised, there is probably a very high error within a single two-face measurement. If Bit 1 is raised too, ignore warning Bit 2.
Bit 3 (0x4)	AtLeastOneDistanceIsNotInRange: At least one of the distances is smaller than the minimum or larger than the maximum recommended distance, according to the recommendations.
Bit 4 (0x8)	NotEnoughMeasInTwoOppositeVerticalPlanesWithGoodDiffOfVerticalAngle: This warning covers all (except the range criterion) possible criteria, which are not fulfilled by the measurement configuration, according to the recommendations.
Bit 5 (0x10)	NotAllCorrectedDoubledTwoFaceErrorsAreWithinCompensationTolerance: Not all measurement residuals are within recommended tolerances.
Bit 6 (0x20)	NotAllMechanicalParametersAreInRange: Not all three (3) mechanical parameters calculated are within recommended tolerance (according to hardware specs).

The *lWarningFlags* value is a decimal value. Use a scientific calculator to convert this value to a binary value to visualize the flagged bits.

Programmatically (in C/C++), a particular bit is set if the following expression evaluates to TRUE.

```
(lWarningFlags & dwCode) // where dwCode is one of the Masks
                         // shown above. For example. 0x10
                         // tests for 5th bit. See C- reference
                         // for details (bit operations)
```

CallTransformationCT/RT

Command structures for executing an ‘Transformation’ process (including reception of results). Result values are in current units CS-type . See chapter 'Transformation Procedure' in chapter 8 for details.

```
struct CallTransformationCT
{
   struct BasicCommandCT   packetInfo;
};

struct CallTransformationRT
{
   struct BasicCommandRT   packetInfo;
   double                  dTransVal1;
   double                  dTransVal2;
   double                  dTransVal3;
   double                  dRotVal1;
   double                  dRotVal2;
   double                  dRotVal3;
   double                  dScale;
   double                  dTransStdVal1;
   double                  dTransStdVal2;
   double                  dTransStdVal3;
   double                  dRotStdVal1;
   double                  dRotStdVal2;
   double                  dRotStdVal3;
   double                  dScaleStd;
   double                  dRMS;
   double                  dMaxDev;
   double                  dVarianceFactor;
};
```

Error codes

A return status other than *ES_RS_AllOK (0)* means that the command could not be completed. In addition to the values defined in *ES_ResultStatus*, the *CallTransformation* command answer status can evaluate to one of the following values:

Code	**Description**
24010	OLE/COM initialization failed (F)
24011	Reading resource string failed (F)
24012	Error on reading input data from database (F)
24013	Error on saving results to database (F)
24020	Least Squares Fit failed
24021	Initial Approximation for Fit failed
24022	Too many unknown nominals
24023	Multiple solutions found

Errors marked with (F) are unanticipated fatalities.

Set/GetTransformationInputParamsCT/RT

Command structures for setting/getting the transformation Input parameters. These are used as input for the Transformation calculation process to fix/weight transformation result parameters.

See struct 'TransformationInputDataT' for details. Also see Section 9.2 .

```
struct SetTransformationInputParamsCT
{
   struct BasicCommandCT            packetInfo;
   struct TransformationInputDataT  transformationData;
};

struct SetTransformationInputParamsRT
{
   struct BasicCommandRT      packetInfo;
};


struct GetTransformationInputParamsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetTransformationInputParamsRT
{
   struct BasicCommandRT            packetInfo;
   struct TransformationInputDataT  transformationData;
};
```

AddTransformationNominalPointCT/RT

Command structures for adding a Point to the Nominal point list. See struct 'TransformationPointT ' and also chapter 'Transformation Procedure' in chapter 8 for details.

```
struct AddTransformationNominalPointCT
{
   struct BasicCommandCT         packetInfo;
   struct TransformationPointT   transformationPoint;
};

struct AddTransformationNominalPointRT
{
   struct BasicCommandRT      packetInfo;
};
```

AddTransformationActualPointCT/RT

Command structures for adding a Point to the actual point list. See struct 'TransformationPointT ' and also chapter 'Transformation Procedure' in chapter 8 for details.

```
struct AddTransformationActualPointCT
{
   struct BasicCommandCT         packetInfo;
   struct TransformationPointT   transformationPoint;
};

struct AddTransformationActualPointRT
{
   struct BasicCommandRT      packetInfo;
};
```

GetTransformedPointsCT/RT

Command structures for retrieving the transformed points and residuals after a successful transformation. Result values are in current units and CS- type (like nominal points).

This command results in as many result packets as specified points through the nominal/actual input points list. This approach is similar to the *GetReflectors* command. See chapter 'Transformation Procedure' in chapter 8 for details.

Residuals are the difference between the nominal and the transformed actual points.

```
struct GetTransformedPointsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetTransformedPointsRT
{
   struct BasicCommandRT   packetInfo;
   int                     iTotalPoints;
   double                  dVal1;
   double                  dVal2;
   double                  dVal3;
   double                  dStdDev1;
   double                  dStdDev2;
   double                  dStdDev3;
   double                  dStdDevTotal;
   double                  dCovar12;
   double                  dCovar13;
   double                  dCovar23;
   double                  dResidualVal1;
   double                  dResidualVal2;
   double                  dResidualVal3;
};
```

GetStillImageCT/RT

Command structures for getting a camera still image. The data is delivered as a BMP file. Jpeg format is not supported yet. The result is a binary block (given by start address and size) in 'File' format. It can directly be viewed with a bitmap viewer.

```
struct GetStillImageCT
{
   struct BasicCommandCT         packetInfo;
   enum   ES_StillImageFileType  imageFileType;
};

struct GetStillImageRT
{
   struct   BasicCommandRT          packetInfo;
   enum     ES_StillImageFileType   imageFiletype;
   long                             lFileSize;
   char                             cFileStart;
};
```

Only the BMP format is currently supported.

GoBirdBath2CT/RT

Command structures for driving the laser to the Bird bath, either in clockwise or counter clockwise direction.

```
struct GoBirdBath2CT
{
   struct BasicCommandCT   packetInfo;
   ES_BOOL                 bClockWise;
};

struct GoBirdBath2RT
{
   struct BasicCommandRT   packetInfo;
};
```

GetCompensationCT/RT

Command structures to read the currently active Compensation ID.

```
struct GetCompensationCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetCompensationRT
{
   struct BasicCommandRT      packetInfo;
   int                        iInternalCompensationId;
};
```

SetCompensationCT/RT

Command to activate one of the intermediate tracker compensations delivered by GetCompensations by its ID.

```
struct SetCompensationCT
{
   struct BasicCommandCT   packetInfo;
   int                     iInternalCompensationId;
};

struct SetCompensationRT
{
   struct BasicCommandRT      packetInfo;
};
```

GetCompensationsCT/RT

Command structures to read all Tracker Compensations stored in the database. Particularly, the relation between ID and compensation name is given. As many packets as compensations exist are delivered (similar to the GetReflectors command.

```
struct GetCompensationsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetCompensationsRT
{
   struct BasicCommandRT      packetInfo;
   int                        iTotalCompensations;
   int                        iInternalCompensationId;
   unsigned short             cTrackerCompensationName[32];
   unsigned short             cTrackerCompensationComment[128];
   unsigned short             cADMCompensationName[32];
   ES_BOOL                    bHasMeasurementCameraMounted;
};
```

GetCompensations2CT/RT

Enhanced version of GetCompensationsCT/RT with some additional information. GetCompensationsCT/RT has been left only for backward compatibility. Newer applications should use GetCompensations2CT/RT.

```
struct GetCompensations2CT
{
   struct BasicCommandCT   packetInfo;
};

struct GetCompensations2RT
{
   struct BasicCommandRT      packetInfo;
   int                        iTotalCompensations;
   int                        iInternalCompensationId;
   unsigned short             cTrackerCompensationName[32];
   unsigned short             cTrackerCompensationComment[128];
   unsigned short             cADMCompensationName[32];
   unsigned short             cADMCompensationComment[128];
   ES_BOOL                    bHasMeasurementCameraMounted;
   ES_BOOL                    bIsActive;
};
```

Note: We do no longer recommend evaluating the 'bIsActive' flag in your application! This flag is redundant information which should better be asked by using the 'GetCompensation' call (which should have been named better 'GetActiveCompensation').

GetCompensations2 (that is, querying all compensations the system currently 'knows') is a rather expensive call. A well- designed application usually does such a call upon start-up and then only when a compensation is being added to or removed from the system (which is not a everyday- task).

While this list remains unchanged in memory, the active compensation may change quite often during runtime. It would be awkward if we always had to reload the entire list just because the active compensation has changed. However, if we would rely on the 'bIsActive' flag, we would have to do so! So better use GetCompensation() to figure out the currently active compensation and do not rely on the 'bIsActive' in the compensations list. This flag may only reliable just after reading the list!

CheckBirdBathCT/RT

Command structures to check the Bird bath position of the current, selected reflector. Values are in current units.

```
struct CheckBirdBathCT
{
   struct BasicCommandCT   packetInfo;
};

struct CheckBirdBathRT
{
   struct BasicCommandRT      packetInfo;
   double    dInitialHzAngle;
   double    dInitialVtAngle;
   double    dInitialDistance;
   double    dHzAngleDiff;
   double    dVtAngleDiff;
   double    dDistanceDiff;
};
```

GetTrackerDiagnosticsCT/RT

Command structures to read tracker diagnostic data. This is a command mainly used for service purposes.

```
struct GetTrackerDiagnosticsCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetTrackerDiagnosticsRT
{
   struct BasicCommandRT      packetInfo;
   double  dTrkPhotoSensorXVal;
   double  dTrkPhotoSensorYVal;
   double  dTrkPhotoSensorIVal;
   double  dRefPhotoSensorXVal;
   double  dRefPhotoSensorYVal;
   double  dRefPhotoSensorIVal;
   double   dADConverterRange;
   double  dServoControlPointX;
   double  dServoControlPointY;
   double  dLaserLightRatio;
   int     iLaserControlMode;
   double  dSensorInsideTemperature;
   int     iLCPRunTime;
   int     iLaserTubeRunTime;
};
```

GetADMInfoCT/RT

Command structures to read ADM-specific properties and feature data. The tracker must be equipped wit an ADM.
Note: with emScon V2.3, variable names have changed from *iFirmWare*... to *iFirmware*... This

will not have any influence to existing applications at runtime. Upon compilation with the new API- include- files, these names need to be adjusted in the code of the application.

```
struct GetADMInfoCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetADMInfoRT
{
   struct BasicCommandRT      packetInfo;
   int  iFirmwareMajorVersionNumber;
   int  iFirmwareMinorVersionNumber;
   int  iSerialNumber;
};
```

GetNivelInfoCT/RT

Command structures to read 'Nivel' -specific properties and feature data. The tracker must have a Leica 'Nivel' inclination sensor connected and enabled.

Note: with emScon V2.3, variable names have changed from *iFirmWare*... to *iFirmware*... This will not have any influence to existing applications at runtime. Upon compilation with the new API- include- files, these names need to be adjusted in the code of the application.

```
struct GetNivelInfoCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetNivelInfoRT
{
   struct BasicCommandRT      packetInfo;
   int  iFirmwareMajorVersionNumber;
   int  iFirmwareMinorVersionNumber;
   int  iSerialNumber;
};
```

GetTPInfoCT/RT

Command structures to read TP-specific properties and feature data. This is a command mainly used for service purposes.

Note: with emScon V2.3, variable names have changed from *iFirmWare*... to *iFirmware*... This will not have any influence to existing applications at runtime. Upon compilation with the new API- include- files, these names need to be adjusted in the code of the application.

```
struct GetTPInfoCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetTPInfoRT
{
   struct BasicCommandRT      packetInfo;
   int  iTPBootMajorVersionNumber;
   int  iTPBootMinorVersionNumber;
   int  iTPFirmwareMajorVersionNumber;
   int  iTPFirmwareMinorVersionNumber;
   int  iLCPFirmwareMajorVersionNumber;
   int  iLCPFirmwareMinorVersionNumber;
   enum ES_TrackerProcessorType    trackerprocessorType;
   enum ES_TPMicroProcessorType    microProcessorType;
   int  iMicroProcessorClockSpeed;
   enum ES_LTSensorType   laserTrackerSensorType;
};
```

SetLaserOnTimerCT/RT

Command structure to set the time in hours and minutes (rounded off to nearest ¼ hour block) to start the laser previously switched-off by a SwitchLaser(off) command. The tracker controller and emScon server must be switched on. Since the laser takes about 20 minutes to stabilize, this command is useful to program laser-on in the morning so the system is ready when work is scheduled to begin.

The laser can be independently switched off.

```
struct SetLaserOnTimerCT
{
   struct BasicCommandCT   packetInfo;
   int                     iLaserOnTimeOffsetHour;
   int                     iLaserOnTimeOffsetMinute;
};

struct SetLaserOnTimerRT
{
   struct BasicCommandRT   packetInfo;
};
```

GetLaserOnTimerCT/RT

Command structures to read the time left in hours and minutes (rounded off to nearest ¼ hour block), to start the laser. A system restart sets this value to zero. The tracker processor / emScon server must be switched on.

```
struct GetLaserOnTimerCT
{
   struct BasicCommandCT   packetInfo;
};

struct GetLaserOnTimerRT
{
   struct BasicCommandRT   packetInfo;
   int                     iLaserOnTimeOffsetHour;
   int                     iLaserOnTimeOffsetMinute;
};
```

ConvertDisplayCoordinatesCT/RT

Command structures to call the DisplayCoordinateConversion function. DisplayCoordinateConversion is a private function/command and is not documented/supported. It should not be used for any client programming

```
struct ConvertDisplayCoordinatesCT
{
   struct BasicCommandCT                      packetInfo;
   enum ES_DisplayCoordinateConversionType   conversionType;
   double                                     dVal1;
   double                                     dVal2;
   double                                     dVal3;
};

struct ConvertDisplayCoordinatesRT
{
   struct BasicCommandRT                      packetInfo;
   double                                     dVal1;
   double                                     dVal2;
   double                                     dVal3;
};
```

Set/GetTriggerSourceCT/RT

Command structures to Set/Get Trigger Source. See enum 'ES_TriggerSource' for details.

```
struct SetTriggerSourceCT
{
    struct BasicCommandCT   packetInfo;
    enum ES_TriggerSource   triggerSource;
};

struct SetTriggerSourceRT
{
    struct BasicCommandRT   packetInfo;
};

struct GetTriggerSourceCT
{
    struct BasicCommandCT   packetInfo;
};

struct GetTriggerSourceRT
{
    struct BasicCommandRT   packetInfo;
    enum ES_TriggerSource   triggerSource;
};
```

GetFaceCT/RT

Command structures to query current Tracker Face, whether in Face I or Face II position.

```
struct GetFaceCT
{
    struct BasicCommandCT   packetInfo;
};

struct GetFaceRT
{
    struct BasicCommandRT   packetInfo;
    enum ES_TrackerFace     trackerFace;
};
```

GetCamerasCT/RT

Command structure to get Measurement Camera properties. The GetCameras command retrieves all measurement cameras (T-Cams) defined. The answer consists of as many answer packets as cameras are defined in the server database. These resolve the relation between camera name (string) and camera ID (numerical). Each packet, in addition (a redundancy), contains the total number of cameras, i.e. the total number of packets to be expected (only for programmer's convenience). Other properties, such as cameraType, serial Number, comment, etc. serve as information, mainly used for user-interface purpose.

```
struct GetCamerasCT
{
    struct BasicCommandCT   packetInfo;
};

struct GetCamerasRT
{
    struct BasicCommandRT           packetInfo;
    int                             iTotalCameras;
    int                             iInternalCameraId;
    long                            lSerialNumber;
    enum ES_MeasurementCameraType   cameraType;
    unsigned short                  cName[32];
    unsigned short                  cComment[128];
};
```

GetCameraCT/RT

Command structure to get the ID of the active Camera. The GetCamera command delivers the currently active measurement camera by its ID (Currently set as the active one in the database). However, since this camera may have been removed, an additional flag indicates whether the active camera is mounted or not.

```
struct GetCameraCT
{
    struct BasicCommandCT   packetInfo;
};

struct GetCameraRT
{
    struct BasicCommandRT   packetInfo;
    int                     iInternalCameraId;
    ES_BOOL                 bMeasurementCameraIsMounted;
};
```

Set/GetMeasurementCameraModeCT/RT

Command structures for setting/getting the measurement camera mode.

```
struct SetMeasurementCameraModeCT
{
    struct BasicCommandCT           packetInfo;
    enum ES_MeasurementCameraMode   cameraMode;
};

struct SetMeasurementCameraModeRT
{
    struct BasicCommandRT   packetInfo;
};

struct GetMeasurementCameraModeCT
{
    struct BasicCommandCT   packetInfo;
};


struct GetMeasurementCameraModeRT
{
    struct BasicCommandRT           packetInfo;
    enum ES_MeasurementCameraMode   cameraMode;
};
```

GetProbesCT/RT

Command structure to get Probe properties. GetProbes command retrieves all probes defined in the Tracker Server. The answer consists of as many answer packets as probes are defined in the server database. These resolve the relation between probe name (string) and probe ID (numerical). Each packet, in addition (a redundancy), contains the total number of probes, i.e. the total number of packets to be expected (only for programmer's convenience). Other properties, such as probeType, serial Number, comment, etc. serve as information, mainly used for user-interface purpose.

```
struct GetProbesCT
{
    struct BasicCommandCT   packetInfo;
};

struct GetProbesRT
{
    struct BasicCommandRT      packetInfo;
    int                        iTotalProbes;
    int                        iInternalProbeId;
    long                       lSerialNumber;
    enum ES_ProbeType          probeType;
    int                        iNumberOfFields;
    unsigned short             cName[32];
    unsigned short             cComment[128];
};
```

GetProbeCT/RT

Command structure to get the ID of active Probe. The GetProbe command delivers the currently active probe by its ID (Currently set as the active one in the database).

```
struct GetProbeCT
{
    struct BasicCommandCT   packetInfo;
};

struct GetProbeRT
{
    struct BasicCommandRT   packetInfo;
    int                     iInternalProbeId;
};
```

GetTipAdaptersCT/RT

Command structure to get measurement Tip properties. The GetTipAdapters command retrieves all tip adapters defined for the Tracker Server. The answer consists of as many answer packets as tips adapters are defined in the server database. These resolve the relation between tip name (string) and tip adapter ID (numerical). Each packet, in addition (a redundancy), contains the total number of tip adapters, i.e. the total number of packets to be expected (only for programmer's convenience). Other properties, such as tipType, serial Number, comment, etc. serve as information, mainly used for user-interface purpose.

```
struct GetTipAdaptersCT
{
    struct BasicCommandCT   packetInfo;
};


struct GetTipAdaptersRT
{
    struct BasicCommandRT      packetInfo;
    int                        iTotalTips;
    int                        iInternalTipAdapterId;
    long                       lAssemblyId;
    long                       lSerialNumberLowPart;
    long                       lSerialNumberHighPart;
    enum ES_TipType            tipType;
    double                     dRadius;
    double                     dLength;
    unsigned short             cName[32];
    unsigned short             cComment[128];
};
```

GetTipAdapterCT/RT

Command structures to get the ID of active Tip Adapter. The GetTipAdapter command delivers the currently active tip adapter by its ID (Currently set as the active one in the database). In addition to the ID, the adapter number, to which the tip is attached, is returned.

```
struct GetTipAdapterCT
{
    struct BasicCommandCT   packetInfo;
};


struct GetTipAdapterRT
{
    struct BasicCommandRT   packetInfo;
    int                     iInternalTipAdapterId;
    int                     iTipAdapterInterface;
};
```

Get/SetTCamToTrackerCompensationsCT/RT

Command structures to get T-Cam To Tracker Compensation properties. The GetTCamToTrackerCompensations command retrieves all such compensations defined in the Tracker Server. The answer consists of as many answer packets as tips are defined in the server database. These resolve the relation between compensation name (string) and compensation ID (numerical). Each packet, in addition (a redundancy), contains the total number of compensations, i.e. the total number of packets to be expected (only for programmer's convenience). Other properties, such as tracker Serial Number, comment, etc. serve as information, mainly used for user-interface purpose. There is a flag bIsActive, which is true for exactly one compensation.

```
struct GetTCamToTrackerCompensationsCT
{
    struct BasicCommandCT   packetInfo;
};


struct GetTCamToTrackerCompensationsRT
{
    struct BasicCommandRT  packetInfo;
    int                    iTotalCompensations;
    int                    iInternalTCamToTrackerCompensationId;
    int                    iInternalTrackerCompensationId;
    int                    iInternalCameraId;
    ES_BOOL                bIsActive;
    long                   lTrackerSerialNumber;
    unsigned short         cTCamToTrackerCompensationName[32];
    unsigned short       cTCamToTrackerCompensationComment[128];
};
```

Note: We do no longer recommend evaluating the 'bIsActive' flag in your application! This flag is redundant information which should better be asked by using the 'GetTCamToTrackerCompensation' call (which should have been named better 'GetActiveTCamToTrackerCompensation').

GetTCamToTrackerCompensations (that is, querying all compensations the system currently 'knows') is a rather expensive call. A well-designed application usually does such a call upon start-up and then only when a compensation is being added to or removed from the system (which is not a everyday- task).

While this list remains unchanged in memory, the active compensation may change quite often during runtime. It would be awkward if we always had to reload the entire list just because the active compensation has changed. However, if we would rely on the 'bIsActive' flag, we would have to do so! So better use GetTCamToTrackerCompensation() to figure out the currently active compensation and do not rely on the 'bIsActive' in the compensations list. This flag may only reliable just after reading the list!

Get/SetTCamToTrackerCompensationCT/RT

Command structures to get/set the ID of the active T-Cam to tracker compensation. The Get/SetTCamToTrackerCompensation command takes/delivers the compensation ID as parameter.

```
struct SetTCamToTrackerCompensationCT
{
    struct BasicCommandCT  packetInfo;
    int                    iInternalTCamToTrackerCompensationId;
};

struct SetTCamToTrackerCompensationRT
{
    struct BasicCommandRT  packetInfo;
};


struct GetTCamToTrackerCompensationCT
{
    struct BasicCommandCT  packetInfo;
};

struct GetTCamToTrackerCompensationRT
{
    struct BasicCommandRT  packetInfo;
    int                    iInternalTCamToTrackerCompensationId;
};
```

GetProbeCompensationsCT/RT

Command structure to get Probe Compensation properties. The GetProbeCompensations command retrieves all such compensations defined in the Tracker Server. The answer consists of as many answer packets as probes are defined in the server database. These resolve the relation between compensation name (string) and compensation ID (numerical). Each packet, in addition (a redundancy), contains the total number of compensations, i.e. the total number of packets to be expected (only for programmer's convenience). Other properties, such as tracker Serial Number, comment, etc. serve as information, mainly used for user-interface purpose. There is a flag bIsActive, which is true for exactly one compensation.

```
struct GetProbeCompensationsCT
{
    struct BasicCommandCT   packetInfo;
};


struct GetProbeCompensationsRT
{
    struct BasicCommandRT      packetInfo;
    int                        iTotalCompensations;
    int                        iInternalProbeCompensationId;
    int                        iInternalProbeId;
    int                        iFieldNumber;
    ES_BOOL                    bIsActive;
    ES_BOOL                    bMarkedForExport;
    ES_BOOL                    bPreliminary;
    unsigned short             cProbeCompensationName[32];
    unsigned short             cProbeCompensationComment[128];
};
```

Note: See important note about 'bIsActive' flag in the chapter describing the command GetTCamToTrackerCompensations. The same applies to Probe compensations: We do no longer recommend evaluating the 'bIsActive' flag. Rather use GetProbeCompensation() to ask for the currently active probe!

Get/SetProbeCompensationCT/RT

Command structures to get/set the ID of active Probe compensation. The Get/SetProbeCompensation command takes/delivers the compensation ID as only parameter.

```
struct SetProbeCompensationCT
{
    struct BasicCommandCT   packetInfo;
    int  iInternalProbeCompensationId;
};

struct SetProbeCompensationRT
{
    struct BasicCommandRT   packetInfo;
};

struct GetProbeCompensationCT
{
    struct BasicCommandCT   packetInfo;
};

struct GetProbeCompensationRT
{
    struct BasicCommandRT   packetInfo;
    int                     iInternalProbeCompensationId;
};
```

GetTipToProbeCompensationsCT/RT

Command structures to get Tip-to-probe compensation properties. The GetTipToProbeCompensations command retrieves all such compensations defined in the

Tracker Server. The answer consists of as many answer packets as tips are defined in the server database. These resolve the relation between compensation name (string) and compensation ID (numerical). Each packet, in addition (a redundancy), contains the total number of compensations, i.e. the total number of packets to be expected (only for programmer's convenience). Other properties, such as underlying probe compensations, comment, etc. serve as information, mainly used for user-interface purpose.
This command should no longer be used. It is only kept for compatibility reasons. Rather use 'GetTipToProbeCompensations2' (Introduced with emScon 2.4)

```
struct GetTipToProbeCompensationsCT
{
    struct BasicCommandCT   packetInfo;
};


struct GetTipToProbeCompensationsRT
{
    struct BasicCommandRT   packetInfo;
    int                     iTotalCompensations;
    int                     iInternalTipToProbeCompensationId;
    int                     iInternalTipAdapterId;
    int                     iTipAdapterInterface;
    int                     iInternalProbeCompensationId;
    ES_BOOL                 bMarkedForExport;
    unsigned short          cTipToProbeCompensationName[32];
    unsigned short          cTipToProbeCompensationComment[128];
};
```

GetTipToProbeCompensations2CT/RT

Command structures to get Tip-to-probe compensation properties. This struct applies to the extended version of the former command GetTipToProbeCompensations, which is only kept for compatibility reasons. New applications should always use 'GetTipToProbeCompensations 2' and the related 'GetTipToProbeCompensations2CT/RT' structs. The only difference to the former struct (see above) are the new properties 'compensationType' and 'shank compensation name'.

```
struct GetTipToProbeCompensations2CT
{
    struct BasicCommandCT   packetInfo;
};

struct GetTipToProbeCompensations2RT
{
    struct BasicCommandRT   packetInfo;
    int                     iTotalCompensations;
    int                     iInternalTipToProbeCompensationId;
    int                     iInternalTipAdapterId;
    int                     iTipAdapterInterface;
    int                     iInternalProbeCompensationId;
    ES_BOOL                 bMarkedForExport;
    enum ES_TipToProbeCompensationType  compensationType;
    unsigned short          cTipToProbeCompensationName[32];
    unsigned short          cTipToProbeCompensationComment[128];
    unsigned short          cShankCompensationName[32];
};
```

GetTipToProbeCompensationCT/RT

Command structures to get the ID of active Tip to Probe- compensation. There is no related 'Set' command since detection is automatic. The GetTipToProbeCompensation command delivers the compensation ID as only parameter.

```
struct GetTipToProbeCompensationCT
{
    struct BasicCommandCT   packetInfo;
};

struct GetTipToProbeCompensationRT
{
    struct BasicCommandRT   packetInfo;
    int                     iInternalTipToProbeCompensationId;
};
```

Get/SetExternTriggerParamsCT/RT

Command structures for setting/getting the external trigger parameters. See 'ExternTriggerParamsT' structure for parameter description.

```
struct SetExternTriggerParamsCT
{
    struct BasicCommandCT packetInfo;
    struct ExternTriggerParamsT triggerParams;
};


struct SetExternTriggerParamsRT
{
    struct BasicCommandRT   packetInfo;
};


struct GetExternTriggerParamsCT
{
    struct BasicCommandCT   packetInfo;
};


struct GetExternTriggerParamsRT
{
    struct BasicCommandRT       packetInfo;
    struct ExternTriggerParamsT triggerParams;
};
```

GetErrorEllipsoidCT/RT

Command structures to calculate an error ellipsoid from a given point and its error statistic. This is a convenience command for user-interface purposes. Input parameters are 3 coordinate values, their standard deviations plus the covariance matrix. Input is in current units, current CS and with applied transformation / orientation settings. Output parameters are 3 Std Dev values (ellipsoid- axes), always related to X,Y,Z (RH cartesian) and 3 Rotation angles that describe the orientation of the error ellipsoid.

```
struct GetErrorEllipsoidCT
{
    struct BasicCommandCT   packetInfo;
    double                  dCoord1;
    double                  dCoord2;
    double                  dCoord3;
    double                  dStdDev1;
    double                  dStdDev2;
    double                  dStdDev3;
    double                  dCovar12;
    double                  dCovar13;
    double                  dCovar23;
};

struct GetErrorEllipsoidRT
{
    struct BasicCommandRT packetInfo;
    double                dStdDevX;
    double                dStdDevY;
    double                dStdDevZ;
    double                dRotationAngleX;
    double                dRotationAngleY;
    double                dRotationAngleZ;
};
```

GetMeasurementCameraInfoCT/RT

Command structures to read T-CAM-specific properties and feature data of the active camera.

The tracker must be equipped with a Measurement camera.
Note: with emScon V2.3, variable names have changed from *iFirmWare*... to *iFirmware*... This will not have any influence to existing applications at runtime. Upon compilation with the new API- include- files, these names need to be adjusted in the code of the application.

```
struct GetMeasurementCameraInfoCT
{
    struct BasicCommandCT   packetInfo;
};


struct GetMeasurementCameraInfoRT
{
    struct BasicCommandRT            packetInfo;
    int                              iFirmwareMajorVersionNumber;
    int                              iFirmwareMinorVersionNumber;
    long                             lSerialNumber;
    ES_MeasurementCameraType         cameraType;
    unsigned short                   cName[32];
    long                             lCompensationIdNumber;
    long                             lZoomSerialNumber;
    long                             lZoomAdjustmentIdNumber;
    long                             lZoom2DCompensationIdNumber;
    long                             lZoomProjCenterCompIdNumber;
    double                           dMaxDistance;
    double                           dMinDistance;
    long                             lNrOfPixelsX;
    long                             lNrOfPixelsY;
    double                           dPixelSizeX;
    double                           dPixelSizeY;
    long                             lMaxDataRate;
};
```

GetMeasurementProbeInfoCT/RT

Command structures to read Probe-property information and features of the active probe.
Note: with emScon V2.3, variable names have changed from *iFirmWare*... to *iFirmware*... This will not have any influence to existing applications at runtime. Upon compilation with the new API- include- files, these names need to be adjusted in the code of the application.

```
struct GetMeasurementProbeInfoCT
{
    struct BasicCommandCT   packetInfo;
};

struct GetMeasurementProbeInfoRT
{
    struct BasicCommandRT       packetInfo;
    int                         iFirmwareMajorVersionNumber;
    int                         iFirmwareMinorVersionNumber;
    long                        lSerialNumber;
    ES_ProbeType                probeType;
    long                        lCompensationIdNumber;
    long                        lActiveField;
    ES_ProbeConnectionType      connectionType;
    long                        lNumberOfTipAdapters;
    ES_ProbeButtonType          probeButtonType;
    long                        lNumberOfFields;
    ES_BOOL                     bHasWideAngleReceiver;
    long                        lNumberOfTipDataSets;
    long                        lNumberOfMelodies;
    long                        lNumberOfLoudnessSteps;
};
```

Get/SetLongSystemParamCT/RT

Command structures to set / get individual system settings parameters (of type long). See enum ES_SystemParameter.

```
struct SetLongSystemParamCT
{
    struct BasicCommandCT       packetInfo;
    enum ES_SystemParameter     systemParam;
    long                        lParameter;
};

struct SetLongSystemParamRT
{
    struct BasicCommandRT       packetInfo;
};


struct GetLongSystemParamCT
{
    struct BasicCommandCT       packetInfo;
    enum ES_SystemParameter     systemParam;
};

struct GetLongSystemParamRT
{
    struct BasicCommandRT       packetInfo;
    enum ES_SystemParameter     systemParam;
    long                        lParameter;
};
```

GetMeasurementStatusInfoCT/RT

Command structures to get information about status of all types of compensations and related hardware.
Such information is useful in cases where the Tracker Status is not ready and one wants to figure out why. Without the information of this command, investigation could be difficult because there are numerous conditions why a

system is not ready to measure (Missing compensations, Beam not attached, no accurate Reflector). This especially applies to 6DoF modes. A look to the bits of ‘lMeasurementStatusInfo’ immediately shows the reason.
The information data is delivered as a long value representing a bit-mask. Use the enum ES_MeasurementStatusInfo values to decode / mask the 'lMeasurementStatusInfo' parameters flags information.
Note the terminology with the 's': GetMeasurementStatusInfo. This is because this command relates to different types of compensations and hardware (which are always related)

```
struct GetMeasurementStatusInfoCT
{
    struct BasicCommandCT   packetInfo;
};

struct GetMeasurementStatusInfoRT
{
    struct BasicCommandRT   packetInfo;
    enum ES_ResultStatus    lastResultStatus;
    long                    lMeasurementStatusInfo;
};
```

GetCurrentPrismPositionCT/RT

Command structures to get the 3D position of the prism the laser is currently attached to. Delivers the ‘same’ values as a stationary measurement would deliver, however, less accurate than stationary measurements. **Do NOT use these values as measurements where precise measurements are required.**
See command description ‘GetCurrentPrismPosition’ for a typical application of this command.

```
struct GetCurrentPrismPositionCT
{
    struct BasicCommandCT   packetInfo;
};

struct GetCurrentPrismPositionRT
{
    struct BasicCommandRT  packetInfo;
    double                 dVal1;
    double                 dVal2;
    double                 dVal3;
};
```

GetObjectTemperatureCT

Command structures for the GetObjectTemperature command.
Details see description of ES_Command: ES_C_GetObjectTemperature.

```
struct GetObjectTemperatureCT
{
    struct BasicCommandCT  packetInfo;
};

struct GetObjectTemperatureRT
{
    struct BasicCommandRT  packetInfo;
    double                 dObjectTemperature;
};
```

ClearCommandQueueCT/RT

Command structures for the ClearCommandQueue command. Input parameter clearQueueType: see enum ES_ClearCommandQueueType. This is for advanced programming issues. Remember that the command- queuing mechanism must be enabled explicitly by setting a value between 1..10. (See ES_SystemParameter 'ES_SP_TcpCommandQueueSize')
Further details see description of ES_Command: ES_C_ClearCommandQueue.

```
struct ClearCommandQueueCT
{
    struct BasicCommandCT           packetInfo;
    enum ES_ClearCommandQueueType   clearQueueType;
};

struct ClearCommandQueueRT
{
    struct BasicCommandRT  packetInfo;
};
```

GetTriggerBoardInfoCT/RT

Command structures to get the properties/features of the trigger board, such as type (see enum ES_TriggerCardType), frequency

etc. This is for advanced programming issues.
Further details see description of ES_Command: ES_C_GetTriggerBoardInfo.
See also 'Tracker Trigger Interface' Appendix for a more detailed description of trigger- issues.

```
struct GetTriggerBoardInfoCT
{
    struct BasicCommandCT   packetInfo;
};

struct GetTriggerBoardInfoRT
{
    struct BasicCommandRT   packetInfo;
    enum ES_TriggerCardType triggerCardType;
    long                    lFPGAVersion;
    long                    lMaxTriggerFrequency;
    long                    lErrorCode; // 0 ==> All OK
};
```

GetOverviewCameraInfoCT/RT

Command structures to get the properties/features of the overview camera, such as name, type (see enum ES_OverviewCameraType), chip size, focal length etc. This is for advanced programming issues.
Further details see description of ES_Command: ES_C_GetOverviewCameraInfo.

```
struct GetOverviewCameraInfoCT
{
    struct BasicCommandCT       packetInfo;
};

struct GetOverviewCameraInfoRT
{
    struct BasicCommandRT       packetInfo;
    enum ES_OverviewCameraType  cameraType;
    unsigned short              cCameraName[32]; // UNICODE
    ES_BOOL                     bIsColorCamera;
    double                      dFocalLength;
    double                      dHorizontalChipSize;
    double                      dVerticalChipSize;
    ES_BOOL                     bMirrorImageHz;
    ES_BOOL                     bMirrorImageVt;
};
```

Get/SetDoubleSystemParamCT/RT

Command structures to set/get individual system settings parameters (of type double).
Further details see description of ES_Command: ES_C_Set/GetOverviewCameraInfo.

```
struct GetDoubleSystemParamCT
{
    struct BasicCommandCT       packetInfo;
    enum ES_SystemParameter     systemParam;
};

struct GetDoubleSystemParamRT
{
    struct BasicCommandRT       packetInfo;
    enum ES_SystemParameter     systemParam;
    double                      dParameter;
};

struct SetDoubleSystemParamCT
{
    struct BasicCommandCT       packetInfo;
    enum ES_SystemParameter     systemParam;
    double                      dParameter;
};

struct SetDoubleSystemParamRT
{
    struct BasicCommandRT  packetInfo;
};
```

GetADMInfo2CT/RT

Command structures to read ADM-specific properties and feature data. The tracker must be equipped wit an ADM.
dMax/dMinDistance specifies the measuring range in current length units. iMaxDataRate gives the maximum measuring frequency the ADM is capable to measure with.
dAccuracyADMDistance informs about the specified accuracy of the measured distance.

```
struct GetADMInfo2CT
{
    struct BasicCommandCT   packetInfo;
};

struct GetADMInfo2RT
{
    struct BasicCommandRT      packetInfo;
    enum ES_ADMType            admType;
    unsigned short             cADMName[32];
    long                       lSerialNumber;
    int                        iFirmwareMajorVersionNumber;
    int                        iFirmwareMinorVersionNumber;
    double                     dMaxDistance;
    double                     dMinDistance;
    int                        iMaxDataRate;
    double                     dAccuracyADMDistance;
};
```

GetTrackerInfoCT/RT

Command structures to read tracker properties / feature data of the currently connected tracker. Includes information about the tracker- type, available optional hardware (ADM, OverviewCamera, Nivel), measuring range for distances and angles, measuring rate, firmware versions etc.

```
struct GetTrackerInfoCT
{
    struct BasicCommandCT   packetInfo;
};

struct GetTrackerInfoRT
{
    struct BasicCommandRT       packetInfo;
    enum ES_LTSensorType        trackerType;
    unsigned short              cTrackerName[32];
    long                        lSerialNumber;
    long                        lCompensationIdNumber;
    ES_BOOL                     bHasADM;
    ES_BOOL                     bHasOverviewCamera;
    ES_BOOL                     bHasNivel;
    double                      dNivelMountOffset;
    double                      dMaxDistance;
    double                      dMinDistance;
    int                         iMaxDataRate;
    int                         iNumberOfFaces;
    double                      dHzAngleRange;
    double                      dVtAngleRange;
    enum ES_TrkAccuracyModel    accuracyModel;
    int                         iMajLCPFirmwareVersion;
    int                         iMinLCPFirmwareVersion;
};
```

GetNivelInfo2CT/RT

Command structures to read Inclination- Sensor (Leica Nivel) -specific properties and feature data. The tracker must have a 'Nivel' sensor connected and enabled. Note that a new Nivel- type 230 is now available (In the past there was only Nivel20). This command also supports newer Nivel- types (2005) and also returns name and type information.

```
struct GetNivelInfo2CT
{
    struct BasicCommandCT   packetInfo;
};

struct GetNivelInfo2RT
{
    struct BasicCommandRT       packetInfo;
    enum ES_NivelType           nivelType;
    unsigned short              cNivelName[33];
    long                        lSerialNumber;
    int                         iFirmwareMajorVersionNumber;
    int                         iFirmwareMinorVersionNumber;
    double                      dMeasurementRange;
    double                      dMeasurementAccuracyOffset;
    double                      dMeasurementAccuracyFactor;
};
```

RestoreStartupConditionsCT/RT

Command structures for the 'RestoreStartupCondition' command. This command has no parameters.

```
struct RestoreStartupConditionsCT
{
    struct BasicCommandCT  packetInfo;
};

struct RestoreStartupConditionsRT
{
    struct BasicCommandRT  packetInfo;
};
```

GoAndMeasureCT/RT

Command structures for the 'GoAndMeasure' command. The parameters specify the location where to drive the laser beam and take the 3D measurement.
Remember: GoAndMeasure is just a convenient (i.e. speed- optimized) combination of the two tasks 'GoPosition' and a stationary measurement. Details see description of item 'ES_C_GoAndMeasure' of enum 'ES_Command'.

```
struct GoAndMeasureCT
{
    struct BasicCommandCT   packetInfo;
    double                  dVal1;
    double                  dVal2;
    double                  dVal3;
};

struct GoAndMeasureRT
{
    struct BasicCommandRT  packetInfo;
};
```

3.5 C - Language TPI Programming Instructions

The C-TPI is made- up of a pure collection of enumeration types and data structures**.** The data structures reflect the 'architecture' of the data packets (= byte arrays) sent and received over the TCP/IP network, between the Application PC and the Tracker Server. This (low- level) interface serves as the basis for all higher level interfaces (C++, C#, COM)

Also refer to C- Language TPI Reference section and the *ES_C_API_Def.h file*.

No functions or procedures are defined.

Since C++ is an extension of C, a C++ compiler can also be used for C programming.

3.5.1 TCP/IP Connection

1. Establish a TCP/IP connection to the tracker server. This is typically achieved by invoking a *Connect* function of the TCP/IP communication library or toolbox. This function will take the IP address (or its related hostname) of your Tracker Server.

2. Set the TCP/IP Port Number to 700 for the Tracker Server.

3.5.2 Sending Commands

3. Call a *SendData* function from the TCP/IP communication library or toolbox (Function name may differ). This function typically takes a pointer to a data packet and probably the size of it (unless the packet is wrapped into a structure that knows its size implicitly, for example a *Variant* structure).

4. The architecture of the packets (TPI protocol) is defined by the data structures in the *ES_C_API_Def.h* file.

5. For invoking for example a *GoPosition* command, use the structure GoPositionCT and assign appropriate initialization values. In particular, assign an *ES_Command* and an *ES_C_GoPosition* as header- data and provide 3 coordinate values as command parameters.
The compiler will not detect, if, for example, an *ES_DT_SingleMeasResult* as type, or an *ES_C_SwitchLaser* as command is assigned to a *GoPositionCT* variable. Inappropriate initialization values cause the command to fail.

GoPosition initialization sample:

```
GoPositionCT data;  // declare packet variable
data.packetInfo.packetHeader.type = ES_DT_Command;
data.packetInfo.packetHeader.lPacketSize = sizeof(data);
data.packetInfo.command = ES_C_GoPosition;
data.dVal1 = -1.879;
data.dVal2 =  2.011;
data.dVal3 =  0.551;
data.bUseADM = FALSE;
```

Note: emScon Version 1.5 was tolerant in not initializing 'packetHeader.lPacketSize' upon sending commands. This is no longer the case for emScon V2.0 and up. Correct Initialization of 'lPacketSize' is compulsory!

3.5.3 Initialization Macros

6. To avoid initialization errors, which may happen through copy/paste errors and are difficult to trace, it is recommended to use initialization macros for correct assignment of type, size and command values.
An *INITStopMeasurement* macro, for example, requires two statements, the parameter declaration and the parameter initialization (macro call). The *StopMeasurement* has no additional command parameters. If there are any, these can be incorporated into the macro.

```
StopMeasurementCT  cmdStop;     // declaration
INITStopMeasurement(cmdStop);   // initialization
```

3.5.4 Excurse: C++ Initialization

C++ offers a much more elegant way for initialization – the 'constructor' approach, which eases the initialization issues.
The good thing is that these initializations are already done implicitly in the C++ interface. Other than when programming with the C-interface, these initializations do not need be done (repeatedly) by the application programmer.
See a C++ programmers reference for details.

7. After initialization of the data variable, send it to the tracker server using the TCP/IP *SendData()* function (or whatever this function is called). Depending on the TCP/IP communication

library used, the data packet may need to be packed into a Variant *vrtData* variable, followed by a *SendData* (*vrtData*) call. Alternatively, a *Send()* function takes the address and size of the data packet variable, Send (&data, sizeof(data)).

3.5.5 Answers from Tracker Server

8. The *SendData()* function does not wait for the Tracker Server (tracker) to complete the requested action - *SendData()* will return immediately. On completion of the requested action, the tracker server sends an answer back to the client. Depending on the command, it may take a few seconds between sending the command and receiving an answer. This requires some type of notification or callback mechanism. That is, as soon as data arrives from the Tracker Server, some sort of event needs to trigger a *ReadData()* procedure in the client application. Depending on the TCP/IP communication, this notification could be a Windows Message, an Event or a Callback Function.

This type of communication is called asynchronous.

3.5.6 Asynchronous Communication

9. From the programmer's point of view, asynchronous communication is much more difficult to handle than synchronous communication. The programmer must ensure, not to send a new command until the answer of the previous one has returned.

3.5.7 DataArrived Notification

10. All TCP/IP communication libraries/toolkits contain either a *DataArrived()* notification or a similar function, which is called

by the framework each time data has arrived. Depending on the toolkit:

- The function may directly return a Variant type parameter that contains the data.
- The function may deliver the data within a byte array.
- The function returns the size of the data packet that is ready to be read. In this case, the *DataArrived()* function subsequently calls a *ReadData()* function immediately, in order to get the data into a local byte array.

3.5.8 Data arrival 'Traffic Jams'

11. If a 'traffic jam' occurs on the incoming TCP/IP line, i.e., if incoming data is being queued, a *ReadData()* call will read **all** the currently available data with no notification for each individual packet (supposed buffer is big enough). Many packets may be queued and only one *DataArrived* notification might be issued. This means that the *byteArr* buffer will contain more than one packet. This may occur on high frequency, continuous measurement streams. The application has to make provisions to correctly treat such cases. The *lPacketSize* value is most convenient when parsing the *byteArr* buffer.
On the other hand, if the *byteArr* buffer is completely filled with data, it is likely that the last packet in the *byteArr* is incomplete. The packet fragment needs to be saved and padded to complete upon the subsequent read-call.

See chapter 'Queued and Scattered Data' for details on how to properly treat such situations.

12. Assuming a received data block has been read into a byte buffer named *byteArr*. In order to interpret the data, a mask is required. This requires knowledge of the type of data packet (enum *ES_DataType*). A typical

PacketHeader interpreting code is as follows:

3.5.9 PacketHeader Masking

```
PacketHeaderT *pData = (PacketHeaderT*)byteArr;
```

13. Type and the size of the packet can be accessed like:

```
pData->type;
pData->lPacketSize;
```

The packet size is only for convenience. *Sizeof(data-type)* alternatively could be used to calculate the packet size.

This redundancy may be used for consistency checks and is helpful when using programming languages other than C that lack the *sizeof()* operator).
From emScon Version 2.0 and up: lPacketSize must be initialized correctly also on sending packets. This information is essential and no longer ignored by the tracker server as this was the case for previous emScon server versions.

3.5.10 Command Subtype Switch

14. Command type answers require a switch statement to distinguish the command subtype. Non-data returning commands can all be treated the same and are handled in the default switch statement. All other command answers need to be masked with the appropriate result structure. The code fragment below demonstrates this with the *GetUnits* command, and shows part of the handling of a single measurement answer:

```
switch (pData->type)
{
   case ES_DT_Command: // 'command- type' answer arrived
   {
      BasicCommandRT *pData2 = (BasicCommandRT *)byteArr;

      // if something went wrong, no need to continue
      if (pData2->status != ES_RS_AllOK)
      {
         // TODO: evaluate and handle the error
         return false;
      }

      switch (pData2->command)
      {
         case ES_C_Initialize:
         case ES_C_PointLaser:
         case ES_C_FindReflector:
            break;

         case ES_C_GetUnits:
         {
            GetUnitsRT *pData3 = (GetUnitsRT *)byteArr;

            // Diagnostics - check whether packet size
            // as expected (in debug mode only)
            ASSERT(pData3->packetInfo.
                          packetHeader.lPacketSize ==
                                  sizeof(GetUnitsRT));

            // now you can access Unit specific data.
            pData3->unitsSettings.lenUnitType;
            pData3->unitsSettings.tempUnitType;

            break;
         }

         // case XXX:
         // Todo: add other command type evaluations
         //    break;

         default:
            break;
      }
   }
   break;

   case ES_DT_SingleMeasResult: // single-meas-result-
   {                            //type answer has arrived
      SingleMeasResultT *pData4 =
                 (SingleMeasResultT *)byteArr;

      if (pData4->packetInfo.status != ES_RS_AllOK)
         return false;

      break;
   }

   // Todo: add further 'case' statements
   // for remaining packet types
}
```

- Declaring variables within case statements, which are suitable for masking data, require curly brackets around a particular case block. Otherwise the compiler will claim.
- If-then-else can be used instead of switch statements. However, switches are more efficient.
- Frequent items should be treated at the top of a switch statement, for example multi-measurement results (not covered above).

3.6 C Language TPI - Samples

Some older Samples distributed with former emScon versions have been dropped because they have 'expired'. For Example Samples 1 and Sample 2 do no longer exist for the emScon V2.0 SDK. Nevertheless, the samples still provided have not been re-named. That's the reason why Sample 3 is the first one referenced here. However, even if the names have not changed, the samples might have improved since earlier versions. Sample 4 (see C++ section) has been completely revised for example).
Make sure to use the samples from the latest SDK version (i.e. the ones that match your current server- version)

3.6.1 Sample 3

Implements a 'lightweight' C-TPI client application, with no graphical interface, GUI overhead or MFC or ATL. This sample fits into a single file with about 350 lines of code (including comments and empty lines), and compiles into a small executable file.

This sample implements only *Initialize Tracker* and *Get Direction* commands. Since no Windows Message Loop is available, the application needs a multi-threaded approach and therefore requires events and threads. For TCP/IP communication, the Winsock API functions are used.
Further details see 'Readme.txt' file in Sample 3 folder and code- comments in source files.

Console Application

To create this or a similar sample from the scratch, the VC++ AppWizard or a text editor can be used to create a 'Console Application' skeleton, and to implement the C standard entry function:

```
int main(int argc, char* argv[])
{
}
```

Add all the source code, save the file (.c or .cpp extension) and invoke the C compiler from the command line.

Comments

These comments refer to the file *EmsyCApiConsoleClient.cpp*.

The following include- files are required:

```
#include <stdio.h>     // standard C input/output
#include <Winsock2.h>  // win32 socket stuff
#include <process.h>   // thread stuff
```

- The *main()* function first does a TCP/IP connection by calling the function *TcpIpConnect(),* starts the *Data Receiver* thread and enters an endless 'User Interface loop'. The default IP address "192.168.0.1" should be adjusted to the actual server address. Alternatively, the IP address can be passed as command- line argument upon running the application.
- This loop looks for user input of one of the two TPI commands '*i*' for *Initialize Tracker* and 'g' for *Get Direction*.
- If the user enters *x*, the loop is stopped, the TCP/IP connection is closed and the application terminates.
  The *TcpIpConnect()* function is straightforward up to the call of *connect()*.
- Call WSAStartup. After connecting, call *WSAEventSelect()*, which takes the following parameters:

  - A socket handle (that has been created before) as a global variable.

  - An event of type *WSAEVENT as* a global variable. This variable must be initialized with the return value of a *WSACreateEvent()* call.

- A flags parameter. *FD_READ* is passed, indicating an interest in data-arrival events (a realistic application would have to also trap *FD_CLOSE* events).

Calling this function will cause the TCP/IP framework to signal the passed event, whenever data has arrived at the socket.

The *DataRecvThread()* has an infinite loop with the following statement:

```
WaitForSingleObject(g_hSocketEvent, INFINITE);
```

This is a blocking call and causes the loop to stop, until the event is signaled to be read. The blocking by the *WaitForSingleObject* is released and the loop passes on.

Reset the event before available data is read into a buffer.

Call a function *ProcessData()* that does the interpretation of the buffer.

Queuing (Traffic Jams)

There are no provisions to handle 'traffic jams' on the network. A real application needs to make provisions to handle such situations with a packet size transmitted in the header of each packet. The Winsock function *setsockopt()* may be used to 'tune' TCP/IP transmission rate by increasing buffer sizes.

See Win32 documentation for more information about Winsock API (especially the WSA… function), threads and events.

See also 'Sample 9' (Receiving Data) in the C++ TPI section. Notice the comments in the source code.

Remarks

This sample can easily be ported to non-Win32 platforms (Unix, Linux, and Mac).

Creating a 'console' application requires the use of the *WSAEventSelect()* function with events and threads.

Excurse: Windows Application

This chapter points out the options we had if we chosen a Windows application instead of a Console application.

For Windows applications, the *WSAAsyncSelect()* function would be more appropriate. It issues Window messages instead of events, which are simpler to handle. No separate thread is required (the window message loop takes this part).

See Win32 documentation on *WSAAsyncSelect()*.

Winsock API

In Windows applications, the Winsock Active X control (MSWinsck.ocx) could be used instead of the Winsock2 API. This especially applies to VB / VBA applications. The Winsock Active X control provides a very high abstraction of socket-commuiation and thus is quite easy to use.
For C++ applications, the use of a MFC library permits a very convenient class wrapper around the Winsock2 API.

Refer to the *CAsyncSocket* and *CSocket classes* in C++ section for details.

Attention: The MFC 'CSocket' class may cause problems when transferring very high rated amounts of data (High frequency continuous measurements). See Sample4/Step5 and Step6 (ReadmeStep5.txt / ReadmeStep6.txt) files for details and how to avoid these problems.

4 C++ Interface

4.1 Class- based TPI Programming

4.1.1 Preconditions

Using the C++ interface requires sufficient knowledge of object- oriented programming.
A programmer should at least know about class-design, class- inheritance, virtual functions, member function overloads, asynchronous programming concepts and TCP/IP socket programming.

This chapter describes wrapper-classes for data structures and two main classes used for sending commands and receiving answers.

The description of the classes in this chapter may be slightly discrepant to the contents of the *ES_CPP_API_Def.h* file in the SDK. **In case of discrepancies, the information in the *ES_CPP_API_Def.h* file should be regarded as correct.**

Sample 4 (former Sample 4_2 in emScon 1.5) comprises all these topics. This sample is most suitable for introduction into emScon C++ programming.

The C++ TPI does not provide any additional functions for the Tracker Server. It is built upon the C- interface and is made up of one include file, *ES_CPP_API_Def.h* with *ES_C_API_Def.h* as its basis. The C++ interface implements two classes ***CESAPICommand*** and ***CESAPIReceive,*** apart from wrapper classes for each data structure (of the C-TPI).

CESAPICommand handles sending of commands from the client application to the Tracker server and *CESAPIReceive* supports receiving and parsing data sent by the Tracker Server back to the client application.

The advantage of a class design is the availability of constructors to perform (struct) initialization. Using the TPI C++ interface is preferable to the C-low-level (native) interface, if a C++ compiler is available.

4.1.2 Platform Issues

Tracker Server client programming remains platform independent since C++ compilers are available for virtually every platform.

4.1.3 TCP/IP

This chapter does not touch TCP/IP basic issues. See C- TPI section since this topic is independent from the interface- type used (except COM interface, where communication is embedded)

4.2 C++ Language TPI Reference

4.2.1 CESAPICommand class

SendPacket

```
virtual bool SendPacket(void* PacketStart, long PacketSize);
```

This is a pure virtual function that **must** be implemented in the class derived from CESAPICommand. Its implementation depends on the selected TCP/IP socket library / API.

Command Functions

Only a few sample of the class' command member functions are listed here since these can be derived directly from the C- interface.

Example for a command taking no parameters (Initialize the tracker):

```
bool Initialize();
```

Example for a command taking basic- type parameters:

```
bool SetContinuousTimeModeParams(long lTimeSeparation,
                                 long lNumberOfPoints,
                                 bool bUseRegion,
                                 ES_RegionType regionType);
```

Example for a command taking a struct parameter:

```
bool SetContinuousTimeModeParams(ContinuousTimeModeDataT
                                 continuousTimeModeData);
```

The latter two functions are different overloads of the same function.

Many of the command- functions exist in two different overloads. Depending on context, it may be more suitable for an application to use one or the other overload.

A complete listing of all these functions is available from the **CESAPICommand** class definition in the file '**ES_CPP_API_Def.h**' file.

Rather than redundantly listing all of these member functions in this chapter, a general rule is presented on how to derive the function names from the related C-TPI structures.
(The text in [brackets] shows the rule applied to a sample).

- Look up the command of interest in the 'enum ES_Command' (C- TPI Reference). [ES_C_SetContinuousTimeModeParams]
- Remove the prefix 'ES_C_' from the command tag- name. This will be the name of the C++ function. [SetContinuousTimeModeParams ()]
- For finding the input parameters, add the Postfix 'CT' to the remaining command- tag

name.
[SetContinuousTimeModeParamsCT].

- Look up this CT structure in the C- TPI reference for a description of all the parameters.

4.2.2 CESAPIReceive class

ReceiveData

```
bool ReceiveData(void* packetStart, long packetSize);
```

ReceiveData is the parser- function for incoming data. It has to be called after receiving a block of data from the emScon server.

Packets passed to this method must be COMPLETE (in terms of an RT struct as defined in the C-API). Packet fragments are not processed correctly. Hence the application (which calls ReceiveData) must ensure to pass complete packets. See chapter 'Queued and Scattered Data' for details.

Data Arrival virtual Functions

The principle is as follows: Derive your own class from **CESAPIReceive** and override those virtual functions on whose data you are interested in.

Only a few sample of the class' virtual data receiver member functions are listed here since these can be derived directly from the C-interface.

Example for a command that does not return any data. If this function is called this means the command has successfully executed (i.e. the tracker has finished initializing):

```
virtual void OnInitializeAnswer();
```

Example for a command returning data. (Which is the case for all 'Get...' functions).

```
    virtual void OnGetContinuousTimeModeParamsAnswer(
                            const ContinuousTimeModeDataT&
                            continuousTimeModeData);
```

A complete listing of all these functions is available from the **CESAPIReceive** class definition in the file '**ES_CPP_API_Def.h**' file.

Rather than redundantly listing all of these member functions in this chapter, a general rule is presented on how to derive the function names from the related C-TPI structures.
(The text in [brackets] shows the rule applied to a sample).

- Look up the command of interest in the 'enum ES_Command' (C- TPI Reference). [ES_C_GetContinuousTimeModeParams]
- Replace the prefix 'ES_C_' by 'On' and pad the name with 'Answer' in addition. This will be the name of the virtual C++ answer function. [OnGetContinuousTimeModeParamsAnswer]
- For finding the passed parameters, ignore the 'On' prefix and replace the 'Answer' Postfix by 'RT'. [GetContinuousTimeModeParamsRT].
- Look up this RT structure in the C- TPI reference for a description of all the parameters.

General Data Arrival virtual Functions

```
  virtual void OnCommandAnswer(const BasicCommandRT& cmd);

  virtual void OnErrorAnswer(const ErrorResponseT& error);

  virtual void OnSystemStatusChange(
                            const SystemStatusChangeT& status);
```

- OnCommandAnswer() is called for every command, in addition to the command-related answer function. This function can be convenient especially for non- parameter taking commands.
- OnErrorAnswer () is called upon an error condition. The status parameter indicates the kind of error and (if known), the

command parameter indicates the command that caused the error. Note that not all errors are caused through commands (e.g. Beam broken). In such cases, the command parameter is 'unknown'.
For status values, see enum 'ES_ResultStatus' and error numbers in the Appendix of this manual

- OnSystemStatusChange() is called for every status change event. For status values, see enum 'ES_SystemStatusChange'

Note that virtual functions are only called if defined int the derived receiver class. Particular arrival data can be ignored if the appropriate virtual function definition is omitted.

Attention: Make sure the signature of the virtual function in the derived class exactly matches the signature in 'CESAPIReceive'. However, the keyword 'virtual' is optional in the derived class.

Mismatching signatures will result in **not** calling the functions. The compiler cannot detect such kind of errors.

It is therefore recommended to copy/paste the virtual function header from CESAPIReceive to the derived class.

4.3 C++ Language TPI Programming Instructions

4.3.1 Sending Data

The class ***CESAPICommand*** contains a virtual function *SendPacket()*, which must be overwritten. This approach allows convenient 'Send…' command functions.

Dealing with C data structures for sending commands is no longer required, as they are completely 'hidden'. Use the related member functions of CESAPICommand instead.

4.3.2 Receiving Data

In order to select the data the application is interested in, *CESAPIReceive* offers a method *ReceiveData,* which is called on data arrival events, as well as numerous virtual member functions..

Dealing with C data structures for receiving data is no longer required, as they are completely 'hidden'. Use the related (virtual) member functions of CESAPIReceive instead.

4.3.3 Class Design Issues

All class member functions are defined 'inline'. Neither a library nor a .cpp file is required. One single include file makes up the C++ interface. The C++ interface is thus fully transparent with complete source code provided.

The C++ interface implements two classes named *CESAPICommand and CESAPIReceive*, apart from wrapper classes for each data structure (of the C-TPI). A class design has the advantage of constructors to delegate initialization issues. The class *CESAPICommand* has a virtual function, *SendPacket()*, which must be overwritten using *Send…* command functions.

While the CESAPICommand class is used to send data to the tracker server, the class CESAPIReceive is used to receive data.

The principle is as follows: Derive your own class from CESAPIReceive class and override those virtual functions on whose data you are interested in. Details see below in 'CESAPIReceive' chapter.

Insertion of the statement

```
#define  ES_USE_EMSCON_NAMESPACE
```

before the inclusion of the *ES_CPP_API_Def.h* file, defines a namespace *EmScon* for the TPI CPP classes. This is only required in case of potential name conflicts with other (third-party) libraries.

Refer to Sample 4 in the emScon SDK, for namespace techniques. Refer also to C++ documentation.

4.3.4 Data Structure Wrapper Classes

About 80 % of the *ES_CPP_API_Def.h* file size is used for definition of wrapper classes for data structures, which are required for 'internal' purposes. These classes are seldom used directly. Each one of these classes contains only one single member variable, a struct variable from C TPI and one or more constructors. Class wrappers are only available for command structures, 'CT', not for return structures, 'RT', since the technique for receiving data implements a completely different approach through virtual functions.

Example: class CGoPosition

```
class CGoPosition
{
public:
   inline CGoPosition(double dVal1,
                      double dVal2,
                      double dVal3,
                      bool bUseADM)
   {
      DataPacket.packetInfo.packetHeader.lPacketSize =
                                      sizeof(GoPositionCT);
      DataPacket.packetInfo.packetHeader.type = ES_DT_Command;
      DataPacket.packetInfo.command = ES_C_GoPosition;
      DataPacket.dVal1 = dVal1;
      DataPacket.dVal2 = dVal2;
      DataPacket.dVal3 = dVal3;
      DataPacket.bUseADM = bUseADM;
   };

   GoPositionCT DataPacket;
};
```

The struct member variable is declared at the bottom and is of type *GoPositionCT* (definition of C-TPI). To initialize the member variable, a so-called constructor, taking the command parameters as input, is provided.

Certain wrapper classes implement two constructors:

- Taking the data as one single struct parameter.
- Taking the data as individual parameters.

Example: class CSetUnits

```
class CSetUnits
{
public:
   inline CSetUnits(SystemUnitsDataT unitsSettings)
   {
      DataPacket.packetInfo.packetHeader.lPacketSize =
                                          sizeof(SetUnitsCT);
      DataPacket.packetInfo.packetHeader.type = ES_DT_Command;
      DataPacket.packetInfo.command = ES_C_SetUnits;
      DataPacket.unitsSettings = unitsSettings;
   };

   inline CSetUnits(ES_LengthUnit      lenUnitType,
                    ES_AngleUnit       angUnitType,
                    ES_TemperatureUnit tempUnitType,
                    ES_PressureUnit    pressUnitType,
                    ES_HumidityUnit    humUnitType)
   {
      DataPacket.packetInfo.packetHeader.lPacketSize =
                                          sizeof(SetUnitsCT);
      DataPacket.packetInfo.packetHeader.type = ES_DT_Command;
      DataPacket.packetInfo.command = ES_C_SetUnits;
      DataPacket.unitsSettings.lenUnitType = lenUnitType;
      DataPacket.unitsSettings.angUnitType = angUnitType;
      DataPacket.unitsSettings.tempUnitType = tempUnitType;
      DataPacket.unitsSettings.pressUnitType = pressUnitType;
      DataPacket.unitsSettings.humUnitType = humUnitType;
   };

   SetUnitsCT DataPacket;
};
```

4.3.5 CESAPICommand

A class for sending commands

The user of the C++ TPI may ignore all struct wrapper classes. The only important class to be used for programming is *CESAPICommand*, which is defined at the end of the *ES_CPP_API_Def.h file*.

Virtual override of SendPacket

In order to use the C++ TPI, a class from the CESAPICommand class must be derived. This derived class, a 'virtual' function, *SendPacket()*, must be implemented. This function cannot be implemented without knowledge of the TCP/IP communication functions the application wants to use. The implementation of *SendPacket()* depends on the TCP/IP communication functions/library/API. The *SendPacket()* function expects a pointer to a data packet and the size of that packet.

Class CMyEsCommand

Derived from CESAPICommand:

Class definition

```
class CMyESCommand : public CESAPICommand
{
public:
    CMyESCommand();
    virtual ~CMyESCommand();

     // virtual function override
     bool SendPacket(void *pPacketStart, long PacketSize);

     // Todo: add members and methods used for
     //       TCP/IP communication
};
```

Class implementation

```
CMyESCommand::CMyESCommand()
{
    // Todo: add initialization code (if any)
}

CMyESCommand::~CMyESCommand ()
{
    // Todo: add cleanup code (if any)
}

// virtual function override
bool CMyESCommand::SendPacket(void *pPacketStart,
                              long lPacketSize)
{
   // Todo: implement this function according to your
   //       TCP/IP communication.

   return true;
}
```

Command Methods

The CESAPICommand class defines a 'Send' method for each one of the TPI commands. These methods are named according to the command they cover.

Examples of such method names include:

- Initialize()
- GetCoordinateSystemType()
- SetSphereCenterModeParams()

The argument list depends on the number of (send) parameters these commands take.

```
bool Initialize();  // example with no arguments

bool GoPosition(double dVal1,  // 3 position coordinate values
                double dVal2,
                double dVal3,
                bool bUseADM = false); // default parameter
```

These functions completely hide command-struct and struct initialization known from the C interface. There is only one method for each one of the command-structs described. A derived class such as *CMyEsCommand* inherits all these methods.

The names of the command functions are derived from the members of the 'enum ES_Command' (C- TPI). Just omit the prefix 'ES_C_' to get the command function related to a command 'packet'.

Example: Given the ES_C_Command 'ES_C_SetBoxRegionParams', the related C++ command function will be called ' SetBoxRegionParams()'.

The methods for sending commands are asynchronous and can only be used for sending commands.

4.3.6 CESAPIReceive

A class for receiving command answers

Virtual override of Answer Functions

In order to use the C++ TPI for receiving data, a class from the CESAPIReceive class must be derived. Then override those virtual functions on whose data you are interested in.
Example: If your application implements a 'GetDirection()' call (a method of the CESAPICommand class – see 'ES_CPP_API_Def.h'), then you must override the virtual function 'OnGetDirectionAnswer(const double dHzAngle, const double dVtAngle)' in your derived

CESAPIReceive class in order to receive the results. In order to track errors, you always also should override the virtual function 'OnErrorAnswer(const ErrorResponseT& error)'.

Class CMyESAPIReceive

Code Sample: (only class and function declaration is shown here, not the implementation. Refer to samples for complete code).

```
class CMyESAPIReceive: public CESAPIReceive
{
   // override virtual functions of those
   // answers you are interested in:

protected:
   void OnErrorAnswer(const ErrorResponseT&);

   void OnGetSearchParamsAnswer(const SearchParamsDataT&
                                 searchParams);
};
```

See Sample 9 (EmsyCPPApiConsoleClient) for a complete example on how to implement the two classes derived from 'CESAPICommand' and 'CESAPIReceive'.
Further see the (revised) Sample 4 (= former Sample 4.2 in emScon 1.5) on how to deal with the CESAPICommand class (ESCppClient_Step3) and the CESAPIReceive class (ESCppClient_Step4).

4.3.7 Queued and Scattered Data

When the Tracker Server delivers more data through the TCP/IP network than the client is able to process, this may result in 'traffic jams'. Although, the TCP/IP network buffers such data (up to the configured buffer size), single data packets will be queued. That is, there are no more 'gaps' between the data packets. When the client is notified from the TCP/IP communication framework that data has arrived, it has to react to this notification by a *Read* call (depending on your communication tools, this can be *recv*, *GetData*, *CSocket::Receive() etc.*).

These read functions are not able to recognize packet boundaries. Read functions read all data that is currently available (In practice, the data will be read in one read- cycle, only limited to current buffer size).

Thus the buffer may now contain several congested packets. The other special case is if there is only a fraction of a packet .

Problem Solution

There are several possible approaches:

- Provide a sufficient read-buffer and read all that is currently pending. The client application parses the data block into packets, using the header information and size of each packet. With a fragmented last packet, the next read- cycle is started and the two fragments from the previous and the current reading are assembled together. This is probably the most efficient method, since it minimizes the number of reading interrupts. However, it is also the most complex one in terms of data parsing.
- Read only the first 4 Bytes to determine the size of the first pending packet. The rest of the packet is estimated by reading (*packetSize* – 4) bytes.
  Alternate method: 'Peek' (instead of Read) the packet-size, without removing data from the socket. With known size, read as many bytes as indicated by *packetSize*. See code sample below.
  This is the method we propagate for all our samples.
  Note: Earlier versions of the Samples /

Manual (up to emScon 2.3.472) propagated to peek the full packet-header (8 bytes). In the meantime, the very seldom situation that a packet boundary ran across the middle of a packet header was encountered indeed! That is, the first part (4 Bytes) of the header (of the next packet) is at the tail of the current packet. Hence, we failed to peek the header for 8 bytes. Only 4 bytes were returned. To avoid such (although rare!) problems, the function was revised in terms it now only peeks for the packet-size (the first 4 Bytes).

The sample code shown below demonstrates a method to ensure complete packets (if data blocks arrive scattered) and to avoid data congestion (traffic jams). It is based on Winsock 2.0 API functions.
Remember: There exist other approaches to implement safe socket reading. Indeed, in terms of performance, Peeking and then Reading may not be the best solution. However, it's probably the easiest one to implement. A most performing algorithm would probably always read all data that is currently pending and then parse the data on the application side. However, such an approach is much more complex.

```
LRESULT CMsgSink::OnMessageReceived(UINT uMsg, WPARAM wParam,
                                    LPARAM lParam,
                                    BOOL& bHandled)
{
   // The read-buffer is kept static for performance reasons.
   // In a real application better make it a member
   // variable of CMsgSink. Buffer size depends on application.
   // (data-amount and rate). Use something between 16 and 64K
   //
   static char szRecvBuf[RECV_BUFFER_SIZE]; // 1028*16

   bool bOK = true;
   long lReady = 0;
   int  nCounter = 0;
   long lMissing = 0;
   long lBytesRead = 0;
   long lPacketSize = 0;
   long lBytesReadTotal = 0;
   int nSizeOfPacketSize = sizeof(long); // 4 Bytes!
   PacketHeaderT *pHeader = NULL;

   TRACE(_T("CMsgSink::OnMessageReceived(%lu, %lu)\n"),
            wParam, lParam);

   if (WSAGETSELECTEVENT(lParam) == FD_READ)
   {
      // Just peek packet size, do not remove data from queue
      lReady = recv((SOCKET)wParam, szRecvBuf,
                    nSizeOfPacketSize, MSG_PEEK);

      if (lReady == SOCKET_ERROR)
      {
         if (WSAGetLastError() == WSAEWOULDBLOCK)
            Sleep(1); // busy - try later
         else
         {
            Beep(1000, 100);
            // not able to peek packet size
         } // else
      } // if

      if (lReady < nSizeOfPacketSize)
         return true; // non-fatal only a peek, try next time!

      pHeader = (PacketHeaderT*)szRecvBuf;

      // only lPacketSize is valid so far...
      // ...do not reference pHeader->type!

      lPacketSize = pHeader->lPacketSize;

      bOK = bOK && lReady == nSizeOfPacketSize&&
             lPacketSize >= nSizeOfPacketSize &&
             lPacketSize < RECV_BUFFER_SIZE;

      if (bOK)
      {
         do
         {
            nCounter++;

            if (lBytesRead > 0)
               lBytesReadTotal += lBytesRead;

            lMissing = lPacketSize - lBytesReadTotal;

            lBytesRead = recv((SOCKET)wParam,
                              (szRecvBuf + lBytesReadTotal),
                              lMissing, 0);

            if (lBytesRead == SOCKET_ERROR)
            {
               if (WSAGetLastError() == WSAEWOULDBLOCK)
               {
                  Sleep(1); // busy - try later
                  continue;
               }
               else
                  Beep(1000, 100);
            } // if
            else if (lBytesRead == 0)
            {
               // See remark in receiver function of Sample9
               Sleep(1);
               continue;
            } // else if

            if (nCounter > 64) // emergency exit
```

```
            {
               if (lBytesReadTotal <= 0)
               {
                  TRACE(_T("not able to read data (recv)\n"));
                  return true; // nothing read, can leave safely
               } // if
               else
               {
                  bOK = false;
                  break;
               }
            } // if

            TRACE(_T("Loop: BytesRead %ld, BytesReadTotal \
                        %ld, PacketSize %ld, Missing = %ld\n"),
                     lBytesRead, lBytesReadTotal+lBytesRead,
                     lPacketSize,
                     lMissing - lBytesRead);

         } while (lBytesRead < lMissing);

         if (lBytesRead > 0)
            lBytesReadTotal += lBytesRead;
      } // if

      bOK = bOK && lBytesRead == lMissing &&
                   lBytesReadTotal <= RECV_BUFFER_SIZE;

      if (bOK)
      {
         // ProcessReceivedData() is assumed to take one single
         // (complete) data packet. It contains a 'switch'
         // statement to evaluate the packet (we have seen this
         // method several times in this manual / samples)

         if (lBytesReadTotal == lPacketSize)
             ProcessReceivedData(szRecvBuf, lBytesReadTotal);
      } // if
   }
   else
      bOK = false;

   if (!bOK)
   {
      // make sure socket is cleaned up on data jam
      // in order to recover ordinary data receiving

      do
      {
         nCounter++;
         lBytesRead = recv((SOCKET)wParam, szRecvBuf,
                             RECV_BUFFER_SIZE, 0);

         TRACE(_T("Recover in loop\n"));

      } while (lBytesRead > 0 && nCounter < 128);

      TRACE(_T("Unexpected data - fatal error\n"));

      Beep(250, 10); // data lost
   } // else

   return bOK; // true when message handled
} // OnMessageReceived()
```

This code ensures that only complete packets are processed. However, the client may still not be fast enough to process all the incoming data. The TCP/IP framework will buffer data, up to a limit. If such limits are reached, arbitrary data may arrive. The above function has (limited) recovery ability in case this should happen. Data may get lost in such situations.

Cause of Data Loss

- The network is not fast enough.
- The client PC is not powerful enough.
- The application is not able to process data fast enough.
- The application is not designed appropriately.
  The client application can still buffer incoming data, for example, in a FIFO list (taking the data packets as list elements). This approach can be chosen if the performance constraint is caused by intensive data processing. The Winsock2 API offers certain 'tuning' functions. These allow, for example, to alter internal network buffers. Increasing the receive- buffer with *setsockopt(),* for example, may increase data throughput significantly.

```
#define SOCKET_READ_BUFFER_SIZE (256 * 1024) // 256 KB buffer

int nBufSize = SOCKET_READ_BUFFER_SIZE;
int nVarSize = sizeof(nBufSize); // we know it's 4 byte, but
                                 //using sizeof is better style!

nRet = setsockopt(m_sock, SOL_SOCKET, SO_RCVBUF,
                  (char *)&nBufSize, nVarSize);
ASSERT(nRet != SOCKET_ERROR);
```

See documentation on *setsockopt()* for further details.

4.3.8 Partial Settings Changes

Consider the command 'SetUnits'. This command takes all selectable unit- types (Length, Angular, Temperature, Pressure, Humidity) as parameters. However, often one wants to change only one of these and leave the others untouched.

The best method to do so is invoking a 'GetUnits' first, then change only the one parameter of interest and finally do a 'SetUnits'.

Here is a C++ sample (although the same approach also applies to C and COM interface).

```
GetUnits(); // trigger a 'GetUnitsCommand'

// The current units are delivered in such that
// the following virtual function will be called:

void OnGetUnitsAnswer(unitsSettings)
{
   SystemUnitsDataT newUnits = unitsSettings;

    // change angle unit and leave all the rest untouched

    newUnits.angUnitType =  ES_AU_Degree;

    // restore changed parameters
    // (assumed g_cmdObj is a pointer to your ApiCommand obj)

    g_cmdObj->SetUnits(newUnits);
}
```

Note: since the parameter of the OnGetUnitsAnswer() is designed as 'const', it is necessary to use a local struct 'newUnits'. It is not possible to directly change 'unitsSettings'.

Another 'favorite' for this technique is the command 'SetSystemSettings'. Often it is required to change only one of the different flags of the 'SetSystemSettings' parameters.

However, this technique can be used for every Set/Get command pair (if the command has more than one parameter or a struct parameter).

4.3.9 Asynchronous Programming Issues

As already stated, all communication through the C++ interface is asynchronous.

It is therefore not possible to 'queue' commands within one function call. In other words, consider a Windows application with a graphical interface. Assume a button named 'InitialSettings' with a button- press handler as follows behind (Note this is pseudo code since no parameters are specified):

```
OnInitialSettingsButtonPressed()
{
    m_myApiCmd->SetUnits(...);
    m_myApiCmd->SetEnvironmentParams(...);
    m_myApiCmd->Initialize();
    m_myApiCmd->GetReflectors();
    m_myApiCmd->SetMeasurementMode(...);
}
```

This won't work at all because this a typical synchronous approach (i.e. It is assumed a command has finished when it returns). In an asynchronous approach, each command returns immediately. In the sample above, SetUnits() and SetEnvironmentParams() may accidentally work (because these commands do not take a long time – but never rely on this!). But Initialize() – since this command takes about 45 seconds to terminate – also returns immediately. The server, however, is not ready to take the next command until initialization of tracker is finished. Hence the command ' GetReflectors()' would fail with a 'Server busy' error.

Note: The emScon COM interface provides a synchronous interface, which allows to queue several commands in one and the same function. However, even when using the synchronous interface, some answers remain asynchronous by nature. These are error events, system status change events and 'multi- packet' command answers, such as 'GetReflectors', 'GetCompensations' etc.

The correct approach is that the application never issues a command before the previous one has returned. Even a non- parameter returning command always indicates its termination by sending an 'acknowledgment'. With the C++ interface, either the general 'OnCommandAnswer()' can be used for that (practically only suitable for commands that do not return any results). In addition, every command has its individual 'On..Answer()' handler. See 'ES_CPP_API_Def.h' file, CESAPIReceive class.

In particular, the next command may not be issued before the 'On..Answer()' handler of the previous command has arrived. There are several possible approaches to achieve correct execution of a series of commands :

- Directly call the next command in the 'On..Answer()' of the previous command. This approach is demonstrated with the 'GetReflectors' / 'GetReflector()' sequence in Step4 of Sample 4.
  Remark: There is a helper function InitReflectorBox() in OnGetReflectorsAnswer(). The next command ' GetReflector()' is called in this 'InitReflectorBox()' function. However, 'GetReflector()' could also be called inside 'OnGetReflectorsAnswer()' function directly.
- Queue your commands in a list. Take the first command from the list and send it to the tracker server. At the same time, set an Event (or another synchronization object, such as Mutex or Semaphore)' that prevents taking the next command from the list. As soon as the answer of the pending command arrives, reset the Event, which will cause to process the next command from the list.
  In contrast to the first approach, where each On..Answer() handler calls a different subsequent command, this second approach is more general in such that every answer handler does the same: 'ResetEvent'. Needless to say that this approach means a multi threaded application.
- Queue your commands in a list. Use an application-defined Windows message handler that removes and processes the first command of the list and sends it to the

tracker server. To start the 'command-chain', do an explicit first call of this message handler. In every 'On..Answer()' handler, a 'PostMessage()' call will cause to trigger the message handler in order to process the next command. (Important to use PostMessage, not SendMessage).
The advantage of this approach is that no multi- threaded application is required since the Windows message loop takes care of synchronization. On the other hand, this approach only works for windows applications and not for console applications or 'windowless server applications' (Hint: you may use an invisible window for message handling).

- To be complete, the most simple approach is also mentioned here, although this does not really mean an 'automated queuing' of commands: Let the synchronization to the user! This means that the application implements an individual Button for every command, i.e. every button handler calls only one command. The user himself must make sure he does not press a button while a pending command has not terminated. The application can support the user in such that it disables all buttons while a command is in action. (Disable all buttons when pressing any button, enable all again when a 'On..Answer()' handler is called).

The 'asynchronous issues' of this chapter also apply to the C- Interface and the emScon COM interface – as far as using the asynchronous interface (or those parts of the synchronous COM interface that remain asynchronous by nature).

4.3.10 Working with multiple trackers

Under C/C++ context, there is nothing special to say about addressing multiple trackers from within one application.
Just 'duplicate' the code from the first tracker to set up a 2nd connection to a different controller/tracker. For the C++ interface, this means to create 2nd instances of the 'CESApiCommand' and 'CESApiReceive' - derived classes.

Remarks: If instances of the same Command- (= Sender) and Receiver- classes are being used for both trackers, these classes must not contain global or shared! In particular, make sure any instance gets its own instance of a communication socket (for example by passing the socket objects through constructor variables to the Sender/Receiver classes).
Note that the Command- and Receiver- classes used in the provided SDK Samples (7, 9) do not consequently follow these principles! Especially socket objects are global or shared. You must either modify these classes in order to make them 'multi- instantiable', or use a 'copy/paste' approach and setup different Send/Receiver classes for the 2nd tracker.
The latter means duplicated code and should be avoided - unless both trackers have to fulfill completely different tasks that require a different set of commands and event handlers.
The former (using multiple instances of one and the same Sender/Receiver class for multiple trackers) in addition may require introducing a 'cookie'- property to the Receiver class. This can be just an integer (tracker# 1 or 2), which is passed as a parameter to the constructor. Upon receiving answers, this cookie can then be used to identify whether the answer came from the first or from the 2nd tracker. Otherwise there would

be no way to identify whether an even handler was triggered from one or the other tracker (consider that both trackers may perform the same command at the same time!).
An alternative (and from object oriented point of view much better) approach than using cookies is to pass a reference of the sender object to the Receiver class. That is, instead of (or in addition to) passing a cookie, we directly pass the MyAPICommand variable. This approach is suitable if both trackers have to do the same sequence of commands. Otherwise, we may need the cookie nevertheless in addition to the command object reference.
See also chapter 'Multi Tracker C# Applications' in section 6; there is a (C#) code- sample demonstrating the cookie- technique. This sample also shows how to make Sender/Receiver classes 'multi-instantiable' - the shown approach there (sockets, command objects, and cookies passed through constructor variables) can easily be equivalently applied to C++ applications.

Threading Issues: All calls to the C++ interface are asynchronous by design; it is therefore **NOT required**, nor recommended to use multi-threading, i.e. running the two tracker instances in two different threads (although - depending on your application design - there might be reasons to do so nevertheless). A (Windows) application will be able to address both trackers in 'parallel' without dealing with the complexity of multiple threads.
However, make sure to carefully synchronize command calls. In particular, avoid mix-matching command-answers from either tracker. Keep in mind that the same command may be executed at the same time for both trackers.

Note: A Console application - like Sample 9 -

needs a multithreaded approach for other reasons (for receiving data while main thread [= user-interface] is blocked). Multithreading is not required because of multiple trackers. Indeed, multithreading is required even for a single tracker in case of a Console application.
Two (or even multiple) trackers can be set up in the same sender- and receiver- thread respectively. That is, regardless how many trackers we have, we always need only two threads - the main thread and a receiver thread.
Nevertheless, in this particular case it may probably make sense to use separate receiver threads for every CESApiReceive instance (i.e. one receiver thread for each tracker).
On the other hand, one single thread (the main thread) is sufficient to deal with several CESApiCommand instances.
See also chapter 'Multi Tracker C# Applications' in section 6.
Further see chapter 'Multi- tracker applications' in the COM section. In contrast to applications using the emScon C++ interface, multi-threading will be compulsory for the COM interface if one wants to take advantage of synchronous calls.

Remember: If we use a Windows application (instead of a Console Application) in combination with the emScon C++ interface, we do not need any multi- threading at all, not even when dealing with multiple trackers!
Instead we use the Windows messaging mechanism (which runs under control of the main thread) for data receiving issues; no receiver threads are required. However, the 'cookie' approach discussed above remains an issue.

4.4 C++ Language TPI Samples

4.4.1 Sample 4

This sample is designed as a 6 Step-by-Step tutorial. It is a Windows application with a graphical dialog user- interface and makes use of the MFC framework.

Step1:
Step 1 offers a simple dialog- based MFC application. It has added some dialog controls with message handlers and required dialog member variables already defined.
However, all message handlers are empty (except Beep).

The framework has been created using the AppWizard and ClassWizard and then a bit cleaned up manually in order to keep the code as slim as possible (Eliminated icons, rc2 and pre-compiled headers). In a real application, these things could be left of course.

Note that the Step 1 application does not yet depend on emScon at all.

Step2:
Step 2 adds TCP/IP communication to the application. There are several ways to do this:

- use an appropriate Socket Class (that's what we do in this application - we use CSocket of MFC, which will be replaced in Step 6 by our own socket class - CESSocket.

- use the Winsock2 C-library (as for example used in the 'Sample9' of the emScon SDK)

- use the Winsck.ocx ActiveX control.

- use any other third-party socket library

We need to provide the following functions:

- connect to server

- disconnect from server
- write data to previously opened server connection

In addition, we need a notification mechanism to get informed that data has arrived and is ready to be read.

Since this is a Windows application, we can use the window message mechanism to achieve this.

(Note that in a non- windows application, we would need to use events and threads to achieve the same - see Sample9).

So far nothing depends from the emScon SDK - we do not need any emScon- include file yet. All is provided by the VC++ development Kit. But nevertheless we will be able to connect to / disconnect from server. But Step2 application will not yet allow to send real emScon commands and receive answers to/from server.

Step3:

Step 3 introduces the emScon command class 'CESAPICommand' to SEND 'understandable' data to the server. More precisely, the class is rather used to construct data blocks 'understandable' to the emScon server. It's the first time that the emScon SDK is involved. We have to include the 'ES_CPP_API_Def.h' file (and - indirectly through this file – some other include files such as 'ES_C_API_Def.h' and 'Enum.h'.

As done with CSocket, we also must derive our own class from 'CESAPICommand' because this class contains a virtual function 'SendPacket'. It is mandatory to provide our own implementation of this class. The implementation depends on the TCP/IP communication package we use.

Step3 application allows us to send commands, but not yet to receive answers. So we will not be able to check whether the command was executed correctly because all commands are ASYNCHRONOUS. That is, a command is sent, then the application is idle while the server executes the command. Then the server sends back an acknowledge or error message. We have no code yet to interpret these answers. We just see how many bytes arrive. In Step4, we will add logic to receive data.

Nevertheless, supposed the server and tracker is running, we will at least see the tracker moving when sending a 'Initialize' tracker command.

If the correct reflector is set, GoBirdbath will also work and we can even perform a measurement (but we will not see the results yet)

Step4:

Step 4 introduces the emScon class 'CESAPIReceive' to RECEIVE 'understandable' data from the server. More precisely, the class provides virtual functions for every type of answer. So the user can just override those virtual functions he is interested in.

Step 4 also covers the topic of 'asynchronous' communication. All C++ TPI communication is asynchronous. That means a new command must not be sent before the acknowledge or result of the previous command has arrived. In addition, the application should always be ready to catch events (system status change, error events)

Correct reflector handling is also demonstrated (relation between reflector ID and reflector name and how to handle this in a dropdown combo box (do not mix up the combo index with reflector ID). Initializing the reflector combo happens in several steps: GetReflectors, fill them into the box, then GetReflector() to get the current one and select it in the box.

Asynchronous techniques are heavily touched with the reflectors handling (filling them into combo box, select the current reflector...)

Further details see 'Readme.txt' file in Sample 4 folder and code- comments in source files.

Step5:
Step 5 adds control for selection of different measurement modes, apart from some user-interface refinements. In particular, the sample shows how to handle continuous measurements. It is possible to switch between 3D and 6DoF stationary and continuous measurement modes. Measurement time (stationary) and measurement rate (continuous) are 'hardcoded' (by calling SetStationaryModeParams() and SetContinuousTimeModeParams() at initialization time.

Note that it only makes sense to select one of the 6DoF modes if the connected Tracker is equipped with a T-Cam and a T-Probe is used as measurement probe.
See important note at the bottom of 'ReadmeStep5.txt' file in folder Step5. To avoid the particular problem described there, another Step 6 has been added to the Sample.

Step 6:
Unfortunately, the CSocket class of MFC has turned out to contain a bug. On heavy data-transfer (high frequency continuous measurements, that is, if the time- separation value is set to about 10ms or less), the socket can get blocked and does not recover until restarting the application. See remark at bottom of file 'ReadmeStep5.txt' in the 'Step5' folder.
To avoid these problems, Step 6 introduces its own socket class 'CESSocket'. Apart from this, the sample is identical to Step5.

Further details see 'ReadmeStep6.txt' in the 'Step6' folder of Sample4.

4.4.2 Sample 9

This Sample, *EmsyCPPApiConsoleClient*, with a *CESAPIReceive* class demonstrates Sending and Receiving features of the C++ TPI (among other features). Like Sample 3, Sample 9 is a simple console application. However, in contrast to Sample 3, it is based on the C++ TPI. In addition, it has a more sophisticated data receiver function in order to handle traffic jams and/or scattered data.

The principle of using the C++ interface is the same as used in Sample 4: Derive your own classes from the C++ TPI classes 'CESApiCommand' and 'CESApiReceive' and define virtual methods as needed.

Set the IP address to the actual Tracker server address, before building the application. Alternatively, the IP address can be passed as command- line argument upon running the application.

Further details see 'Readme.txt' file in Sample 9 folder and code- comments in source files.

4.4.3 Sample 12

This *ReflectorCtl* sample provides an ActiveX component comprising the most common reflector commands.

This control skips building up a lookup table for ID/Name mapping, querying all the defined reflectors from the system and providing the appropriate user interface controls.

The Sample contains full source code (Visual C++) and has a compiled component *Reflector.ocx*, which allows use without a Visual C++ compiler.

Remarks

- The *Reflector.ocx* control must be registered before it can be used.
- Only one instance of such a control can be instantiated per Form/Dialog box.
- The properties 'ServerAddress' and 'PortNumber' can be specified at (Form/Dialog) design time. However, this only makes sense if these parameters are constant. The more common way is to set these properties programmatically.
- Call the method *Initialize* after having set the properties and not before the client application has successfully connected to the same address/port. This lets the client application, instead of the *Reflector.ocx*, handle any connecting problems.
- The client application must ignore answers from commands triggered by the *Reflector.ocx* (*Get Reflectors*, *GetReflector* and *SetReflector*).
- Do not implement an Error Event handler for *Reflector.ocx*. The control has a built- in handler. Visual Basic does not allow it– it causes a compiler error. If correctly applied, the component should never fire an error event.
- Here is a code sequence for a VB application. Typically executed in Form Load:

```
Reflector1.ServerAddress = "192.168.0.1"
Reflector1.PortNumber = 700
Reflector1.Initialize
```

  - It is assumed that the client application has already successfully connected to the same address/port before these calls.

Keyboard Interface Limitation

- This component is primarily designed for mouse control and does not work properly with a keyboard interface (E.g. use of arrow keys in VB).

See VC/VBA/VB documentation for general information on ActiveX controls, and how to include them in applications.

Further details see 'Readme.txt' file in Sample 12 folder and code- comments in source files.

4.4.4 Sample 19

LiveVideo display C++ application.

See Chapter 8 / Special Functions / Live Image display for details.

Attention:

New Live Image Format with emScon 3.0 !
Up to emScon 2.4, bitmap format frames were used for the live video stream. With emScon 3.0, this has changed to JPEG format. Sample 19 thus has undergone an extension since emScon 2.4 SDK was released; it supports now both, Bitmap and Jpeg formats. Support of bitmaps is only left for backward compatibility to former emScon servers.
For Jpeg image conversion and display, a public-domain Third-Party library has been used (CxImage by Davide Pizzolato). The emScon 3.0 SDK just contains a few parts of the CxImage framework (some include- files and two libraries for static linking - i.e. only those parts as far as needed to build our sample). If interested, you may get the complete CxImage source from the internet.

5 COM - Interface

5.1 High-level TPI Programming

The emScon high-level TPI (COM interface) is convenient for creating applications using Visual Basic, MS Excel, MS Access and other VBA hosts. It can also be used with C++ (although less recommended) and C# / VB.NET.

5.1.1 Drawbacks

The emScon / tracker server (TS) high-level interface, in contrast to the C++ TPI, may cause some performance drawbacks. During high data rates, some data may get lost under certain conditions. In this case, using the C/C++ TPI would be more suitable, since this would allow for 'tuning' the TCP/IP communication. The TS high-level interface does not provide such tuning capabilities.

The emScon COM interface is limited to Win32 platforms.

5.1.2 Introduction

The emScon high-level interface is made up of a COM component, as an ATL COM server. It comes as a DLL named 'LTControl.dll', and it is part of the emScon SDK.

COM components have to be registered on the application computer. In order to register *LTControl.dll* (Windows platforms only), execute the following command from the command line:

```
Regsvr32.exe  <Path>\LTControl.dll
```

See the 'Readme.txt' file that comes with the SDK (lib folder) for a more detailed description.

Remark: The LTControl.dll component (as well as LTVideo2.ocx) up to emScon Version 2.3.472 failed to register when performed by a user without administrator privileges.
From emScon (SDK) version 2.3.477 and higher, restricted users also may register these components. However, be aware that only the 'owner' may then use them. Whenever possible, it is recommended to have these components registered by an administrator so that all users may use them without any restrictions.

COM Components provide standardized programming interfaces. LTControl provides several custom interfaces and 'Connection Point Interfaces' (of type IDispatch). This chapter does not list all the methods and properties of these interfaces in detail - rather view the so-called type-library that comes with the control.

A type library describes COM object interfaces. The type library *LTControl.tlb* is also implicitly included in *LTControl.dll*.

All enumeration types and structures defined in the C-TPI are also provided by the LTControl's COM interface. These enums and structs will be available for applications using LTControl, supposed the programming language supports user-defined data types.

To get an overview of the interfaces (including properties, methods, events and UUIDs) exposed by a COM object, a COM viewer may be used.

- Select the tools menu of Visual Studio.
- Select OLE/COM Object Viewer.
- Choose File > View Type Lib.
- Select *LTControl.dll* or *LTControl.tlb*.

The LTControl component is very convenient for developing simple tracker applications using Visual Basic, MS Excel, MS Access etc.

However, where performance and customized TCP/IP communication are an issue, the C/C++ interface should be preferred.
It is generally not recommended to use the COM TPI for writing C++ client applications, although this is possible and also demonstrated in Sample 7. Especially receiving data is complicated in such applications. The advantage of the COM TPI (in contrast to the C++ TPI) is, however, that synchronous calls can be used for many commands and that all the socket communication functionality is already implemented.
On the other hand, using the COM interface for VisualBasic (VB.NET), VBA and even C# is very convenient, including receiving data (through Event handlers).

Refer to Samples 5 (VB) and Sample 8 (Excel) for further information on how to apply the emScon COM TPI for Visual Basic / VBA clients.
Sample 7 shows the usage from within C++, although we do not recommend this. For C++ applications, we rather recommend to use the C++ API directly.
Samples 14 and 15 show the usage of the COM TPI from VB .NET and C# applications respectively.

5.2 COM TPI Programming Instructions

5.2.1 VisualBasic and VBA Applications

Due to several problems and bugs in Office 97, it is recommended to use at least Office 2000 (Excel 2000/Word 2000) for VBA client programming.

The following steps apply to VisualBasic/VBA (Excel, Access):

1. Import *LTControl* to the project's references list.
   Select *Project* > *References* > *LTControl.dll*. (You may need to browse if the DLL is not shown in the list). **Make sure the selected one matches the one registered.**
2. Declare an object of type *LTConnect*.
   LTConnect is the only so called 'creatable' object, hence the keyword 'New'.

```
Dim ObjConnect As New LTConnect
```

3. Declare **only one** of the TPI controlling interfaces, **either synchronous or asynchronous**. It is not recommended using both, synchronous and asynchronous interfaces, from within one *LTConnect* instance (although shown in some of the provided Samples). When doing so in spite, some answers will be duplicated and will arrive on ‘both’ channels, making it difficult to manage these by the application.
   The keyword *WithEvents* is optional, and should only be used in combination with *LTC_NM_Event* selected as *NotificationMethod*. It activates the related connection point interface for event handling.

```
Dim WithEvents ObjSync As LTCommandSync
Dim WithEvents ObjAsync As LTCommandAsync
```

4. Connect to the tracker- server and initialize the interface pointer(s), typically in an application startup procedure.
   In Visual Basic, this is often performed in the *Form_Load* function.

```
Private Sub Form_Load()
   On Error GoTo ErrorHandler

   ObjConnect.ConnectEmbeddedSystem "192.168.0.1", 700
   ObjConnect.SelectNotificationMethod LTC_NM_Event, 0, 0
   Set ObjAsync = ObjConnect.ILTCommandAsync

   Exit Sub
 ErrorHandler:
   End ' Exit application when connect failed
   MsgBox (Err.Description)
End Sub
```

5. Call *ConnectEmbeddedSystem()* with the IP address of the Tracker Server and port 700.
6. Select the *LTC_NM_Event* method, if using events (Other options may apply).
7. Initialize ObjAsync pointer with the related property of the *ObjConnect*.
   Use error handlers as shown, since interface methods may throw exceptions.
8. Call Tracker functions:

```
Private Sub Initialize_Click()
   On Error GoTo ErrorHandler

   ObjAsync.Initialize
   Exit Sub
 ErrorHandler:
   MsgBox (Err.Description)
End Sub
```

Invoke only one command at a time when using the asynchronous interface. No other command should be sent until a pending one has completed. This behavior makes up the **asynchronous** approach.
With the **synchronous** interface, calls can be queued within one function, although some answer types (Errors, Status change events, continuous measurements, reflectors…) remain always asynchronous by nature, regardless whether using the synchronous or asynchronous interface.

9. Declare event handlers.
   VB provides automatic code generation for event handler bodies. (Note: an underscore character (_) preceded by a blank character means a line-break advice to the VB interpreter. This is only supported by newer VB versions. Alternatively, you can omit the

underscore and write the entire statement onto one line).

```
Private Sub ObjAsync_ErrorEvent( _
               ByVal command As LTCONTROLLib.ES_Command, _
               ByVal status As LTCONTROLLib.ES_ResultStatus)

      ‘For example indicates a beam broken event
      If not (status = ES_RS_Unknown) Then
         MsgBox command & CStr(" , ") & status
      Else
         MsgBox(“unknown Error”)
      Endif
End Sub
```

10. Retrieve data during continuous measurement events.
    Events for continuous measurements (and StillImage results) do not provide the data directly. The data must be retrieved explicitly by using *ILTConnect::GetData()*.
    In C++ mask a data block with struct type casts. For VB and VBA, *ILTConnect* provides some helper functions, as shown below.

```
Private Sub LtSync_ContinuousPointDataReady( _
                          ByVal resultsTotal As Long, _
                          ByVal bytesTotal As Long)

      On Error GoTo ErrorHandler

      Dim numResults As Long
      Dim measMode As Long
      Dim temperture As Double
      Dim pressure As Double
      Dim humidity As Double
      Dim data As Variant

      LtConnect.GetData data

      LtConnect.ContinuousDataGetHeaderInfo data, numResults, _
                          measMode, temperture, pressure, _
                          humidity

      For index = 0 To numResults - 1

          LtConnect.ContinuousPointGetAt data, index, status, _
                           time1, time2, dVal1, dVal2, dVal3

          ‘ Todo: Do something with the measurement data here
      Next

      Exit Sub
  ErrorHandler:
      MsgBox (Err.Description)
  End Sub
```

ContinuousDataGetHeaderInfo()/ *ContinuousPointGetAt()* may affect the performance. They have been primarily designed for use with VBA.
For C++ applications, there exist more efficient ways to extract continuous measurements (masking data with structs).

5.2.2 C++ Applications

A complete C++ Console Application based on the COM TPI is shown below. It shows the import of the *LTControl* interface and how to declare and initialize objects. The application uses the synchronous interface (queuing several commands). Events cannot easily be implemented with a console application. The conclusion is that the LTControl (emScon COM interface) is not really of practical use for a console application!
Console applications should rather be based on the C/C++ interface.
See Sample 9 of the emScon SDK for a minimal C++ console application, demonstrating CESCommandApi as well the CESAPIReceive class

```
#include <stdio.h>
#include <atlbase.h>

extern CComModule _Module;
#include <atlcom.h>

#import "LTControl.dll" no_namespace, named_guids,
                          inject_statement("#pragma pack(4)")

int main(int argc, char* argv[])
{
   CoInitialize(NULL);

   ILTConnectPtr g_pLTConnect;
   ILTCommandSyncPtr g_pLTCommandSync;

   try
   {
      g_pLTConnect.CreateInstance(__uuidof(LTConnect));

      g_pLTConnect->ConnectEmbeddedSystem("127.8.34.61", 700);
      g_pLTCommandSync = g_pLTConnect->GetILTCommandSync();

      g_pLTCommandSync->SetCoordinateSystemType(ES_CS_LHRZ);
      g_pLTCommandSync->Initialize();
      g_pLTCommandSync->PointLaser(1.7, 2., 0.6);

      g_pLTConnect->DisconnectEmbeddedSystem();
   }
   catch(_com_error &e)
   {
      printf("Exception:%s \n", (LPCTSTR)e.Description());
   }

   CoUninitialize();
   return 0;
}
```

Note the statement:

```
#import "LTControl.dll" no_namespace, named_guids,
                             inject_statement("#pragma pack(4)")
```

This statement must, and not as shown, reside on one single line. It is assumed that *LTControl.dll* resides in the current directory, otherwise specify

the path, for example
..\ES_SDK\lib\LTControl.dll.

Other than VB applications, COM TPI- based C++ applications need to call *CreateInstance()* using the statement:

```
g_pLTCommandSync = g_pLTConnect->GetILTCommandSync();
```

replaces the related VB call:

```
Set ObjSync = ObjConnect.ILTCommandSync
```

See Sample 7 for setting up an event sink for a Windows application (Although this approach is not recommended).

5.2.3 Notification Method

The following enumeration type defines the different methods the *SelectNotificationMethod* can take. Only one of these methods can be active at a time. Therefore, *SelectNotificationMethod* should be called only once with one of the following values:

```
enum LTC_NotifyMethod
{
   LTC_NM_None,          // No notification (using nothing else
                         // but synchronous calls)
   LTC_NM_Event,         // notify through connection point
                         // interfaces (Events)
   LTC_NM_WM_CopyData,   // notify through copydata and pass
                         // data directly with message
   LTC_NM_WM_Notify,     // notify through WM message and
                         // pass only size through lParam
};
```

- LTC_NM_None
  Neither events nor Windows messages are sent. Hence neither a continuous measurement nor trapping error events (beam broken etc.) is possible. This option therefore only makes sense for applications that strictly use synchronous calls. The *targetHandle* and *cookie* of the *SelectNotificationMethod* method should be zero.

- LTC_NM_Event:
  Events are used to notify the client on asynchronous answers (sync and async interface). The *targetHandle* and *cookie* of the *SelectNotificationMethod* method should be

zero. This is the most commonly used approach.

- LTC_NM_WM_CopyData
  The client is notified by a *WM_COPYDATA* message upon data arrival. The arrived data block is transferred with the message.
  See Win32 API documentation on *WM_COPYDATA* for details.
  The handle of the window that gets the message must be passed through *targetHandle*. If there are multiple *LTControl* instances (more than one tracker), the call of *SelectNotificationMethod* for each *LTControl* instance must get a different cookie, in order to identify incoming messages with the respective tracker. The number of cookies is not limited. They are passed to the client through the *pCopyDataStruct* → *dwData member*. The transferred data needs to be interpreted by using the structures defined in the C TPI as masks.
- LTC_NM_WM_Notify
  The client is notified by a user-defined message, *WM_USER+XXX* or a 'registered message'. The CopyData method has one cookie for each tracker. Other methods have cookies only if there is more than one tracker. The cookie is available as *wParam* at the client application. The handle of the window that gets the message must be passed through *targetHandle*.
  Only the size of the block is passed with the message (through *lParam*). The *GetData()* method of the *LTConnect* interface must be called in order to retrieve the data.

The method *SelectNotificationMethod* is defined as follows:

```
HRESULT SelectNotificationMethod(
                    /*[in]*/ LTC_NotifyMethod notifyMethod,
                    /*[in]*/ long targetHandle,
                    /*[in]*/ long cookie);
```

For implementing an event-sink in a Windows application, using the *LTC_NM_WM_CopyData* or *LTC_NM_WM_Notify* is recommended.

Using the 'LTC_NM_Event' option, although possible (as Sample 7 shows), is more complicated.
Sample 7 demonstrates all different approaches (in commented code sections). Although most complicated, the 'LTC_NM_Event' method is enabled as the default.

5.2.4 Exceptions and Return Types

All methods/interfaces have *HRESULT* return types, as per COM design. Applications are usually not required to test these return codes, since method failures are signaled by exceptions. These exceptions come with error information (mainly a text string describing the reason for failure)

Exceptions must be 'caught'. Unhandled exceptions lead to program aborts.

Exception Handling in Visual Basic / VBA

Each VB function calling COM interface methods must provide the following statement before the first call:

```
On Error GoTo ErrorHandler
```

At the bottom of the function, before the *EndSub* statement, the following (minimal) code block must be inserted:

```
Exit Sub

ErrorHandler:
   MsgBox Err.Description
```

Err.Description is only a default minimal error text (always in English). Of course any other error message of your choice can be displayed.

To get the related error number rather than the default- text, the error handler may look as follows:

```
Exit Sub

ErrorHandler:
    MsgBox (CStr("Error occurred: ") & _
            ObjConnect.LastResultStatus)
```

Use the **LastResultStatus** property! The term **Err.Number** relates to a COM error number, which is usually not of interest for the application.

Alternatively, the number of the last error (LastResultStatus property) can also be retrieved with the TPI command 'GetSystemStatus'.

Additional or different error handling code can be inserted after the *ErrorHandler* label.

Exception Handling in C++

In C++ applications, exception handling is performed through **try/catch** statements. The caught exception is of type *_com_error*.
See Win32API COM documentation for details of *ISupportError* Interface.

```
try
{
    pLTCommandSync->FindReflector(5.0);
}
catch(_com_error &e)
{
    MessageBox("Exception:%s", (LPCTSTR)e.Description());
}
```

e.Description() returns the appropriate default string (same as Err.Description in VB). Try/catch-statements may be nested, and are required when queuing several synchronous commands within one C++ function.

If the error number rather than the (default) text is of interest, use the property **objConnect.LastResultStatus**.

```
try
{
    pLTCommandSync->FindReflector(5.0);
}
catch(_com_error &e)
{
    MessageBox("Error Nr:%d", pLTConnect->LastResultStatus);
}
```

Alternatively, the number of the last error (LastResultStatus property) can also be retrieved with the TPI command 'GetSystemStatus'.

Exception Handling in C#

When using LTControl (COM TPI) with C#, essentially the same concepts as with C++ applies. C# uses a very similar try/catch approach.

Evaluating the Return status

The necessary exception handling precludes evaluation of the return status of the COM method call.

Certain constellations, such as *S_FALSE* return values, may require a distinguished evaluation.

Success return values:

```
S_OK
S_FALSE
```

S_OK is returned for an ordinary success case.

Certain commands may return a TPI result-status of type *Out of Range OK*. Example: *ES_RS_Parameter1OutOfRangeOK.* In this situation, the COM method returns *S_FALSE*. This means that the command (setting) has succeeded, but that its value is out of specified tolerance. In other words, this means just a warning and thus, no exception will be thrown. appropriate status information can be obtained in two different ways:

- Evaluate the property ILTConnect::LastResultStatus.
- Get the error Information (error string) with GetErrorInfo().

Note that there exist only a few commands that may return S_FALSE (For example environment parameter setting commands).

```
BSTR bstrError;
IErrorInfo *pInfo;

HRESULT hr = GetErrorInfo(0, &pInfo);

if(pInfo && SUCCEEDED(pInfo->GetDescription(&bstrError)))
{
  _bstr_t errorString(bstrError);

  pInfo->Release();
} // if
```

Failure return value:

```
E_FAIL
```

In case of any command failure, *E_FAIL* is returned. This automatically leads to an exception (thrown by the COM framework).

5.2.5 COM TPI supporting Programming Languages

- Visual C++

  - All Interfaces supported.

  - User defined TypeLibrary (enum, structs) supported.

  - Event and message notification methods supported.

- **VisualBasic** (VB 6)

  - All interfaces supported.

  - User defined TypeLibrary (enum, structs) supported.

  - Event and WM Message Notification methods supported (Events to be preferred).

- **VisualBasic for Applications** (VBA) (Excel, Word, and Access)

  - All interfaces supported.

  - User defined types of TypeLibrary (enum, structs) supported with Office 2000, but not fully supported with Office 97.

- Event notification methods supported (WM Messages not supported).

- **C# and VB .NET**

  - All interfaces supported.

  - User defined types of TypeLibrary (enum, structs) supported

  - Event notification methods supported

- **Scripting Languages** (VBS, JavaScript)

  Currently not supported. Support of these languages requires 'Dual' or *IDispatch* COM interfaces.

  Could be achieved by providing a COM *IDispatch* wrapper around the LTControls custom interfaces.

- **Delphi**

  - All interfaces supported.

  - User defined types of TypeLibrary (enum, structs) supported

  - Event notification methods supported

It is recommended to use at least Office 2000 or XP for TPI VBA Programming. Office 97 (Excel 97, Word 97) lacks user-defined types (UDT) and contains some bugs that make development of TPI clients virtually impossible, as soon as events are involved.

Interface methods using 'struct' parameters, which do not support UDT (Office 97 only), cannot be used from within VBA. However, functions are available based on basic data types, as a work around.

Older versions of VBA may lack support of enum-type symbols, so they need to be passed as 4 Byte (long) values. Therefore the numerical representation of particular enum values must be known. In C-language TPI, these values are explicitly enumerated.

See *ES_C_API_Def.h* in SDK, for enum definitions. A type library viewer will also show the numerical values.

Example

Enum definition:

```
enum ES_TrackerTemperatureRange
{
   ES_TR_Low,
   ES_TR_Medium,
   ES_TR_High,
   ES_TR_Automatic,
};
```

ES_ TR_Low =0, TR_Medium=1, ES_TR_High=2 and ES_TR_Automatic=3.

- Command in a VB application

```
ObjSync.SetTemperatureRange ES_TR_High
```

- Command in (old version) VBA

```
ObjSync.SetTemperatureRange 2
```

Only use the second approach if the first one is not supported with your programming environment!

5.2.6 Proper Interface Selection

Unlike the C and C++ TPI, the COM TPI is a DLL library and not an include file. This DLL provides an easy to use programming interface for the Tracker Server. This makes it suitable for programmers with minimal programming expertise to design simple tracker applications. The COM TPI also opens doors to programming languages such as VisualBasic, Delphi, C#, VB.NET, VBA (Office Macro Languages) etc.

The interface is made- up of a so-called COM component. It is designed as an *ATL DLL COM* server. The DLL is named '*LTControl.dll'* and comes as part of the emScon SDK. LTControl provides built-in TCP/IP communication.

The LTControl COM-object DLL is based on the tracker server C++ TPI, the Win32 Sockets 2.0 API and VC++ ATL. The *LTControl.dll* is, in a sense, a Tracker Server C++ Client. However it acts as Server from applications (based on LTControl) point of view.

The programmer is not required to deal with TCP/IP communication libraries or system programming interfaces.

The high-level TPI supports both synchronous and asynchronous methods.
Note: Using the 'synchronous' interface may provide some convenient properties. However, there are also some disadvantages: Long- taking actions cannot be interrupted (FindReflector, OrientToGravity..), as this is possible with asynchronous communication on using 'StopMeasurement' command. Synchronous commands also imply potential timeouts.
The COM component is binary and thus also lacks transparency. Other than with the C/C++ interface, **no debugging down to the source level is possible**. For highly professional applications, we rather recommend programming in C++ or C#, hence using the C++ or C# interface directly (which are asynchronous be design).

COM objects expose 'interfaces', described by a Type-Library, which is implicitly included in the DLL. A pure Type Library *LTControl.tlb* is also available, although not really needed. This High-level interface does not provide any additional functions (in terms of Tracker Server controlling functions). *LTControl* is strictly based on the C++-TPI, with a high-level, convenient programming interface.

COM interfaces work well together with Visual Basic, Delphi and Office Macro programming languages (VBA) on the Win32 platform, while using the emScon C or C++ interface is difficult for those types of languages.

Advantages	Disadvantages
No include-file to deal with on using COM TPI.	Comes as a DLL (binary). Its source code is not public. Lacks full transparency and complicates application debugging.
No TCP/IP library or function needs to be provided. All these functions are built-in. Only the IP address of the tracker server needs to be provided.	Is limited to Win32 platforms.
The COM interface offers both synchronous (to a certain degree) and asynchronous communication support.	Due to COM overhead, the performance may be affected.
There are wide varieties of notification methods for arrival data when using asynchronous communication.	Since TCP/IP communication is built-in, there are no 'tuning' possibilities.
Supports various programming languages. Easy to use due to support of 'IntelliSense' for Microsoft Visual and Office programming tools.	The component needs to be registered on the client PC.

Interfaces and Notification Methods

See chapter 'COM Interface' for more information on the interfaces provided.

5.2.7 Type- Library

In order to get detailed information about the Interfaces (including data types, properties, methods and events) exposed by a COM object, a COM viewer may be used. Visual Studio offers such a viewer: The OLE/COM Object Viewer can be launched from the *Tools* menu of VC++.

File > View Type Lib > LTControl.dll or LTControl.tlb.

5.2.8 COM TPI Reference

The type library of a COM object can be seen as Interface Reference.

Listing all the methods redundantly in this manual would not make sense.

The type library enables a development environment to provide 'IntelliSense' support. That is, the development environment supports the programmer in selecting methods and parameters in an active manner.

The method names of the COM TPI partly differ from those of the C++ interface (Although most of them – especially the 'Set/Get' functions – are named accordingly). This 'inconsistency' comes from the high- level approach of certain methods. However, by viewing the list of available functions (type- library, Intellisense), it is quite easy to find the proper methods and their relatives to the C / C++ interface (where the parameters are described).

Note that asynchronous methods never return any data. Data is returned through events in these cases. On the other hand, synchronous methods always return the result data (if any) as parameters.

Concerning input parameters (sent to the tracker server), there is no difference between the synchronous and asynchronous approach.

Note: The event [id(76), "SystemParameterData"] of the interface _ILTCommandAsyncEvents should no longer be used. For new applications,

use [id(80), "LongSystemParameterData"] instead.
The former one is only kept to ensure compatibility to existing applications.
Old and new event only differ by name (and dispatch ID). The parameter list remains unchanged. The reason for the name change is to avoid a mess-up with the newly introduced event "DoubleSystemParameterData".

5.2.9 Registering COM Objects

COM objects must be registered on the application PC before they can be used. For details refer to the 'Readme.txt' file that comes with the SDK (Lib folder)

5.2.10 Synchronous versus Asynchronous Interface

When designing a client application using the LTControl COM component, either the synchronous or asynchronous interface can be used.

Differences between the synchronous and asynchronous interface.

- The functions of the synchronous interface do not return before the task is completed, while the asynchronous functions do so (see C/C++-TPI).
- In general, programming with synchronous functions is much easier. Handling *Data-Arrival Events* or *Notifications* is not required (except in some special cases).
- With the asynchronous interface and the events notification (that is, calling *SelectNotificationMethod* with *LTC_NM_Event*), an Event- Sink must be implemented. In VB, this is done by defining the *WithEvents* keyword, but in C++ this is a bit more complicated. In addition, the appropriate event handlers must be

implemented.
With any other notification mechanism, the event sink is not required and the *WithEvents* keyword must be removed. Implement Windows Message handlers, not Event handlers, in this case.

- With the synchronous interface, some answers remain asynchronous by their nature - *continuous measurement packets*, *Reflectors* and *error answers* (these may partly occur non-command related, for example *beam broken*).
  With synchronous commands, events or notifications must still be caught - See former paragraph. Any other notification mechanism does not need an event sink, and the *WithEvents* keyword must be removed. In this case, do not implement Event handlers; appropriate Windows Message handlers must be implemented instead.
- Using both interfaces in the same LTConnect instance – although possible – usually makes no sense and partly leads to duplicate answers. Use of both interfaces within one and the same application is therefore not recommended.

5.2.11 Visual Basic Boolean variable evaluation

- Do not test explicitly against the VB keyword '**True**' when using ***Get<FunctionName>Ex*** methods of the LTControl, for those commands returning Boolean data within their result structure. This is because the Boolean member in these structures, if true, is one (1). However, the VB keyword 'True' evaluates to (-1). Always test the variable as a logical expression, or against 'Not False'.

Example

```
ObjSync.GetContinuousDistanceModeParamsEx dataout

If (dataout.bUseRegion) Then     '(tested as logical expression)
    MsgBox "bUseRegion is True"
End If

or

If Not (dataout.bUseRegion = False) Then
    MsgBox "bUseRegion is True"
End If

are both correct. However, the following would evaluate to a
wrong result:

If (dataout.bUseRegion = True) Then
    MsgBox "bUseRegion is True"  'No message even flag true!
End If
```

5.2.12 Reading Data Blocks with Visual Basic

Arrival data reading with C++, as shown in 'Handling Data Arrival – Continuous Measurements', can also be ported to VB. *Events* for VB are used here, with unique events for almost every type of arrival data (especially when using the asynchronous interface). Most of these pass their results through basic data type parameters.

See chapter 'Handling Data Arrival – Continuous Measurements'. See also Sample 13.

Message notification methods with VB are not demonstrated here.

However, there are some exceptions where the data must be retrieved explicitly upon an incoming event. These types of events can be identified by the *DataReady* term in their names. The continuous measurement *events* are among these.

The code below shows an implementation of the *ContinuousPointMeasDataReady()* event handler. It does not demonstrate the processing of the data received. This handler does some diagnostics – checks whether the size of read data complies with the passed parameter. If OK, the size is displayed, otherwise an error message is shown.

By calling the *ObjConnectGetData()* function, the arrived data (that caused the *event*) is being read into a local buffer. The application interprets and processes the data. In order to get the measurement values, loop through the array and interpret the array elements with *MeasValueT* (not shown here).

VB may not be the right choice to process (high rate) continuous measurements, especially when running the interpreter. The VB project must be compiled first.

```
Private Sub ObjAsync_ContinuousPointMeasDataReady( _
                                  ByVal resultsTotal As Long, _
                                  ByVal bytesTotal As Long)
    Dim data As Variant
    Dim tp As VbVarType
    Dim sz As Long

    ObjConnect.GetData data
    tp = VarType(data) ' type; we expect a Byte arryay

    If (tp = vbArray + vbByte) Then ' Byte Array
        sz = UBound(data) + 1  ' index is zero based!

        If (bytesTotal = sz) Then
            MsgBox sz 'display # of bytes received
        Else
            MsgBox CStr("Unexpected size:") & sz _
            & CStr(", expected:") & bytesTotal
        End If

     End If
End Sub
```

It is not necessary to read data here (with GetData). Answers may be filtered out and only those data packets of interest can be read.
With TCP/IP data must be read at socket level (see previous samples) otherwise no notification will arrive again.

The principles shown here also apply to message handlers, if one of the message notification mechanisms is selected.

See chapter 'Answers from Tracker Server' on how to mask/evaluate incoming data blocks.

5.2.13 VBA Macro-Language Support

Excel, Word, Access

The *LTControl* COM component can also be used with VBA (Visual Basic for Applications), the built-in Macro language of MS Excel, Word and Access – with the exception that *structs* and *enums* are not fully supported with VBA that comes with Office 97. 'Ex' functions that take struct parameters cannot be used. VBA that comes with Office 2000 no longer has such limitations.

It is highly recommended to use Office 2000 or higher for Tracker Server VBA Programming. Office 97 (Excel 97/Word 97) - apart from a missing UDT - contain some bugs that make development of Tracker Server clients virtually impossible, as soon as *events* are involved. This bug leads to a completely corrupted file upon file saving, after an event has arrived.

For this reason, Excel samples delivered with the TPI-SDK are in Excel 2000 format. They may run with Excel 97 , but may be destroyed as soon as any changes are saved. Always maintain a safe (read-only) copy.

The following remarks only apply to Office 97 programming (Office 2000 VBA behaves as ordinary VB).

User-defined Types, the Differences between Visual Basic and VBA97

- Both allow defining user-defined *structs* locally. However, those *structs* exported by the LTControl (such as *PacketHeaderT*, *SingleMeasResultT*) are only recognized from within Visual Basic. VBA claims an error *Automation type not supported* if declaring, for example, a variable like:

```
Dim val As SingleMeasResultT // works with VB, but not VBA97
```

- Enums are not supported by VBA97. The compiler does not know the keyword *Enum*. User-defined *enums* cannot be defined locally, although this works with ordinary Visual Basic. It is also not possible to use *enum*- type variables that are exported by the

LTControl. Declaration as follows are not possible in VBA97:

```
Dim cmd as ES_Command   // works with VB, but not VBA97
```

- When implementing an *EventHandler* that has *enum-type* parameters in Visual Basic will read as follows (only function header shown):

```
Private Sub CommandSync_ErrorEvent( _
                 ByVal command As LTCONTROLLib.ES_Command, _
                 ByVal status As LTCONTROLLib.ES_ResultStatus)
```

- When doing the same in VBA97 it will read as follows:

```
Private Sub CommandSync_ErrorEvent(ByVal command As Long, _
                                   ByVal status As Long)
```

Visual Basic keeps the enum type information and recognizes the parameters with their correct *enum- types,* while VBA just passes them as long parameters.
However, the symbols of the *enum* values are correctly recognized, although not checked by the compiler for correct typing (which can lead to errors, which are difficult to find).
This problem is not specific to VBA, it also exists in VB. There are two different situations where *enums* and their value-symbols affect the interface:

Method takes enum type parameters, for example, call *SetMeasurementMode* the same way for both VB and VBA:

```
ObjSync.SetMeasurementMode ES_MM_ContinuousDistance
```

1. *ES_MM_ContinuousDistance* will be correctly recognized as having the value '2' (see *enum* definition).

2. Correct typing of values: VB as well as the VBA interpreter will not recognize typing errors in *enum* symbols here. However, both VB and VBA provide 'IntelliSense', providing for a selection from a list rather than having to type them in.

3. *Event* handlers, as we have seen above, pass *enums* as long values in VBA. The

incoming values can be tested against *enum* symbols. In an event handler, the following code might be typical (example *ErrorEvent* in VBA):

```
Private Sub CommandSync_ErrorEvent(ByVal command As Long, _
                                   ByVal status As Long)
If (command = ES_C_Initialize) Then
   ' do something
End If

If (status = ES_RS_NoTPFound) Then
   ' do something
End If
End Sub
```

Use extreme caution while typing the symbols with VBA 97. No 'IntelliSense' support is available.

Summary

- There is no problem with enums and VBA97. It is just a potential error source due to missing type checking.
- Structs (unless locally defined) are not supported in VBA97. LTControl always offers an alternative to those functions returning struct parameters.
- None of the e*vent* functions has *struct* parameters (technical restriction), and have, therefore, no restriction with VBA97.

5.2.14 Continuous measurements and VBA

Events of continuous measurements do not directly pass the data.

See chapter 'Handling Data Arrival – Continuous Measurements ' for details.

Handling continuous measurements within VBA requires care. *Events* can be 'subscribed' with the *WithEvent* keyword and pending data can be read with *GetData()*, as shown in:

See chapter 'Reading Data Blocks with Visual Basic' for details. Also see Sample 13 for a working code example.

Masking Data

The unavailability of (LTControl) structures in VBA prevents masking the data. With the byte-layout of the data blocks, the appropriate bytes can be extracted 'manually' and assigned to basic data types.
This is not convenient and exceeds the typical Excel programmer's expertise.

Even with VB, although *structs* are available, masking data is not as easy as in C++. By providing some helper functions, data blocks can be copied to appropriate *struct* parameters instead of using pointer type-casts:

```
ILTConnect::ContinuousDataGetHeaderInfo()
ILTConnect::ContinuousPointGetAt()
ILTConnect::ContinuousPoint2GetAt()
ILTConnect::Continuous6DDataGetAt()
```

This allows extracting information of interest from data blocks of type *ES_DT_MultiMeasResult*, *ES_DT_MultiMeasResult2* and *ES_DT_Multi6DMeasResult*.

A VB (VBA) implementation of the *ContinuousPointMeasDataReady* event handler that demonstrates usage of these functions reads as follows (note the many comments):

```
Private Sub LtSync_ContinuousPointMeasDataReady ( _
         ByVal resultsTotal As Long, ByVal bytesTotal As Long)

    ' a continuous point meas packet came in. Note that in
    ' case of continuous measurements (due to multiple points /
    ' variable size of packet) only # of results and packet size
    ' are passed in (which both are not really needed here)
    ' So we first must GET the data, then retrieve information
    ' out of the gotten block.

    ' since we are doing function calls to a COM object
    ' (LtConnect) that can throw exceptions, we need an error
    ' handler. Note we would not require an error handler in the
    ' other Event Handlers (LtSync_ReflectorsData,
    ' LtSync_ReflectorPositionData) because (usually) no COM
    ' functions are called there subsequently

    On Error GoTo ErrorHandler

    ' 1. Get the data

    Dim data As Variant
    ObjConnect.GetData data

    ' 2. Get header info. Calling this function is optional.
    ' the only thing we need here is numResults. However,
    ' it's the same as resultsTotal passed to the functions.

    Dim numResults As Long
    Dim measMode As Long
    Dim temperture As Double
    Dim pressure As Double
    Dim humidity As Double
    Dim mstatus As ES_MeasurementStatus
    Dim time1 As Long
    Dim time2 As Long
    Dim dVal1 As Double
    Dim dVal2 As Double
    Dim dVal3 As Double

    ObjConnect.ContinuousDataGetHeaderInfo data, numResults, _
            measMode, temperture, pressure, humidity, False

    ' since we have numResults twice from different paths, lets
    ' check them for compliance!

    If Not (numResults = resultsTotal) Then
       MsgBox "Fatal Error - unexpected discrepancy"
    End If

    ' since we know how many results, we can loop over the index
    ' Note that index runs form 0 to numResults - 1

    For Index = 0 To numResults - 1

        ' data and index are input parameters, rest  output

        ObjConnect.ContinuousPointGetAt data, Index, mstatus, _
                           time1, time2, dVal1, dVal2, dVal3

        ' TODO: do something with each result here

    Next

    Exit Sub
ErrorHandler:
    MsgBox Err.Description
End Sub
```

ContinuousPointGetAt()/Continuous6DDataGetAt() may have an impact on performance. They have been primarily designed for use with VB(A). For C++ applications, more efficient ways to extract continuous measurements exist.

VBA applications, depending on data processing, may not have enough performance when using continuous high data rates. Always run compiled versions. In special cases the incoming results need to be buffered.

Use of values instead of symbols, in Visual Basic, avoids the problem of typing incorrect *enum* symbols, which cause errors difficult to detect.

A complete *.tlh* file is automatically generated when importing *LTControl.tlb* into a VC++ project.

5.2.15 Scripting Language Support

Pure scripting languages VBS (Visual Basic Script), JavaScript etc. are currently not supported by the LTControl COM component.

This would require *IDispatch* interfaces rather than custom interfaces. Combinations of *IDispatch* and custom interfaces (dual interfaces) have the same disadvantage as *IDispatch* – lack of performance.

5.2.16 Exception Handling for Non-Microsoft Clients

The emScon LTControl COM interface also supports Windows application development with some Non- Microsoft Tools, such as Borland Delphi.

For such applications, it may be necessary to set the **property** 'LTConnect::ExceptionHandlingPolicy' to 1 (Before connecting to emScon server). Otherwise exceptions may not be raised in the client application.
Do not set this property for Microsoft clients (VB, C++, C#, Excel..), that is, leave its default value 0.

For further information, see commented code in Sample 20 (LtcDelphiClient), where this property is set to 1.

Example (Delphi):

```
LTConnect.Set_ExceptionHandlingPolicy(1);
```

5.2.17 Multi- Tracker Applications

For multi tracker applications, create a separate instance of 'LTConnect' for each tracker/ controller.
For **single-threaded** applications, the usage of the **asynchronous** interface is compulsory in order to allow 'parallel' control of multiple trackers.
If using the **synchronous** interface, the application will not be able to do parallel calls to multiple trackers! That means the application waits for pending answers from any tracker before another command (to the same or another tracker) can be issued.
As an example, consider a 2-tracker application using the synchronous interface that wants to initialize both trackers upon startup. With a single- threaded approach, initialization can only be performed for one tracker after another.
Especially for long-time taking commands like 'Initialize', it would of course be convenient to execute this command in parallel for both trackers. In order to do so, the application must provide a separate thread for every instance of the LTControl/LTConnect.
Note that LTControl is designed to run in so-called 'Apartment Threaded' context. For details about this, refer to Microsoft documentation.
For our purpose, there is no need to go too far into details; we just provide some code-fragments in order to illustrate how multithreaded applications (using the LTControl) have to be set-up (for different programming languages).

Using COM Control for Multi- Tracker Support in C++

Take Sample 7 (C++ application using the emScon COM- interface) as a basis. Consider we'd like to extend this application in order to control a 2nd tracker in parallel.
Any C++ application using COM needs to make a

COM initialization call prior to use any COM object. This usually happens in InitInstance(). So does Sample 7. See 'CoInitialize(NULL)' in CCPPClientApp::InitInstance() (As it does CoUninitialize() upon exit).
It is important to notice that this COM initialization will **only be effective for the main-thread**; it will **not apply to any child-thread**!
In order to take full advantage of the synchronous interface, we must instantiate a 2nd instance of LTControl in a 2nd thread. This will only succeed after having called 'CoInitialize(NULL)' within this new thread!
Note that - due to thread protection reasons - it is not possible to instantiate a 2nd LTConnect/SyncInterface in the main thread and then call methods from the worker function of a child-thread; the **instantiation itself must occur in the 2nd threads worker function**.
Typically, for an application like Sample 7, the following steps will be required to add support for a 2nd tracker:

In the class 'CCPPClientDlg' (header file), add a declaration for the (secondary) thread worker function (must be a static member):

```
static UINT SecondTrackerThread(LPVOID pParam);
```

Next, implement the worker function in related .cpp file:

```
UINT CCPPClientDlg::SecondTrackerThread(void *pParam)
{
  // Do not declare/instantiate these in main thread.
  // These must be local to the current thread!
  //
  ILTConnectPtr pLTConnect2;
  ILTCommandSyncPtr pLTCommandSync2;
  CLtcCppEventSink *pEventSink2 = NULL;

  CoInitialize(NULL); // IMPORTANT - call this for every thread
                      // where ILTConnectPtr is instantiated!

  CCPPClientDlg *dlg = (CCPPClientDlg*)pParam;

  TRACE(_T("Thread for 2nd tracker started"));

  // 1. Initialization part (instantiation and connection)

  try
  {
    pLTConnect2.CreateInstance(__uuidof(LTConnect));

    pLTConnect2->SelectNotificationMethod(LTC_NM_Event, 0, 0);

    // attach Sync object
    pLTCommandSync2 = pLTConnect2->GetILTCommandSync();

    if (pLTCommandSync2)
    {
      // The following (commented) block sets up the event-sink
      // for tracker 2. However, we first would have to
      // implement class CLtcCppEventSink2 (note that
      // event sink CLtcCppEventSink from Sample 7 is not
      // suitable to use with tracker 2 in this sample).
      // You may of course design a common event sink that
      // can be shared for both trackers (i.e. both trackers
      // may have an instance of the same event sink class)
      // Be careful with thread safety issues when accessing
      // main- thread context (GUI!) from secondary thread
      // from within a shared event sink!

      /***
      // Comments see related code in main thread of Sample 7

      pEventSink2 = new CLtcCppEventSink2();

      LPUNKNOWN pUnkSink = pEventSink2->GetIDispatch(FALSE);

      DWORD dwCookie = 0;
      VERIFY(AfxConnectionAdvise(pLTCommandSync2,
                                 DIID__ILTCommandSyncEvents,
                                 pUnkSink, FALSE, &dwCookie));

      pEventSink2->SetConnectPtr(pLTConnect2);
      ***/
    } // if

    // hardcoded arbitrary address due sample code.
    // Adjust to your controllers address, use variable
    // and pass for example from user- interface
    //
    pLTConnect2->ConnectEmbeddedSystem("10.62.35.53", 700);
  }
  catch(_com_error &e)
  {
    TRACE(_T("Exception:%s \n"), (LPCTSTR)e.Description());

    ES_ResultStatus rs = ES_RS_Unknown;

    if (pLTConnect2)
    {
      rs = pLTConnect2->GetLastResultStatus();

      CString s;
      s.Format(_T("%s [Status %d]"),
               (LPCTSTR)e.Description(), rs);
                AfxMessageBox(s);
    }
    else
      AfxMessageBox(
       _T("LTControl not loaded - Missing or not registered?"));
  }


  // 2. Worker part ('endless' loop)

  for (;;)
  {
```

```
    // Just sample code - of course it does not make sense to
    // continuously call change Face, but we just want to
    // demonstrate that tracker 1 be controlled independently
    // from tracker 2, even while tracker2 is continuously busy

    // A real application would provide a parser here (still
    // within an endless loop) for user-interface commands
    // dedicated to tracker 2.
    // Note that as soon as we would leave this function, the
    // thread dies and connection to 2nd tracker gets lost!
    // A real application needs a correct thread termination
    // mechanism and should do cleanup tasks for the
    // instantiated interfaces and objects

    TRACE(_T("ChangeFace\n"));

    pLTCommandSync2->ChangeFace();
  } // for

  return (0); // never be reached in this sample! - in a real
              // application, the for() loop would have a thread
              // control flag that would cause to exit the loop
              // if flag status changes
} // SecondTrackerThread()
```

Finally, we must start the thread. This is done most likely at the end of the main dialogs OnInitDialog() member function:

```
  ...
  HANDLE hSecondTrackerThreadHandle = 0;

  hSecondTrackerThreadHandle =
    (HANDLE)AfxBeginThread(SecondTrackerThread, this);

  if (hSecondTrackerThreadHandle == 0)
  {
    TRACE (_T("Failed to start thread for 2nd tracker\n"));
    return FALSE;
  }
  ...
```

Note that the shown code- fragments only contain essential stuff. A real application would probably do extra error diagnostic and of course more proper thread termination and cleanup tasks.

Important: The shown code fragments do not yet include implementation of an **event sink** to receive data from the 2nd tracker (see commented block in the code above!) The existing event sink for tracker 1 cannot be shared for use with tracker 2! We either need a separate event sink for tracker 2, or we would have to make some adjustments to the provided Sample 7 code in order to share it for a 2nd tracker.
In particular, a common event sink must make sure there is no direct access to main-thread context (GUI!) from within its event handlers.

Otherwise this would lead to access violations if these event handlers were being triggered by the 2nd thread.
As far as we just do endless calls of synchronous functions (i.e. 'ChangeFace' in our sample), receiving data trough events may not be an issue for the 2nd thread. (But even when only using synchronous calls, an event sink at least for unsolicited errors and events - such as 'beam break' - should be provided anyway!)
The simplest approach was to duplicate the class 'CLtcCppEventSink' (Sample 7, files LtcCPPEventSink.h /cpp) for a new class 'CLtcCppEventSink2' (especially if 2nd tracker supports a different set of commands being called and therefore applies to a different set of event handlers).
Using the same event sink class for both trackers (i.e. two instances of the one and only class 'CLtcCppEventSink') is possible, but again, be careful concerning thread protection and shared data issues etc. There are many potential pitfalls to this respect!

Remark: Due to adding 2nd tracker support to an existing single tracker sample 'after the fact', we have resulted into a 'code- asymmetry'.
A cleaner design could be achieved by using 3 threads: The main thread for user- interface issues only and two (symmetrically- designed) child- threads, one for each of the two trackers. This model easily extends to any number of trackers.

Summary: For making **synchronous** calls to two trackers in **parallel** from within a C++ application, two instances of LTControl need to run in their own threads. It is important to call CoInitialize() for both threads! Both threads need their own independent instances of data-

receiving event-sinks.
Multi-threading can be avoided; it is neither required for issuing commands to two (or more) trackers in parallel when using the asynchronous interface, nor for issuing commands sequentially by using the synchronous interface.

Remember: Despite to its name, the 'synchronous' interface of the 'LTControl' also comprises some asynchronous aspects. This applies to Continuous Measurements, List-type data (e.g. Reflectors, Compensations), and unsolicited events.
As if using the asynchronous interface, it's up to the application to synchronize these calls. Hence make sure that no command is being issued unless the answer of any pending (asynchronous behaving) command has arrived.
Using mixed synchronous and asynchronous communication in combination with multithreading for multiple tracker support may result into quite complex code!

Using COM control for Multi- tracker support in Visual Basic / VBA

Although principally possible, we do not recommend creating multi- threaded Visual Basic (V5 or V6) or VBA applications.
In order to get access to threading functionality within a VB application, lots of functions need to be imported from the Win API since they are not natively available within VB.
Such declarations (or better call it 'code- hacks?) would then typically look like as follows:

```
Declare Function CreateThread Lib "kernel32" (ByVal _
     lpSecurityAttributes As Long, ByVal dwStackSize As Long, _
     ByVal lpStartAddress As Long, ByVal lpParameter As Long, _
     ByVal dwCreationFlags As Long, lpThreadId As Long) _
  As Long

Declare Function CoInitialize Lib "ole32.dll" _
 (dwCoInit As Long) As Long
```

No multi-threading means **no parallel synchronous calls** to multiple trackers! However, you may nevertheless instantiate two (or more) instances of LTControl for two different trackers in your single-threaded VB application. If using the synchronous interface, there is just a restriction that you can issue commands only sequentially to either tracker (for example initialize one tracker after another - not in parallel).
If using the asynchronous interface, even parallel command execution for both trackers is possible without multi- threading. The price to pay is just that all commands need to be synchronized by the application.

Instantiating second instances of COM objects is quite simple within VB: Just duplicate all involved variables and calls. Here are some code-fragments (using the asynchronous interface). See further comments within code- block below:

```
'variables for first tracker
Dim ObjConnect As New LTConnect
Dim WithEvents ObjAsync As LTCommandAsync

'2nd set of variables for 2nd tracker
Dim ObjConnect2 As New LTConnect
Dim WithEvents ObjAsync2 As LTCommandAsync

...

'connect to both trackers/servers
ObjConnect.ConnectEmbeddedSystem "192.168.0.1" 700
ObjConnect2.ConnectEmbeddedSystem "10.62.35.53", 700

ObjConnect.SelectNotificationMethod LTC_NM_Event, 0, 0
ObjConnect2.SelectNotificationMethod LTC_NM_Event, 0, 0

Set ObjAsync = ObjConnect.ILTCommandAsync
Set ObjAsync2 = ObjConnect2.ILTCommandAsync

...

'Trigger a stationary measurement for both trackers (parallel!)
ObjAsync.MeasureStationaryPoint
ObjAsync2.MeasureStationaryPoint

...

'Independent event handlers are required for both trackers.
'Implementation of (function bodies of) these is supported
'by the VB IDE. Do not manually create these! Note that not
'all parameters are listed here (due just sample code fragment)

Private Sub ObjAsync_StationaryPointMeasData(_
                                     ByVal val1 As Double, _
                                     ByVal val2 As Double, ...)
   MsgBox val1 'just display one param
End Sub

Private Sub ObjAsync2_StationaryPointMeasData(_
                                     ByVal val1 As Double, _
                                     ByVal val2 As Double, ...)
   MsgBox val1 'just display one param
End Sub
```

If trying to create a multi-threaded VB application nevertheless, the same rules apply as described above for C++ applications: The second thread needs to call 'CoInitialize()' (for the main-thread, this call for VB applications happens implicitly when referencing COM controls). The COM objects need to be instantiated within the 2nd thread, and event handlers need to be defined independently for both threads.

Using COM control for Multi- tracker support in VB.NET and C#

Addressing COM controls from within VB.NET and C# is simple and does not much differ from the approach used for VB 6.
The same rules as for VB 6 applications apply here: Multi-threading is not required unless one wants to use **synchronous** calls to different

trackers in **parallel**. For all other cases, single threaded applications are sufficient.
Here are some code- fragments showing how to instantiate LTControl within VB.NET and C# respectively. Note that LTControlLib must be added as reference to the VB.NET or C# project in order to get access to it.
Only declarations are shown, and for one tracker only (asynchronous interface); just duplicate variables for a 2nd tracker.
The IDE then provides available methods and properties ('Intellisense') as well as implementation of event handlers even more sophisticated than with VB 6.

```
'VB.NET

Imports LTCONTROLLib

...

Public _LTConnect1 As New LTConnect
Public WithEvents _ObjAsync1 As LTCommandAsync

...

_LTConnect1.ConnectEmbeddedSystem("10.62.34.30", 700)

_LTConnect1.SelectNotificationMethod( _
               LTCONTROLLib.LTC_NotifyMethod.LTC_NM_Event, 0, 0)

_ObjAsync1 = _LTConnect1.ILTCommandAsync

...

'C#

using LTCONTROLLib;

...

LTConnect ltc;
LTCommandAsync async;

...

ltc = new LTConnect();

ltc.ConnectEmbeddedSystem("10.62.34.30", 700);

this.async = (LTCommandAsync)ltc.ILTCommandAsync;

ltc.SelectNotificationMethod(LTC_NotifyMethod.LTC_NM_Event,0,0);

...
```

Other than VB 6 applications, VB.NET and C# natively support multi-threading.
For multithreaded VB.NET and C# applications - which usually only make sense when using synchronous calls for two or more trackers in

parallel - the following important requirement applies: Any secondary thread must call

```
thread.ApartmentState =
                ApartmentState.STA
```

This has essentially the same effect as calling CoInitialize for C++/VB threads; STA stand for 'Single Threaded Apartment'.
All the rest is essentially the same as already discussed for multithreaded C++ applications above. There is a worker function for the secondary thread; Instantiation of LTControl objects for the 2nd thread needs to occur within this function. Hence the code samples below for VB.NET and C# should not leave open any questions.
Note that mainly only 'our' code is shown in VB.NET sample. Missing standard and/or generated code is indicated by "…"
Note that a separate class is required for implementing secondary threads in C#.

```
'VB.NET
'======

Imports LTCONTROLLib
Imports System.Threading

Public Class Form1
...

'Objects for main thread (Form1); 'LTConect1 can be
'instantiated here with 'New' (could also omit the 'New'
'here and instantiate object later)

Public _LTConnect1 As New LTConnect
Public WithEvents _ObjSync1 As LTCommandSync

'Objects for 2nd Thread:
'ATTENTION: If we did a 'New' for _LTConnect2 here, this
'object would be owned by the main thread and we would not
'be able to access it from within the thread worker
'function! (unless you pass it somehow through a parameter
'to the worker function?)

Public _LTConnect2 As LTConnect '(NO 'New'!)
Public WithEvents _ObjSync2 As LTCommandSync

' Thread object
Private _th1 As Thread

Private Sub Form1_Load(ByVal sender As ...)
   On Error GoTo ErrorHandler

   'Form_Load first starts 2nd thread, then does its own tasks
   _th1 = New Thread(AddressOf exeCommandeTh1)

   'This is VERY Important since LTControl runs as STA -
   'Otherwise you will get 'QueryIntrface fails' exceptions
   _th1.ApartmentState = ApartmentState.STA

   _th1.Start() 'start secondary thread


   'connect to first tracker
   _LTConnect1.ConnectEmbeddedSystem("10.62.34.20", 700)
   _LTConnect1.SelectNotificationMethod( _
              LTCONTROLLib.LTC_NotifyMethod.LTC_NM_Event, 0, 0)

   _ObjSync1 = _LTConnect1.ILTCommandSync

   Exit Sub
ErrorHandler:
    MsgBox("Exception in form load (main thread), " + _
           Err.Description)
End Sub


Private Sub exeCommandeTh1() 'secondary thread worker function
   On Error GoTo ErrorHandler

   'create 2nd instance within new thread (not in main thread!)
   _LTConnect2 = New LTCONTROLLib.LTConnect

   'connect to 2nd tracker
   _LTConnect2.ConnectEmbeddedSystem("10.62.35.53", 700)
   _LTConnect2.SelectNotificationMethod( _
              LTCONTROLLib.LTC_NotifyMethod.LTC_NM_Event, 0, 0)

   _ObjSync2 = _LTConnect2.ILTCommandSync

   While (treadRunning)
      'Parse and execute command- input from GUI
      ...

      'ObjSync2.GoBirdBath ' just a sample
   End While

   Exit Sub
ErrorHandler:
    MsgBox("Exception in thread worker function, " + _
           Err.Description)
End Sub


Private Sub _ObjSync1_StatusChangeEvent( _
     ByVal statusChange As LTCONTROLLib.ES_SystemStatusChange) _
     Handles _ObjSync1.StatusChangeEvent
   MsgBox("StatusChangeEvent1")
```

```
End Sub


Private Sub _ObjSync2_StatusChangeEvent( _
     ByVal statusChange As LTCONTROLLib.ES_SystemStatusChange) _
     Handles _ObjSync2.StatusChangeEvent
   MsgBox("StatusChangeEvent2")
End Sub

End Class


----------------------------------------------------------------


// C#
/////

using System.Threading;
using System.Runtime.InteropServices;

...

LTConnect conn1;
LTCommandSync sync1;

private void Form1_Load(object sender, System.EventArgs e)
{
  // In a real application, it would probably not make sense
  // to do all this in the FormLoad method. In particular,
  // connecting would probably happen thru connect handlers
  // (in order to specify address(es) first). Also invoking
  // commands (not to tall of an endless loop!) in FormLoad
  // is an academic approach. Instantiation and subscribing
  // for event handlers however makes sense in FormLoad, as
  // also does starting the secondary thread

  try
  {
    conn1 = new LTConnect();

    // Initialize synchronous interface variable
    this.sync1 = (LTCommandSync)conn1.ILTCommandSync;

    // Note: Despite of using the 'synchronous' interface,
    // we get certain information through events, although
    // events are 'asynchronous' by design.

    // without this we would not get event notifications
    conn1.SelectNotificationMethod(
                            LTC_NotifyMethod.LTC_NM_Event,0,0);

    // So we need to subscribe for every event we are
    // interested in. Here we just subscribe for one event
    // type: status change events
    //
    this.sync1.StatusChangeEvent += new
          _ILTCommandSyncEvents_StatusChangeEventEventHandler(
                                  this.StausChangeEventHandler);


    // start other thread for 2nd tracker
    OtherThread otherThread = new OtherThread();

    // Create the thread object, passing in the ReceiverThread.
    // Receiver method via a ThreadStart delegate. This does
    // not yet start the thread.
    //
    Thread thread = new Thread(
                       new ThreadStart(otherThread.WorkerFunc));

    // IMPORTANT - if missing we get 'QueryInterface failed'
    thread.ApartmentState = ApartmentState.STA;

    // Start the thread
    thread.Start();

    // Put the Main thread to sleep for 100 millisecond
    // to allow secondary thread to become alive (maybe
    // not really needed)
    //
    Thread.Sleep(100);

    // Connect to emScon server of tracker 1 (main thread)
    conn1.ConnectEmbeddedSystem("127.0.0.1", 700);

    // Run commands in main thread - eternal change face does
    // not really make sense, but we want to show parallel
```

```
    // working. see comment at bottom of worker thread function
    //
    while (true)
       sync1.ChangeFace();

    conn1.DisconnectEmbeddedSystem();
  }
  catch(Exception except)
  {
    MessageBox.Show(except.Message);
  }
}

private void StausChangeEventHandler(
                LTCONTROLLib.ES_SystemStatusChange changeEvent)
{
  // handler for status change events; just display to console

   System.Console.WriteLine(
             "StatusChangeEvent(MainThread)={0}", changeEvent);
}

/////////////////////////////////////////////////////////

public class OtherThread
{

LTConnect conn2;
LTCommandSync sync2;

// This method that will be called when the thread is started
public void WorkerFunc()
{
  try
  {
    // comments see corresponding part in main thread
    conn2 = new LTConnect();

    sync2 = (LTCommandSync)conn2.ILTCommandSync;

    conn2.SelectNotificationMethod(
                            LTC_NotifyMethod.LTC_NM_Event,0,0);

     sync2.StatusChangeEvent += new
         _ILTCommandSyncEvents_StatusChangeEventEventHandler(
                                 this.StausChangeEventHandler);

     conn2.ConnectEmbeddedSystem("10.62.35.53", 700);

     // Thread worker loop; here UI commands need to be handled
     // Due to sample nature of this code, just do endless
     // change face of tracker2 (while tracker 1 does the same
     // in parallel. If we started both while in green status,
     // each change face will cause status change events, hence
     // status change event handlers will be called for both
     // trackers (see console output)

     while (true) // endless loop!
         sync2.ChangeFace();

     conn2.DisconnectEmbeddedSystem();
  }
  catch(Exception except)
  {
    MessageBox.Show(except.Message);
  }
}

private void StausChangeEventHandler(
                 LTCONTROLLib.ES_SystemStatusChange changeEvent)
{
  // handler for status change events; just display to console
  System.Console.WriteLine(
            "StatusChangeEvent(OtherThread)={0}", changeEvent);
}

} // class OtherThread
```

5.3 COM TPI Samples

5.3.1 Sample 5

This chapter is related to the 'Sample5' folder of the emScon SDK Samples.

Sample 5 (*LtcVBClient*) comes as an LTControl-based Visual Basic emScon Client.

Note: 'LTControl.dll' must be correctly registered before proceeding.

See chapter 'LTControl.dll Installation' for details.

If LTControl is correctly registered, 'LtcVBClient.vbp' can directly be opened with Visual Basic Studio. It should be ready to compile and run.

In order to create a Sample 5- type application from scratch, follow the steps:

- Launch Visual Basic 6.0, choose *New Project > Standard exe*. Click *OK*.
- Save the default Form1 as *LtcVBClient.frm* and the project as *LtcVBClient.vbp* (or use any name of your choice).
- Choose menu *Project > References.*
- In the 'Available References' list, look for the entry '*LTControl 2.x Type Library'* and check the box in front of.
  Ensure that the file path at the bottom of the dialog matches the control's registration location. Otherwise browse for the correct location.
  Finally click *OK*.

Accessing COM Interfaces

Other than ActiveX (OCX) controls, *LTControl.dll,* which is an ATL-type COM object, can also be used for non-window based applications. For example, it will also support, pure C-clients (console applications).

It is neither necessary nor possible to place an *LTControl* control object to the VB application

Form (as *ActiveX* controls require).

Interface Variable Declaration

- To access LTControl's interfaces, an object variable of type *LTConnect* is needed in the 'General' declaration part of the code behind the application form. Note the essential keyword 'New':

```
Dim ObjConnect As New LTConnect
```

- Just after that, declare an object for each one of the shown types. Note the keyword 'WithEvents'.(In a real application, **only one - either a synchronous or an asynchronous interface –** should be declared. Declaring both, as done here for demonstration purposes, could result in some duplicate data arrivals and other confusion).

```
Dim WithEvents ObjAsync As LTCommandAsync
Dim WithEvents ObjSync As LTCommandSync
```

Connecting / Disconnecting to Server and Initialization Tasks

A variable of *LTConnect* object is always required, whereas, in a real application, only one of the *LTCommandSync* or *LTCommandAsync* objects is required. Depending on the selected notification mechanism, *LTCommandAsync* or *LTCommandSync* is to be declared with/without event support (*WithEvents* keyword).

The *LTCommandSync* and *LTCommandAsync* variables act like 'pointers'. These 'pointers' must be initialized with the related properties of *LTConnect:*

- Just after calling the ObjConnect.ConnectEmbeddedSystem() method, initialize the 'pointers' as shown below (In the sample, this is done in the event handler of the 'Connect' button). Further, the notification method must be selected (SelectNotificationMethod ()).

- COM methods throw exceptions in case of failure. The sample code shown below shows how to handle these (On Error GoTo...). It's highly recommended to wrap every COM-method calling function with an 'On Error Got Error Handler' statement. Do not forget the 'Exit Sub' statement just before the 'ErrorHandler' label.

Here is a 'stripped down' version of the Samples' 'Connect' handler. It shows only the essential steps.
See Sample code for a more sophisticated 'Connect' handler (with getting the IP address from user- interface etc.)

```
Private Sub Button_Connect_Click()
    On Error GoTo ErrorHandler

    ObjConnect.ConnectEmbeddedSystem "192.168.0.1", 700

    ' This is important if events want to be received
    ObjConnect.SelectNotificationMethod LTC_NM_Event, 0, 0

    ' NEVER FORGET to initialize the objects this way !!!!!
    Set ObjSync = ObjConnect.ILTCommandSync
    Set ObjAsync = ObjConnect.ILTCommandAsync

    Exit Sub
ErrorHandler:
    MsgBox (Err.Description)
End Sub
```

The *End* statement in the error case exits the application, when connection to the tracker server has failed.

To disconnect from Tracker Server use a handler as shown below (Only essential code is shown):

```
Private Sub Button_Disconnect_Click()
    ObjConnect.DisconnectEmbeddedSystem
End Sub
```

See Sample 7 for an explanation of the call '*SelectNotificationMethod LTC_NM_Event, 0, 0'*. However, for VisualBasic applications, it usually does not make sense to call this method with other parameters.

Implementing Synchronous Commands

Add a button named *InitSync*. The button handler should be completed with the following code:

```
Private Sub InitSync_Click()
    On Error GoTo ErrorHandler

    ObjSync.Initialize

    Exit Sub
  ErrorHandler:
    MsgBox (Err.Description)
End Sub
```

Since this is a synchronous call:

- *ObjSync.Initialize* will not return before the tracker has finished initializing.
- The *Exit Sub* statement will not be reached until initialization is finished. A real application would at least display an hourglass cursor while the program resides in the *InitSync* function.

The error handler should be implemented in every command (button) handler, otherwise the application will terminate in case of an error (unhanded exception).

Add another Button/Handler *Measure Single Point* and implement the handler as shown below. It is presumed the tracker server is set to 'stationary' when triggering this command (In Sample 5 code, this is ensured in the Button_Connect_Click() handler'. Of course the laser beam must be attached to a reflector in order to perform this command successfully. The result – since a synchronous answer – can be shown directly in a message box (only x, y and z are shown).

```
Private Sub StartMeas_Click()
    Dim x As Double
    Dim y As Double
    Dim z As Double
    Dim d As Double 'd is a dummy variable
    Dim b As Boolean

    On Error GoTo ErrorHandler

    ObjSync.MeasureStationaryPoint x, y, z, d, d, _
                                    d, d, d, d, d, d, _
                                    d, d, d, d, d, d, b

    MsgBox (x & CStr(" , ") & y & CStr(" , ") & z)

    Exit Sub
ErrorHandler:
    MsgBox (Err.Description)
End Sub
```

If this command was an asynchronous call, it would not be possible to display the result within this function. A result display is performed in the appropriate asynchronous answer handler.

For more details, refer to Sample 5 source code.

Implementing Asynchronous Commands

Visual Basic with 'IntelliSense' provides support for the available functions of an interface with the function parameters.

Add a button named *InitAsync*.

The command handler should be completed with the following code:

```
Private Sub InitAsync_Click()
    On Error GoTo ErrorHandler

    ObjAsync.Initialize

    Exit Sub
ErrorHandler:
    MsgBox (Err.Description)
End Sub
```

In contrast to the synchronous initialize function, this one does not stop at the *Initialize()* function, *Exit Sub* is reached immediately. When tracker initialization is done, a notification or event is sent.

Catching Events and Messages

For asynchronous commands, the answers must be handled by some event mechanism. This could be *Events*, *Windows Messages* (custom window-bound, registered, WM_COPYDATA).
For Visual Basic, *Events* are the right choice. The event mechanism is provided by the *_ILTCommandAsyncEvents* interface, which is a subsidiary of *ILTCommandAsync*. To activate this mechanism for a Visual Basic application, we provided the keyword *WithEvents* upon the declaration:

```
Dim WithEvents ObjAsync As LTCommandAsync
```

When no requirements for catching events exists, omit the *WithEvents* keywords in order to save overhead.

Not only the asynchronous interface – where absolutely crucial – has an Event interface. Also the synchronous interface has an Event interface, *_ILTCommandSyncEvents*. It is required for receiving continuous measurements and other 'multi- answer' results (such as results to a 'GetReflectors' call), as well as for error messages (such as beam broken events), which cannot be handled synchronous by their nature.

Events are one of the notification methods of the LT Control. When alternatively using Windows messages for asynchronous notifications the keyword *WithEvents* becomes obsolete. Windows messages (instead of Events) may be more appropriate for VC++ clients and will be discussed later. For VisualBasic, Events are always the right choice.

- The application must declare what notification mechanism to use. We did this with the statement shown below. Without calling this function in the initialization part of the application, no notification mechanism will be activated.
  See remarks on continuous measurement in chapter 'Handling Data Arrival – Continuous Measurements'.

```
ObjConnect.SelectNotificationMethod LTC_NM_Event, 0, 0
```

- As soon as the *WithEvents* keyword is declared, the *ObjAsync* object (or whatever the variable is called) is listed in the top **left** list box of the *Form's* source code window.
  Just as an experiment: Remove *WithEvents* and save the code – the list entry will vanish.

- If *ObjAsync* is selected in the list box, a list of all available event handlers is shown in the **right** drop-down list.
- To generate the code framework for an event handler, select it from the right list .

Selecting *ErrorEvent* will generate a function named *ObjAsync_ErrorEvent*. Do this and complete the generated function frame with a message box to read as follows:

```
Private Sub ObjSync_ErrorEvent( _
          ByVal command As LTCONTROLLib.ES_Command, _
          ByVal status As LTCONTROLLib.ES_ResultStatus)
    MsgBox (command & CStr(" , ") & status)
End Sub
```

This event handler will now be triggered, for example on a Beam Broken Event.

Note: The 6Dof part of the interface contains some event- types with a huge count of parameters. To mention 'StationaryProbeMeasData', which is the most extreme with 49 parameters (!)

Such excessive parameter lists – depending on VB version - partly are beyond code- generating Wizards capability. Lines may be cut, which will lead to syntax errors (for generated code). In these cases, the cut lines need to be completed manually (see type-library for signature).

Extended Synchronous Functions

ObjSync.MeasurStationaryPoint has 18 (basic data type) parameters. Basic data type parameters are a requirement in order to use these functions with (older versions of) VBA (Excel, Access…).
For programming languages supporting user-defined data types (VC++, Visual Basic), having a function with only one struct parameter would be more convenient. LTControl provides a collection of such 'extended' functions.

Note that such extended functions cannot be provided for Event handlers (Technical limitation)

One of these extended functions, *MeasureStationaryPointEx,* is implemented in the sample:

```
Private Sub StartMeasEx_Click()
    Dim result As SingleMeasResultT

    On Error GoTo ErrorHandler

    ObjSync. MeasureStationaryPointEx result

    ' display the result
    MsgBox(result.packetInfo.status & CStr(" , ") & _
              result.packetInfo.packetHeader.Type & _
              CStr(" , ") & result.dVal1 & CStr(" , ") & _
              result.dVal2 & CStr(" , ") & result.dVal3)

    Exit Sub
ErrorHandler:
    MsgBox (Err.Description)
End Sub
```

The data type *SingleMeasResultT* from the C-TPI is transparent through the COM interface. The VB application 'knows' this type, through its reference to the *LTControl.*

Remark

Do not test explicitly against the VB keyword 'True', if using the *Get<FunctionName>Ex* methods of the LTControl, for those commands returning Boolean data within their result structure. This is because the Boolean member in these structures – if true – are (1). However, the VB keyword 'True' evaluates to (-1).

Always test the variable directly, or against 'Not False'.

Example

```
Dim dataout As ContinuousDistanceModeDataT

ObjSync.GetContinuousDistanceModeParamsEx dataout

If (dataout.bUseRegion) Then
    MsgBox "bUseRegion is True"
End If

or

If Not (dataout.bUseRegion = False) Then
    MsgBox "bUseRegion is True"
End If

are both correct. However, the following would evaluate to a
wrong result:

If (dataout.bUseRegion = True) Then
    MsgBox "bUseRegion is True" ‘ No message even flag is true!
End If
```

Further details see 'Readme.txt' file in Sample 5 folder and code- comments in source files.

5.3.2 Sample 7

The *LtcCPPClient* provides a dialog- based MFC C++ application. It uses the synchronous interface, but also implements an event sink to catch asynchronous answers (continuous measurements and error events).

Programmers need to be familiar with ATL/COM in order to understand the event sink implementation.

Refer to a COM book for further details.

The *LtcCPPClient* covers all essential initial steps for a successful system start and accurate results, with some disabled code, which demonstrates all other variants of notification methods, which may be more familiar to programmers than event handling.

See comments in source code.

Message Notifications

The disadvantages of message notifications are:

- The result parameters cannot be received directly.

- There are only general messages for all types of answers.
- Usually only the size of a data block is passed with the message.
- The data block must be first read with *GetData()* (except for WM_COPYDATA) and then interpreted. Interpretation is done with a 'switch' statement with the *ProcessData()* sample code.

See chapter 'Handling Data Arrival – Continuous Measurements '. See also Sample4 / Step5: This sample uses directly the emScon C++ interface (rather than COM from C++, like Sample7 does)

This sample also shows one of the features not shown so far: How to retrieve the reflectors known to the system. It also demonstrates continuous measurements.

View the source code for details. Note that this code contains a relatively big overhead needed for user interface issues. The Tracker Server specific part is not that dominant.

Source Code Description

- Information that is displayed in list boxes, such as units, CS-type, is automatically read from the Tracker Server upon startup. What is seen has been actually selected.
- Changing the items of one list box automatically creates a 'Set' for the newly selected item.
- On changing units, CS-type etc., some dependent information may vanish from the related edit fields to ensure consistency. This is due to the paradigm 'What you see is selected'. Do a 'Get' to recover it, which can also be done by the application.

- On setting new values, the 'Set' command is automatically followed by a 'Get' (two beep sounds). The 'Get' is not required (only for testing and demonstration purpose).
- Reflectors are read upon client startup. Can be heard by characteristic beeps. They must be selected in the reflectors list box.
  The *GetReflectors* button is only required in 'emergency' cases. If the client starts before the Tracker Server is ready and the client dialog shows up, but is not able to read the reflectors yet.
- The application is based on *LTC_NM_Event* notification selection. By changing the parameter of *SelectNotificationMethod* in *CCPPClientDlg::OnInitDialog()* (all variants are prepared), a different notification method can be activated. However, there is only an incomplete implementation of *ProcessData()* for these alternate methods (reflector processing, for example, is not yet complete).
- Only the *LTC_NM_Event* notification method is fully implemented in this sample. However, data transfer also works with message methods. One or the other methods can be activated by enabling the commented source code.
  Only the last call of *SelectNotificationMethod* is effective (there should be only one call to this function).
  See chapter 'Handling Data Arrival – Continuous Measurements' for details on obtaining data in general and continuous measurements in particular.

Handling Data Arrival – Continuous Measurements

Continuous measurement streams are always handled asynchronous. That is, even if only a *LTCommandSync* is implemented (through which the *Start Measurement* command may be invoked), the continuous measurement packets will arrive asynchronously.

A continuous measurement may last very long. It is not suitable to block execution all the time.

Methods to Catch Packets

- Provide a *LTCommandSync* object with a call to *SelectNotificationMethod,* with *LTC_NM_Event* as first parameter.
  This setting allows catching the continuous measurement packets through the event mechanism. This is especially convenient for Visual Basic.
- Use one of the Windows Messages notification methods.
  See 'Sample 7' – where this method is shown (disabled) in the source code.
  These may be methods preferred with VC++ clients, especially if the programmer is not familiar on setting up event sinks. On the other hand, receiving Windows messages within VB application is permissible.
- The *MultiMeasResultT* structure only covers the first item of the array. The rest of the *lNumberOfResults - 1*-array elements are padded to the packet without gaps.
  Continuous measurement packets mostly contain more than one measurement value. Iteration through an array of measurements is necessary.
- A code fragment, on how to process a continuous measurement packet using the event mechanism, is shown below. This is a client implementation, stripped down and altered from sample 7, of the *ContinuousPointMeasDataReady* event, which exists for both *_ILTCommandSyncEvents* and *_ILTCommandAsyncEvents* interfaces

```
void __stdcall OnContinuousPointDataReady(long resultsTotal,
                                           long bytesTotal)
{
   CString s;
   VARIANT vt;
   VariantInit(&vt);

   if (m_pLTConnect == NULL)
     return;

   m_pLTConnect->GetData(&vt);

   MultiMeasResultT *pData =
                (MultiMeasResultT *)vt.parray->pvData;

   ASSERT(pData->lNumberOfResults == resultsTotal);

   for (int i = 0; i < pData->lNumberOfResults; i++)
   {
      s.Format(_T(" %.7lf, %.7lf, %.7lf"),
         pData->data[i].dVal1,
         pData->data[i].dVal2,
         pData->data[i].dVal3);

      // this is application dependent. May differ in your app
      m_pMainWnd->m_edit_Result.SetWindowText(s);
   } // for
} // OnContinuousPointMeasDataReady()
```

- On using a Windows message notification method, *LTC_NM_WM_Notify*, it looks quite similar. However, with the event method there is a unique event function for just receiving continuous results. With message notify methods, all types of data packets come in through the same message handler. The data must be interpreted with a 'switch' statement. This is done in the *ProcessData()* function. Use of the *CESAPIReceive* class of the C++ interface is another possibility.
- The following implementation demonstrates receiving, not only data of continuous measurements, but also, any kind of data.

```
LRESULT CCPPClientDlg::OnNotifyMsg(WPARAM wParam, LPARAM lParam)
{
   CString s;
   VARIANT vt;
   VariantInit(&vt);
   m_pLTConnect->GetData(&vt);

   // wParam = msg ID = cookie!
   ProcessData(vt.parray->pvData, wParam);

   return true; // return non-zero if msg handled
}
```

- Activating this function calls *SelectNotificationMethod()* with the following parameters:

```
// cookie must be in the valid range for a user defined message
m_pLTConnect->SelectNotificationMethod(LTC_NM_WM_Notify,
                                       (long)m_hWnd,
                                        MY_NOTIFY_MSG);
```

- The message ID (which also acts as a cookie here) is defined as:

```
#define MY_NOTIFY_MSG (WM_USER+99)
```

- Entry in the message map must exist as follows:

```
ON_MESSAGE(MY_NOTIFY_MSG, OnNotifyMsg)
```

- Provide the *ProcessData()* subroutine. Not every type of data packet is fully implemented:

```
void CCPPClientDlg::ProcessData(void *ptr, int nCookie)
{
   CString s, s2;

   PacketHeaderT *pHeader = (PacketHeaderT*)ptr;

   switch (pHeader->type)
   {
      case ES_DT_MultiMeasResult: // most frequent ones on top
      {
         MultiMeasResultT *pData = (MultiMeasResultT *)ptr;

         for (int i = 0; i < pData->lNumberOfResults; i++)
         {
            s.Format(_T("%lf, %lf, %lf"),
                     pData->data[i].dVal1,
                     pData->data[i].dVal2,
                     pData->data[i].dVal3);

            // do something with data -
            // application dependent
            m_staticContMeas.SetWindowText(s);
         } // for
      }
      break;

      case ES_DT_Error:
      {
         ErrorResponseT *pCmdData = (ErrorResponseT *)ptr;

         s.Format(_T("error: command=%d, status=%d\n"),
                  pCmdData->command,
                  pCmdData->status);

         AfxMessageBox(s);
      }
     break;

      case ES_DT_SingleMeasResult:
      {
         SingleMeasResultT *pData = (SingleMeasResultT *)ptr;
         ASSERT(pData->measMode == ES_MM_Stationary);

        // TODO: do something with data
      }
      break;

      case ES_DT_ReflectorPosResult:
      {
          // Not implemented
      }
      break;

      case ES_DT_Command:
         break; // nothing to do

      default:
         Beep(100, 100); // all other data currently unhandled
   } // switch
} // ProcessData()
```

For further details refer to the sample source code.

Limitations for high frequency continuous measurements (like loss of data) may occur due to hardware (LAN, PC performance) limitations. Tests have shown that under good conditions (LAN, PC, Client program design), the LT Control is able to handle the maximum data rate of 1000 points per second, even through the event notification mechanism, which might have slightly less performance than the message methods – Low performance of IDispatch Interfaces.

Further details see 'Readme.txt' file in Sample 7 folder and code- comments in source files.

Handling Continuous Measurements on using the emScon C++ interface directly (which is much more common than using the COM interface from a C++ application) can be found in Sample4/Step5.
Other sources (for VB) can be found in Sample13. See Readme.txt files at the Samples locations.

5.3.3 Sample 8

This sample works only with Excel 2000 and higher, and consists of an Excel sheet with a VBA macro *LtcExcel*. Tracker server client VBA-programming with Excel 97 (Office 97) is not recommended.
See chapter 'VBA Macro-Language Support (Excel, Word, Access) '.

The essential difference between a VB client and an Excel client is that the Excel sheet takes the role of a VB Form. That is, data input/output goes through cells.

Further details see 'Readme.txt' file in Sample 8 folder and code- comments in source files.

5.3.4 Sample 14

This sample shows integration of emScon COM TPI to a C# application. The focus of this sample is on how accessing COM methods from C#. An application just calling SetCameraParams / GetCameraParams (using synchronous interface) may not be very much related to practice.

This sample is preliminary an might be improved in future SDK versions.

Note: In order to build/run this sample, the .NET framework and VisualStudio V7 (VisualStudio.NET) is required.

Further details see 'Readme.txt' file in Sample 14 folder and code- comments in source files.

5.3.5 Sample 15

This sample shows integration of emScon COM TPI to a VB .NET application. The focus of this sample is on how accessing COM methods from VB .NET. The application just demonstrates some system settings.

This sample is preliminary an might be improved in future SDK versions.
Note: In order to build/run this sample, the .NET framework and VisualStudio V7 (VisualStudio.NET) is required.

Further details see 'Readme.txt' file in Sample 15 folder and code- comments in source files.

5.3.6 Sample 18

LiveVideo display application. This sample is based on the 'LTVideo2.ocx' ActiveX COM control.
Attention: emScon 3.0 servers require Version 3.0 'LTVideo2.ocx'. This version of the control is backward compatible to older emScon servers.

See Chapter 8 / Special Functions / Live Image display for details.

5.3.7 Sample 20

Concerning its functionality, this sample is similar to Sample 5, i.e. an LTControl- based client. However, it is based on **Borland Delphi 7** instead of Visual Basic.

If no Delphi 7 programming environment is available, you may download a trial version from Borlands homepage.

For details, refer to the 'Readme.txt' file in the Sample20 folder and to heavily commented code.

6 C# - Interface

6.1 Client Programming with C#

6.1.1 Introduction

The samples 14 and 15 (see chapter 4, COM-Interface) show how to embed the LTControl COM object into C# applications.
However, there is also a C# class- interface similar to the C++ class- interface (shown in Sample16). Using the C# class interface is shown in Sample17.

In order to use this interface, the .NET framework and VisualStudio V7 (VisualStudio.NET) is required for client application programming.

6.1.2 C# Application Programming

The C# class interface is represented through include file 'ES_MCPP_API_Def.h' (MCPP relates to 'Managed C++). This file defines two abstract classes, 'CES**CS**APICommand' and 'CES**CS**APIReceive', from which a C# application must derive its own classes. This is quite the same approach as for the C++ interface.
Note the name prefixes 'CESCSAPI' (C#) versus 'CESAPI' (C++).

Since C# does not support the C++ like 'include-file' approach, the classes defined in 'ES_MCPP_API_Def.h' must be packed into a (Managed C++) DLL. This DLL then can be added as reference to a C# application.

For convenience, this DLL named 'ES_MCPP_API_Wrapper.dll' is also provided with the SDK (ES_SDK\Lib\Unicode).

If the DLL should be missing, or if it needs to be rebuilt due to changes in the 'ES_MCPP_API_Def.h' file, Sample 16 shows how to create this DLL.
(Note: An emScon programmer may make changes to the files 'ES_MCPP_API_Def.h' and/or 'ES_CPP_API_Def.h', although this should normally neither be necessary nor recommended)

Sample 17 shows a C# Application based on the emScon C# class interface.

6.1.3 Sample 16

This sample shows on how to create the required 'ES_MCPP_API_Wrapper.dll' from the 'ES_MCPP_API_Def.h' file.

This is quite simple: There is only one source file 'ES_MCPPAPIWrapper.cpp' which contains nothing else than the statement

```
#include "ES_MCPP_API_Def.h"
```

In addition, some well known emScon C- include files need to be provided in order to compile this project. (ES_C_API_Def.h, Enum.h etc.)

Note that the resulting DLL 'ES_MCPP_API_Wrapper.dll' has already been built and added to the SDK for convenience. It is therefore not really required to build it as shown in Sample16.
However, Sample16 may help developers to debug their applications if code in 'ES_MCPP_API_Def.h' needs to be traced.

Further details see 'Readme.txt' file in Sample 16 folder and code- comments in source files.

6.1.4 Sample 17

This sample implements a C# emScon application based on the C# class interface. The C++ interface cannot be used directly in C# applications. A specific C# class interface is therefore provided as described above.
Note the difference to Samples 14/15, where the emScon COM interface was used. The one and the same COM object ca be used for C++ and C# as well as for visual basic, VBA (e.g. Excel) and VisualBasic.NET applications.

The programming approach is quite the same as for the C++ interface: Derive classes from both, 'CES**CS**APICommand' and 'CES**CS**APIReceive' classes, override the 'SendPacket' virtual function in 'CESCSAPICommand' and override those virtual functions of 'CESCSAPIReceive' in which the application is interested in.

The application must provide Socket communication, and the same conditions as for C++ applications apply: Commands are invoked by calling 'CES**CS**APICommand' member functions and arriving data from the socket must be passed to the 'CES**CS**APIReceive::ReceiveData' Parser. Note that only one packet at a time must be passed to the parser. The sample shows one possible approach: First always peek the packet header, then only read as many bytes as the 'packet- size' variable indicates. The helper method CES**CS**APIReceive::GetPacketHeader() is useful in this context.
There is a difference to the C++ interface concerning continuous measurements. If a continuous packet arrives, it contains only the measurement header info, but not the elementary measurements itself (like in C++ in a variable sized array). The application must rather use the CES**CS**APIReceive :<MeasType>MeasValueGetA () function to access the measurements.

See code in sample 17 (file 'EmsyCSApiConsoleClient.cs'), for example in function 'OnMultiMeasurementAnswer()' for details.

As already known from C++ samples, sample 17 requires a separate Receiver Thread since it is a Console application. In Windows applications, the Window Message Loop can be used instead. Hence windows application do not require to be designed as multi threaded applications. See related C++ Windows emScon applications.

Make sure the 'ES_MCPP_API_Wrapper.dll' is added as reference to the project and that the reference path points to the correct location. (Sample 17 expects the DLL being in the applications runtime directory. However, this may be changed of course).

Sample 17 in not sophisticated in terms of error /exception handling and command synchronization. Remember that emScon commands are asynchronous and it is the applications responsibility not to send a new command to the server before the previous one has completed.

Answer- handlers (virtual overrides) for all types of answers are implemented.
Also calls for all emScon commands are implemented, but all except one are commented in the sample code (any other call may be enabled instead). Due lack of synchronization, the provided sample application will mostly mess-up if sending more than one command.

The most simple way to synchronize the application was providing an old- style key-press user- interface (as done in Sample 9). This means the user performs synchronization by not pressing the next key before the answer of the previous command has arrived.

See also the many comments in the code.
This sample is preliminary an might be improved in future SDK versions.

Further details see 'Readme.txt' file in Sample 17 folder and code- comments in source files.

6.1.5 Multi- Tracker C# Applications

Applications based on the 'native' C# emScon interface behave much the same like applications based on the native C++ interface. The approach for multi-tracker controlling is therefore very similar to what's said under section 4 'Working with multiple trackers' - apart from the (language specific) differences that apply between C++ and C#.
Multi- threading is neither required nor recommended in order to support multiple trackers (except if there is a Console- application, where multi- threading is required even for a single tracker application). Just designate an instance of a Sender and Receiver object to each one of the trackers (as described above for the C# interface and like applied in Sample 17).
However, be aware that Sample 17 is a Console application and therefore requires multi-threading by design. If it was an ordinary Windows application, we would not require receiver-threads since the Windows messaging mechanism could be used for handling incoming data. Again: The secondary thread in Sample 17 (or even 2 of them if using 2 trackers) is NOT due to multiple tracker support; it is because a Console applications main thread blocks while waiting for user- input; hence we need a separate listener thread to process incoming data during blocking periods.
Other than with the C++ SDK Samples, the Sender and Receiver classes of Sample 17 do not share any common data and therefore can just be

instantiated for several trackers without redesign. The only thing one may want to do: Introducing a 'cookie' property to the receiver class so that we will be able to recognize which tracker an answer comes from (The cookie approach was already described in section 4 'Working with multiple trackers'). Alternatively, we may directly pass the references of the Sender objects to the related Receiver objects. This, however, does not always make the cookies obsolete.
The code- fragments below show Sample 17 - extended with the cookie- approach - and with a 2nd set of Sender / Receiver instances for a 2nd tracker. Note that Sample 17 remains somehow academic since it calls only one command (for both trackers) upon startup, waits for the answers and then immediately exits.
However, it shows the techniques and basics in order to understand on how to design a mature multi- tracker application.

The only extension we make to class CESCSMyAPIReceive: Add an integer property (= cookie) and let it be initialized through a constructor parameter:

```
class CESCSMyAPIReceive: CESCSAPIReceive
{
    // constructor gets an additional parameter
    public CESCSMyAPIReceive(Socket s, int cookie)
    {
       sock = s;
        _cookie = cookie;
    }

    ... // leave all the rest (except evaluating
        // cookie in event handlers)

    private int _cookie; // to identify where answer comes from
}
```

We can then just duplicate all variable instances and calls for a 2nd tracker. This all happens (in Sample 17) in the Main() function:

```
static void Main(string[] args)
{
  Console.WriteLine("Application Start");

  try
  {
    // Create 2 sockets, s and s2, for two trackers and
    // connect to servers (note: hardcoded IP's due to sample)

    Socket s = new Socket(AddressFamily.InterNetwork,
                          SocketType.Stream, ProtocolType.Tcp);

    System.Net.IPAddress ipAdd =
                      System.Net.IPAddress.Parse("10.62.34.30");
    System.Net.IPEndPoint remoteEP = new IPEndPoint(ipAdd, 700);
    s.Connect(remoteEP);

    Socket s2 = new Socket(AddressFamily.InterNetwork,
                           SocketType.Stream, ProtocolType.Tcp);

    System.Net.IPAddress ipAdd2 =
                      System.Net.IPAddress.Parse("10.62.35.53");
    System.Net.IPEndPoint remoteEP2= new IPEndPoint(ipAdd2,700);
    s2.Connect(remoteEP2);

    // Create sender and receiver class (2 instance of same
    // Command and Receiver class), only the cookie (and socket
    // parameter of course) is different

    CESCSMyAPICommand apiCommand = new CESCSMyAPICommand(s);
    CESCSMyAPIReceive apiReceive = new CESCSMyAPIReceive(s, 1);

    CESCSMyAPICommand apiCommand2 = new CESCSMyAPICommand(s2);
    CESCSMyAPIReceive apiReceive2 = new CESCSMyAPIReceive(s2,2);

    // We need a receiver thread due to the Console application
    // nature of this sample, NOT primarily because of two
    // trackers! However, it makes sense here to dedicate
    // a separate receiver thread to every tracker (although
    // we could principally deal with one shared thread - we
    // would have to pass both sockets and both receiver objects
    // to the ReceiverThread worker function and handle
    // incoming data from both sockets within one thread).

    ReceiverThread receiverThread =
                         new ReceiverThread(apiReceive, s);

    ReceiverThread receiverThread2 =
                        new ReceiverThread(apiReceive2, s2);

    // Create the thread objects
    Thread thread =
         new Thread(new ThreadStart(receiverThread.Receiver));

    Thread thread2 =
         new Thread( new ThreadStart(receiverThread2.Receiver));

    // Start the threads
    thread.Start();
    thread2.Start();

    // Spin for a while waiting for the started
    // thread to become alive. (really needed?)
    //
    while (!thread2.IsAlive);
        Thread.Sleep(100);

    // Make some calls - Typically, initial calls after
    // application start may be issued here. Note that these
    // calls are asynchronous; we must not make more than
    // one single call (per Tracker!) here. There is no waiting
    // until first tracker has changed face; the call
    // immediately returns and the call to 2nd tracker is also
    // issued so that both tracker do a change face virtually
    // at the same time.

    apiCommand.ChangeFace();  // make a call to 1st tracker

    apiCommand2.ChangeFace(); // make same call to 2nd tracker

    // Do not make next call here! If there is a 'chain of
    // initialization commends' to be executed, subsequent
    // call(s) must be triggered by the answer handler(s)
    // of ChangeFace. However, note that apiCommand/apiCommand2
    // objects are local and therefore not accessible from
    // within the event handlers. This is just due to sample
    // code - nothing prevents you to relocate these objects so
```

```
    // that they are accessible from event handlers (and UI
    // handlers, such as ButtonPress handlers)

    // The rest of the code does not make sense to a real
    // application. We just stop for a few seconds in order to
    // allow receiving the command answers. If we would not
    // stop the Main() function here, it would immediate close
    // connections and exit, hence there would be no chance to
    // get the command acknowledgements. Note that exiting the
    // Main() function means exiting the application.
    // In a real (Console) application, the Main() function
    // here would rather enter an user-interface loop and
    // wait stop/loop for user- input.

    Thread.Sleep(7000); // let main thread sleep for a while
                        // (That is, Main function Stops here)

    // disconnect from server
    s.Close();
    s2.Close();

    // Request receiver Threads be stopped
    thread.Abort();
    thread2.Abort();

    // Wait until Threads finished
    thread.Join();
    thread2.Join();
  }
  catch
  {
     Console.WriteLine("Main init failed (No Connection ?)");
  }

  Console.WriteLine("Application End");
} // Main()
```

The last thing to consider: Check for the cookie in the incoming answer so that we know which tracker the answer came from.

We could then trigger the next command right here in the answer handler (in order to implement synchronized command-chains as often used upon application startups). This would require relocating the 'apiCommand' and 'apiCommand2' variables - these are currently local to the Main() method and therefore cannot be accessed from within Event handlers.

However, noting prevents us to relocate these so that they can be accessed from anywhere else (or to pass the object references to the receiver class - this is shown as comment in the code below).

Note that there is no 'OnChangeFaceAnswer()'. All non- data returning commands trigger the general 'OnCommandAnswer()' handler. So we have to check not only fort he cookie but also for the command.

Alternatively, we directly could pass a reference of the Sender object to the Receiver object. This approach may make cookies superfluous in some situations. This technique is also shown in the code below as comment.

```
public override void OnCommandAnswer(BasicCommandRT answer)
{
    ES_Command cmd = answer.command;

    string s = "Derived OnCommandAnswer() was called, cmd=" +
          cmd.ToString() + " fromTracker=" + _cookie.ToString();

    Console.WriteLine(s);

    // First check whether the call relates to the command
    // whose answer we are expecting.
    //
    // By then evaluating the cookie we can identify the
    // source of the answer (tracker 1/2) and - if required -
    // invoke a subsequent command.
    // Currently apiCommand/apiCommand2 are not accessible
    // since local to Main; hence commented. You may relocate
    // apiCommand/apiCommand2 objects in order to get access
    // form anywhere (most likely from UI control handlers,
    // such as ButtonPress handlers)

    if (answer.command == ES_Command.ES_C_ChangeFace)
    {
      /***
      // Cookie approach, it is required that apiCommand and
      // apiCommand2 are visible and public to receiver class

      if (_cookie == 1)
        apiCommand. StartMeasurement(); // to first tracker
      else if (_cookie == 2)
        apiCommand2. StartMeasurement(); // to 2nd tracker
      ***/


      /***
      // Alternative with Sender objects passed to Receiver:
      // this is a cookie-less approach. The constructor of
      // CESCSMyAPIReceive then needs looking like this:
      //
      //   public CESCSMyAPIReceive(Socket s,
      //                            CESCSMyAPIReceive apiCmd)
      //   {
      //     sock = s;
      //     _cmd = apiCmd; //_cmd is a CESCSMyAPIReceive member
      //   }
      //
      // and construction would look like:
      //
      // CESCSMyAPIReceive apiReceive =
      //                  new CESCSMyAPIReceive(s, apiCommand);
      //
      // CESCSMyAPIReceive apiReceive2 =
      //                 new CESCSMyAPIReceive(s2, apiCommand2);
      //
      // subsequent calls are then automatically directed to
      // the correct tracker; there is no need to distinguish
      // the correct target by a cookie. However, this approach
      // only is suitable if both tracker have the identical
      // sequence of commands to perform.

      _cmd.StartMeasurement(); // always goes to correct tracker

      ***/


      /***
      // As soon as we need to apply different commands to
      // answers for different trackers, we need the cookies
      // anyway in spite of passing command references:

      if (_cookie == 1)
        _cmd.StartMeasurement(); // different subsequent..
      else if (_cookie == 2)
        _cmd.GoBirdBath();  // .. command for 2nd tracker

      ***/
    } // if
}
```

7 Base User Interface (BUI)

7.1 Client Programming and BUI

7.1.1 Measurement BUI versus Compensation Applications

The emScon software comes with several graphical User- Interfaces represented by a WEB- application (running on internet explorer).
It is important to distinguish between standalone applications and integrated applications.
The Compensation-, Field Check- and Tracker Server modules are pure 'stand- alone' applications. For details see the designated special manuals fore these applications.
On the other hand, the so-called Measurement- 'Base User Interface' (BUI) does not make sense to be used as a stand- alone application, **except for system testing reasons.**
This chapter exclusively addresses the Measurement- BUI.
The BUI requires a Master- application the BUI is hosted by. It mainly acts as a 'Display' component of such a host application. There is also a Toolbar to control the most common Tracker actions. However, there is (other than in the stand-alone WEB applications) no way to perform settings such as 'Units', CS- Type, Filters etc. These have to be performed by the Master application the BUI is hosted by.

7.1.2 EmScon Basic User Interface (BUI)

The emScon Base User Interface (emScon BUI) provides a graphical interface to emScon's most common functions. Access to it is provided through the Microsoft Internet Explorer.

The BUI includes:

- A Toolbar for common sensor control such as sensor moving or triggering measurements.
- A window for result display (DRO).
- Web pages providing access to selected sensor and system settings.

7.1.3 Integration of BUI into applications

The BUI can be used as standalone application for testing reasons. However, there is no real practical use for the BUI as a standalone application.
The BUI, however, allows to be integrated to client applications. This approach is demonstrated in Sample 13.

The BUI provides a graphical interface to emScon. However, general system settings, such as Units, CS-type etc. are not provided by the BUI. An application hosting the BUI will have to do emScon settings control through the ordinary TPI interface. Also retrieving measurement data has to be provided through the TPI (Unless one wants just to VIEW the data through the DRO).
The BUI can be launched from within an application (see Sample 13), if not already running. However, it is also possible to start the BUI manually and execute a 'data- catcher' application (without BUI launch) after that. Such an application then is capable to process data (triggered by the BUI) as far as appropriate handlers are provided.

7.1.4 Sample 13

This sample is a 'BUI- launcher and - listener', to launch the emScon BUI from within a client application. That is, the BUI becomes part of the client application. The client application (= BUI host) is mainly used to 'catch' measurements triggered by the BUI in order to do further data processing.
The application shows how to perform initial settings (that cannot be set with the BUI) and how to catch the measurements (triggered from the BUI). These measurement- results are just written to the applications dialog (which does not really make sense because they are already displayed on the BUI Page. A real application would do further processing, such as storing the measurements into a database etc.)
The sample is in Visual Basic. However, the principles would not change for a C++ application.

Further details see 'Readme.txt' file and code-comments in 'BUILaunch.frm' source- file in Sample13 Folder.

Also refer to BUI documentation (User Manual) for details.

Hint: Even if you are not interested in a 'BUI-controlled' application, this sample may still be useful to demonstrate the handling of continuous measurements on using the COM (LTControl) interface. That is, if writing emScon application with VisualBasic or VBA (Excel etc.). At the very end of the file 'BUILaunch.frm', you can find an event- handler function that demonstrates on how to receive continuous measurements through the emScon COM interface.

8 Selected Commands in Detail

8.1 Special Functions

Some of the more complex commands/procedures, which have been referred to in this manual are described in detail, with some background information.

8.1.1 Get Reflectors Command

The *GetReflectors* command is often misinterpreted. *GetReflectors* is used to 'ask' the Tracker Server, which reflectors are currently defined, and to get the relation between reflector names and reflector IDs.

Related Commands

- SetReflector
- GetReflector

Comments

GetReflectors causes as many *GetReflectorsRT* data packets to arrive, as reflectors are defined in the tracker database. Each one of these packets contains the following information:

```
struct GetReflectorsRT
{
   struct BasicCommandRT      packetInfo;
   int                        iTotalReflectors;
   int                        iInternalReflectorId;
   enum ES_TargetType         targetType;
   double                     dSurfaceOffset;
   short                      cReflectorName[32];  // Unicode!
};
```

iTotalReflectors

iTotalReflectors is just for programmers' convenience.

- Names the number of reflectors known to the system and has the same value in every packet.
- Provides information, on arrival of the first packet, as to how many packets are still outstanding.
- Counts the incoming packets to know when the last one has arrived.

IinternalReflectorId / cReflectorName

The commands *iInternalReflectorId* and *cReflectorName* provide important information for the user interface/programmer

- The reflector name is a string value (in Unicode), which is see on the user interface of the application software.
- This reflector name is an alias for the reflector ID and cannot be resolved by the system.
- The system can (internally) only deal with reflector IDs, which are integer numbers.
- The commands take/return a reflector ID as a parameter.

- It is crucial to provide the correct reflector ID to *SetReflector*.
  Passing the ID of an unintended (but existing) reflector will cause wrong measurement results.
- Programmers often fill all reflector names in a list box. When the user selects one of the reflectors shown in the list box, a *SetReflector* command is carried out.
  Hence the need for a 'lookup table'.

List index

- It is not correct to use the index of the list box as a reflector ID. This is because the reflector IDs are arbitrary in sequence and may contain gaps.
- The programmer must not assume that the reflector IDs are a sequence of 1….n without any gaps. Although most systems may deliver reflectors with sequential reflector IDs starting from 0 with no gaps
  This may not be presumed. Every system behaves differently.
- *GetReflectors* may deliver for example 3 reflectors with the following Names and IDs:

Name	ID
CCR-75mm	7
CCR-1.5in	2
TBR-0.5in	5

Lookup Table

The list box indices will range from 0 to 2, when the three names are entered in a control list box, in the order shown above. A lookup table is therefore required to match the index values to the reflector IDs. Such a lookup table is shown below:

Index	**ID**
0	7

1	2
2	5

The call to *SetReflector* must pass the reflector ID, not the list box index. A frequent source of a programming error.

Reflector Name – Unicode Format

The reflector name is always in Unicode format, irrespective of whether the application is in Unicode or ANSI.

Names in C/C++ applications may have to be converted accordingly.

See "Sample 7" which implements reflector handling with a list box. It uses (rather complicated) a MFC Map as a lookup table. Simple solutions can be achieved with just an integer array.

See also 'Sample 9' on how to interpret reflector names in Unicode format correctly.

Persistence of Reflector Name - ID Mapping

Each tracker- compensation has its own set of reflector- definitions! However, the mapping between reflector-name and ID remains the same throughout all available tracker-compensations!

Example: A T-Cam is mounted on the tracker; hence, the active tracker compensation is one that was performed with a mounted camera. Assume this tracker - compensation has definitions for three valid reflectors as follows:

Name	ID
CCR-75mm	7
CCR-1.5in	2
TBR-0.5in	5

Now, the T-Cam is removed, and hence another tracker- compensation becomes active (one that was performed without a mounted T-Cam). Let's assume that this compensation has only two reflector definitions: CCR-1.5in and TBR-0.5in. **Conveniently, the mapping between name and ID remained the same** as it was in the previous compensation:

Name	ID
CCR-1.5in	2
TBR-0.5in	5

If reflector ID 7 was the active one at the time the camera was removed, you will now get a 'wrong current reflector' error message on executing reflector- dependent commands. Thus, the application must first set one of the now available IDs 2 or 3 with the 'SetReflector' command.

The fact that the relation between reflector ID and Name remains the same throughout all tracker-compensations may be convenient to application programmers since there is no need to re-query all reflector mappings upon a tracker compensation change.

8.1.2 Still Image Command

For trackers equipped with an Overview Camera, the *GetStillImage* command takes an image and delivers it as a file image data block.

Related Commands

- GetStillImage
- SetCameraParams
- GetCameraParams
- StillImageGetFile (COM, not in C++)
- WriteDiskFile (COM only)

These commands are available on all TPI levels (C, C++, COM). *Set/GetCameraParameters* is not explained here further.

Preconditions

The following preconditions have to be fulfilled:

- Camera mounted on tracker
- System settings: "Has video" flag activated
- Tracker must be in camera view (command ActivateCameraView)

Application of GetStillImage – C/C++

The application of GetStillImage is explained below using code fragments.

GetStillImage must be called with the parameter *ES_SI_Bitmap*. The parameter *ES_SI_Jpeg* is not supported yet.

- The answer to a successfully executed *GetStillImage* command results in a *GetStillImageRT* data structure.
- Apart from the common header information, this structure echoes the file type (imageFiletype =ES_SI_Bitmap), the size of the file (lFileSize), and the first Byte of the file (cFileStart).
- The following code accesses the core file data and writes it to a physical disk file:

```
// assume pData contains the data- block received
// to a GetStillImage(ES_SI_Bitmap) command

long lFileSize = ((GetStillImageRT*)pData)->lFileSize;
char cFileStart = ((GetStillImageRT*)pData)->cFileStart;

FILE *pFile = NULL;

if ((pFile = fopen("C:\\Temp\\img.bmp", "wb" )) != NULL )
{
   long lWritten =
        fwrite(&cFileStart, 1, lFileSize, pFile);

   if (lWritten != lFileSize)
      printf("File could not be written(\n");
   else
      printf("wrote %d bytes\n", lWritten);

   fclose(pFile);
}
```

- The disk- file can be skipped and a memory-mapped file can be used instead, **or**
- With the file structure of the Bitmap file, the bitmap information can be extracted from the data block and used directly with GDI functions.
- In the code above, it was assumed that pData contained a complete *GetStillImageRT* structure with complete file data padded.

WinSock2 API / MFC CAsyncSocket

- Using WinSock2 API or MFC CAsyncSocket, to read directly from the socket, must consider the implications of large file data.
- Since the file data is relatively big (~70 KB), it is very unlikely that it will arrive as one single data block over TCP/IP.
- Provisions must be made to repeat reading data until the data packet is complete.
- A technique to achieve this is shown in the *OnMessageReceived* code sample
  See chapter 'Sample9' and chapter 'Queued and Scattered Data'.

COM TPI within C/C++

When using the COM TPI (within a C/C++ application), the results of the LTControl's *GetStillImage* (synchronous) function can be assumed to be complete. See related code extract below. When receiving StillImage data asynchronously (Event Handler, MessageHandler), the difference is that the data will not be provided directly through a parameter. So *ILTConnect::GetData()* must be used first.

Note the Variant- type parameter of the fileData.

GetStillImage – Synchronous

```
void CCPPClientDlg::OnButtonStillImage()
{
   HRESULT hr = 0;
   long lFileSize;

   VARIANT vt;
   VariantInit(&vt);

   try
   {
      if ((hr = m_pLTCommandSync->GetStillImage(ES_SI_Bitmap,
                                    &lFileSize, &vt)) == S_OK)
      {
         ASSERT(vt.parray->rgsabound[0].cElements ==
                (unsigned long)lFileSize);

         FILE *pFile = NULL;

         // write file to current runtime location
         if ((pFile = fopen("image.bmp", "wb")) != NULL )
         {
           long lWritten = fwrite(vt.parray->pvData, 1,
                                  lFileSize, pFile);

           if (lWritten != lFileSize)
              AfxMessageBox(_T("File could not be written\n"));

           fclose(pFile);

           // Display the image using MSPaint,
           // but first close previous instance
           //
           HWND hWnd = ::FindWindow(_T("MSPaintApp"), NULL);

           if (hWnd) // paint is already running - close first
              ::SendMessage(hWnd, WM_SYSCOMMAND, SC_CLOSE, 0);

           WinExec("mspaint.exe image.bmp", SW_SHOWNOACTIVATE);
         } // if
      } // if
   }
   catch(_com_error &e)
   {
      Beep(4000, 100);
      AfxMessageBox((LPCTSTR)e.Description());
   }

   VariantClear(&vt);  // Avoid memory leak
}
```

GetStillImage – Asynchronous

```
void __stdcall OnStillImageDataReady(ES_StillImageFileType
                 imageFileType, long fileSize, long bytesTotal)
{
   ASSERT(m_bUseAsync);

   VARIANT vt;
   VariantInit(&vt);

   m_pLTConnect->GetData(&vt);

   ASSERT(vt.parray->rgsabound[0].cElements ==
          (unsigned long)bytesTotal);

   GetStillImageRT *pData =
                  (GetStillImageRT *)vt.parray->pvData;

   ASSERT(pData->lFileSize == fileSize);

   // Do something with the file, for example write out
   // to a disk file – like shown in code above

    VariantClear(&vt); // Avoid Memory leak
}
```

COM/VB(A)

Neither type-casts nor writing binary files are common tasks in VisualBasic. In order to achieve the same StillImage features from VB(A), some convenience Functions have been added to the COM TPI: *StillImageGetFile* and *WriteDiskFile*.

This is an extract from an Excel application. The image is displayed in an Image dialog control (named Image1):

```
Private Sub GetStillImage_Click()
   On Error GoTo ErrorHandler

    Dim fileData As Variant
    Dim size As Long

    ObjSync.GetStillImage ES_SI_Bitmap, size, fileData
    ObjConnect.WriteDiskFile fileData, "C:\Temp\img.bmp"

    ' Now load picture into sheet
    Image1.Picture = LoadPicture("C:\Temp\img.bmp")

    Exit Sub

ErrorHandler:
   MsgBox (Err.Description)
End Sub
```

Event handler

Within an event handler, the file data structure must be extracted first, since *GetData* delivers the complete data packet including header information. A similar helper function is required in VB, since no casting to (*GetStillImageRT**) is available.

See chapter 'Continuous measurements and VBA' for similar method using *ContinuousDataGetHeaderInfo*.

```
Private Sub ObjAsync_StillImageDataReady(ByVal imageFileType As
LTCONTROLLib.ES_StillImageFileType, ByVal fileSize As Long,
ByVal bytesTotal As Long)

    Dim fsize as Long ‘dummy

    ObjConnect.GetData data 'Get whole packet (incl header)

    ' retrieve out size and file data
    ObjConnect.StillImageGetFile data, fsize, file

    ObjConnect.WriteDiskFile file, "img.bmp"

    ' Now load picture into sheet
    Image1.Picture = LoadPicture("img.bmp")

End Sub
```

Although designed for use with VB, *StillImageGetFile* and *WriteDiskFile* can also be used in LTControl based C++ applications.

Image Click Position

Click positions on the Image are currently written out to Excel cells. These values can be used to calculate relative tracker movement angles, call *MoveRelativeHV* to direct the tracker there and then request a new Image.

```
Private Sub Image1_MouseDown(ByVal Button As Integer, ByVal
Shift As Integer, ByVal X As Single, ByVal Y As Single)
    Beep
    ws.Cells(2, 2).Value = X
    ws.Cells(3, 2).Value = Y
    ws.Cells(5, 2).Value = Shift
End Sub
```

8.1.3 Live Image display

Live Image Control LTVideo2.ocx

The live camera display from the Overview Camera can be implemented into user applications by using an ActiveX control, LTVideo2.ocx. See SDK lib directory, ANSI/Unicode subdirectories.

Note: emScon SDK version 2.4 and higher does no longer provide ANSI versions of 'LTControl.dll' and 'LTVideo2.ocx'! This means that the operating systems Win95/98/ME are no longer supported by emScon 2.4 client software.

Registering LTVideo2.ocx

LTVideo2.ocx is an ActiveX type COM object and requires registration on the Application Processor.

From the command line perform the following command:

Regsvr32 <Path>\LTVideo2.ocx, where <path> depends on the location of the file – typically C:\WINNT\System32.

Remark: 'LTVideo2.ocx' controls up to emScon Version 2.3.472 failed to register when performed by a user without administrator privileges. From emScon (SDK) version 2.3.477 and higher, restricted users also may register these components. However, be aware that only the 'owner' may then use it. Whenever possible, it is recommended to have LTVideo2.ocx registered by an administrator so that all users may use them without any additional measures.

Limitations:

As mentioned, the controls 'LTControl.dll' and 'LTVideo2.ocx' do no longer require administrator privileges for registering (From SDK V 2.4.x). However, developing applications as restricted users may cause certain problems when using older development tools (Which is a limitation of these tools, not a limitation of emScon components). For example Visual Basic V6 (and maybe also Office V6- built-in VBA) is likely to cause problems when referencing COM objects. (VB 6 for example tries to write temporary files to the location of registered components, which often fails for restricted users).

Hence we have to recommend being administrator while developing emScon applications. This does not apply to the users of those applications, i.e. once finished developing, they will also run for restricted users.

On the other hand, most recent development environments, such as VB.NET (2003 and up) and Office XP should not cause any problems for restricted users, even not for development tasks. Moreover, we considered major problems on using Windows XP SP1 in combination with restricted users and registration issues. We highly recommend using Win XP SP2 or Win 2K.

ANSI/Unicode Version

Use the Unicode version for WinNT/2000/XP.

See Version info of LTVideo2.ocx for details, under *File Properties > Version TAB*.

Note: emScon SDK version 2.4 and higher does no longer provide ANSI versions of 'LTControl.dll' and 'LTVideo2.ocx'! This means that the operating systems Win95/98/ME are no longer supported by emScon 2.4 client software.

Development Platforms

For Visual Basic or Office, the ActiveX controls must be added as a reference.

For VC++, a wrapper class is generated using:

Add to Project/Components > Controls > Controls type library from Visual Studio.

LTVideo2.tlb

LTVideo2.tlb is the related type library delivered for convenience. LTVideo2.ocx contains all type information required.

Server Address

LTVideo2.ocx has a property server address, which must be set according to your server address.

The port number is 5001. Any changes to the port number must also be done on the server side.

The size must have a width/height proportion of 4:3. The image must be started/stopped by invoking the method Start/StopLiveImage.

See Microsoft documentation, for further information on how to use ActiveX controls in general.

Events/Methods

The essential methods of the camera OCX are:

- StartLiveImage()

- StopLiveImage()

To alter the default frame rate (15/sec), the following methods are used:

- FrameRateStepUp()
- FrameRateStepDown()

In addition, there is a Method for advanced usage (details see below upon event description):

- GetCameraParameters()

Moreover, the following events, are defined:

```
void VideoClick(double deltaHz,
                double deltaVt,
                long posX,
                long posY,
                long flags);
```

This event occurs when clicking on the image with the mouse. The event parameters are as follows:

- DeltaHz, deltaVt: The angles that can be passed to the PositionRelativeHV command, in order to move the tracker to the clicked position.
- PosX, posY: The pixel values of the clicked position within the image coordinate system (top/left = 0, 0).
- The flags parameter can be used to figure out which modifier keys are pressed during the click. The flags parameter is the same as provided by the OnLButtonDown standard message.
  See Microsoft MFC documentation, for details.
- Server address and Port number must be passed as properties.
- An RGB triplet can be passed to alter the color of the crosshair

The following event is fired on a GetCameraParameters method call:

```
void CameraParams(long brightness,
                  long contrast,
                  double focalLength,
                  double horizontalChipSize,
                  double verticalChipSize,
                  VARIANT_BOOL mirrorImageHz,
                  VARIANT_BOOL mirrorImageVt);
```

This is usually done once upon initialization to get the actual overview properties. FocalLength, Chip characteristics and mirror status are for advanced programming issues (If one wants to implement it's own 'image click handler', i.e. determine relative tracker movement parameters out of image coordinates).

Important Remark:

Up to LTVideo2.OCX version 2.0.0.13 (part of emScon 2.0.54 release), it was essential for an application to call ‘GetCameraParameters’ as part of the control’s initialization process (i.e. before calling ‘StartLiveImage’ for the first time).

Since ‘GetCameraParameters’ is an asynchronous command, calling this command upon initialization was a somehow struggling task because the application had to wait for the event coming back (a synchronization issue, which is prone to bugs!).

If ‘GetCameraParameters’ was omitted, the ‘deltaHz’ and ‘deltaVt’ values of the click event were not correct for certain types of video cameras.

LTVideo2.OCX versions 2.0.0.15 and higher (delivered with emScon versions >= 2.0.55) do no longer require calling ‘GetCameraParameters’ explicitly by the application! The application may call it for informational issues, but in most applications, ‘GetCameraParameters’ may never get used.

Attention: emScon 3.0 servers require Version 3.0 of 'LTVideo2.ocx'

Up to emScon 2.4, bitmap format frames were used for the live video stream. With emScon 3.0, this has changed to JPEG format. This change

requires using 'LTVideo2.ocx' Version 3.0.x (or higher).
This new version of the control (it comes with SDK 3.0) is backward compatible to earlier emScon server versions. That means, it is able to handle JPEG as well as BITMAP formatted video frames and will therefore also work with older emScon servers. Old versions of 'LTVideo2.ocx', however, will not be able to display live videos of emScon 3.0 servers.

Sample 18

This Visual Basic sample demonstrates how to implement a Live Video image based on the 'LTVideo2.ocx' ActiveX component.

Note that 'LTVideo2.ocx' (part of the emScon SDK) must be registered first.

If no Visual Basic development environment is available, the code can easily be ported to VBA (Excel, or any other MS Office application with VBA support).
Sample 18 demonstrates the full functionality of the control, including GetCameraParameters events and 'Click- handler'.
The code is simple enough to be self- explaining. Further details see 'Readme.txt' file in Sample18 folder and code- comments in source files.
Attention: emScon 3.0 servers require version 3.0 of the 'LTVideo2.ocx'. This version of the control is also compatible to older emScon servers.

Sample 19

This C++ (MFC) sample demonstrates how to implement a Live Video image without using the 'LTVideo2.ocx'. It is rather based on emScons native video API.
Nevertheless, we do not recommended using

this approach for Windows- platform targeted applications!

For Windows based applications, we highly recommend rather using the 'ready to use' 'LTVideo2.ocx' control. 'LTVideo2.ocx' is part of the SDK and its usage is demonstrated in Sample 18.

However, the current LiveVideo CPP application might be useful for non- Windows based applications (e.g. Linux) since support for LTVideo2.ocx will not be available there.

In this sample, the application directly connects to the Video Port (# 5001) of the emScon server. The command interface is based on Ansi text tokens. The following commands are supported:

"LiveImageStart"

"LiveImageStop"

"FrameRateStepUp"

"FrameRateStepDown"

"RequestCameraParameters"

These tokens can be sent directly to an open socket connection to port 5001.

Arrival Data includes the following types:

- Live Image Data Blocks (Bitmap format)

Note that each image arrives in two chunks and must be composed to a complete image before displaying it.

- Camera Parameter Block

Result of a 'RequestCameraParameters' call. See source code, function OnReceive(), on how to parse incoming data.
See source code, function OnPaint(), on how to display image data.

The source code is commented in detail and should be self- explaining. However, as already mentioned, using the LiveVideo TCP/IP interface directly, as shown in this sample only is recommended for non Windows client platforms. Rather base clients on 'LTVideo2.ocx' for Windows platform targeted application.
Further details see 'Readme.txt' file in Sample19 folder and code- comments in source files.

Attention:
New Live Image Format with emScon 3.0 !

Up to emScon 2.4, bitmap format frames were used for the live video stream. With emScon 3.0, this has changed to JPEG format. Sample 19 thus has undergone an extension since emScon 2.4 SDK was released; it supports now both, Bitmap and Jpeg formats. Support of bitmaps is only left for backward compatibility to former emScon servers.
For Jpeg image conversion and display, a public-domain Third-Party library has been used (CxImage by Davide Pizzolato). The emScon 3.0 SDK just contains a few parts of the CxImage framework (some include- files and two libraries for static linking - i.e. only those parts as far as needed to build our sample). If interested, you may get the complete CxImage source from the internet.

8.1.4 Orient To Gravity Procedure

This function is used to measure the tilt of the tracker's primary z-axis (standing axis) with respect to the vertical. This can be used to orient the measurement network to gravity. The tilt is specified by two angular components about the tracker's internal x and y-axes.

Related Command

- CallOrientToGravity

Comments

- This command is only available in combination with a Leica 'Nivel' inclination Sensor.
- Executing this command drives the tracker head to 4 different positions on the xy plane:
  1. Taking 'Nivel' measurement samples.
  2. In addition, the station inclination parameters Ix and Iy are calculated and returned as result parameters.
- Executing this command does not 'implicitly' apply any orientation values to the system.
- In order to 'activate' the station orientation to gravity, the two result values, Ix and Iy, must be explicitly set with the command *SetStationOrientationParams* (Rotation angles rot1 and rot2).
  See Section 9.2 for mathematical description.

8.1.5 Transformation Procedure

See Section 9.2 for a detailed discussion of the Transformation issue.

This procedure matches a measured set of points to a given set of nominal points by using a least squares, best fit method. The procedure calculates the 7 parameters (x,y,z, omega, phi, kappa, scale), which describe the 'transformation filter' to be applied to the measured points in order to represent these in the coordinate system defined by the nominal points.

Related Commands

- ClearTransformationNominalPointList
- ClearTransformationActualPointList
- AddTransformationNominalPoint
- AddTransformationActualPoint
- SetTransformationInputParams
- GetTransformationInputParams
- CallTransformation
- GetTransformedPoints

Comments

The command *CallTransformation* delivers a set of parameters that can then be applied as a measurement 'conversion filter' to the emScon server by using the command *SetTransformationParams.*
In other words: *CallTransformation* is just a mathematical routine for providing these values; there is no effect to the measurements delivered by the emScon per se. Only after applying these values to the system in a second step (through using *SetTransformationParams)*, they start acting as a filter.
Note that you also may get the input values for *SetTransformationParams* from a different source (e.g. your own transformation routine or by some nominal design). Therefore, *CallTransformation* is only a utility routine provided by the emScon server. In contrast to *SetTransformationParams*, it does not belong to the core-functionality of the system for performing measurements.

Before doing a *CallTransformation,* both point lists, Nominal and Actual must be prepared by using the 'Add…' commands (use 'Clear…' commands prior to setup a new list, since existing lists remain persistent). Both lists must contain the same number of elements in matching order.

The system settings of emScon (units, coordinate type and coordinate system) must reflect the current input data. Point input values (nominal/actual) are interpreted by emScon based on the current emScon system settings.

- Additional (optional) parameters can be set by using the *SetTransformationInputParams* command (Mainly used to fix certain result parameters, for example if scale shall be fixed to exactly 1.0). By default, i.e. if no call to *SetTransformationInputParams* was ever made, all result parameters are assumed as 'Unknown' (not fixed). That means that all 7 parameters to be determined are given a low StdDev of 1e+35, which means a low weight and therefore means no constraint). However, since these Parameters - once explicitly set by using *SetTransformationInputParams* - remain persistent, it is **highly recommend always to call this command prior to a transformation calculation**. Passing values (0, 0, 0, 0, 0, 0, 1) all with StdDev 1e+35 in practice means to 'clear' all the input parameter- constraints (i.e. reset to default).

  Example: The following call

  ```
  SetTransformationInputParams(
   ES_TR_AsTransformation,
   0.0, 3.0, 0.0, 0.0, 0.0, 0.0, 1.0,
   1e+35, 0.0, 1e+35,
   1e+35, 1e+35, 1e+35, 0.0)
  ```

  causes to fix the Y-Coordinate to 3.0 (i.e. a known, fixed value by design) and the Scale to 1.0 since these parameters are specified with low StdDev 0.0 (high weight). All the other parameters theoretically can be given any value (not necessarily 0.0) since their weight is low. It is nevertheless recommended to pass 0.0

for 'free' result parameters.
When using the COM TPI, you may use predefined symbols 'ES_UnknownStdDev', 'ES_FixedStdDev' for 1e+35 and 0.0 respectively.
Note that any intermediate value can also be used for weighting. (Not only 'fix' and 'free'). In case of a value is known approximately, it is suggested to use 1.0e+15 (ES_ApproxStdDev).
For further details - especially the meaning of 'resultType' (ES_TransResultType) - see section 9.2

- After a successful calculation, additional results in terms of transformed points and residuals can be retrieved optionally by using *GetTransformedPoints.*
Again: None of the 7 calculated transformation parameters (received as output from *CallTransformation)* are automatically applied to the system. This must be done explicitly by calling *SetTransformationParams.*
See Section 9.2 for mathematical description.

8.1.6 Automated Intermediate Compensation

The Intermediate Compensation is a simple and fast procedure to perform a fully automated intermediate compensation, where the tracker is in a fixed installation.

Tracker Geometry

Out of a total of 15 parameters, which affect the trueness of the tracker geometry, the most significant changes are affected by these three parameters:

See emScon manuals, for more information.

- Transit axis tilt, i
- Mirror tilt, c
- Vertical index error, j

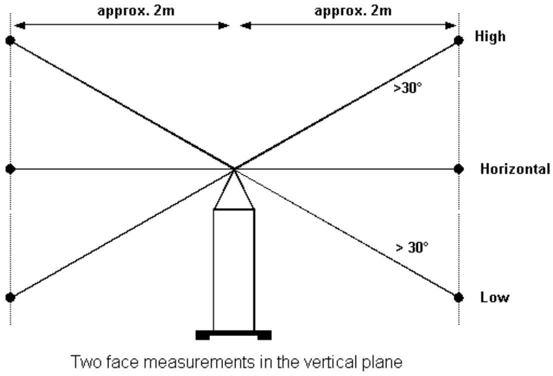
Intermediate Compensation refreshes these three parameters by taking a small number of Two-face measurements. If the result is accepted, it updates only these three parameters and takes over the rest of the overall 15 parameters from the last Full Compensation. It is a simpler and faster procedure than a Full Compensation.

Intermediate vs. Full Compensation

Intermediate Compensations do not replace Full Compensations. Regular intermediate compensations extend the interval at which full compensations need to be carried out.

Setup

A recommended setup is shown below with a network of fixed targets. Based on a given drive library the laser tracker measures the target points automatically and calculates the Intermediate Compensation results.



Two face measurements in the vertical plane

The automated Intermediate Compensation routine requires that all target locations are fitted with reflectors (recommended 0.5" Tooling Ball or Corner Cube), before the routine is started.

Area Required

Make sure that no one walks around the area during the whole Compensation procedure. Vibration can affect the measurement and walking through the beam causes the signal to break. If a measurement fails, the system automatically repeats the measurement to achieve a successful measurement, a maximum of three times.

Procedure

Requirements

The automated Intermediate Compensation can only be started when the Leica Tracker system is ready to measure.

For the initial setup it is required that the locations of the fixed targets are measured manually. These locations provide the information for the driver points.

- Six Two Face measurements, in two groups of 3 each.
- Each group of 3 points is in an approximate vertical line.
- Minimum distance from the tracker is 2m.
- The high and low measurements should be more than 30 degrees from the horizontal.
- The groups should have a horizontal angle separation of about 180 degrees, i.e. all measurements should lie approximately in the same vertical plane.

Minimum Measurements

A minimum of 4 measurements is required (mathematically). More measurements reduce the influence of errors. In addition, unstable conditions, such as vibrations and rapid temperature changes, make it necessary for more measurements to be taken. The following combinations are examples:

- Eight measurements in 4 pairs (high and low) separated by approx. 90 degrees.
- Twelve measurements in 4 groups of 3 each (high, low, horizontal), separated by

approx. 90 degrees.

Related Commands

- ClearDrivePointList
- AddDrivePoint
- CallIntermediateCompensation
- SetCompensation

Comments

Settings

Current emScon system settings, such as units, coordinate system and coordinate type, are taken over when emScon interprets point input (driver point) values. All points in the drive library must be known within ± 2mm (0.0787 in) tolerance, otherwise this will cause an error in the measurements.

The settings, such as units, coordinate system and coordinate system type, must correspond to the input data. Ensure that the settings describe the environment of the driver points before they are uploaded to the server.

One of the first actions of the automated compensation algorithm is to check the geometry of the used driver points. If the target setup fits the requirements (as described above), then the process continues with the measurements, otherwise it will abort.

Compensation Results

A successful Intermediate Compensation procedure returns the following information:

- Total RMS
- Max. Deviation

- Error bit filed with the information of warnings and errors.

Compensation Intervals

An intermediate compensation is recommended when the maximum deviation is ≤ 0.0012 deg (13^{cc}).
With the command '*SetCompensation'*, the newly calculated compensation can be activated by passing a zero parameter: SetCompensation(0).

See detailed description of 'ES_C_SetCompensation' (enum ES_C_Command) about the meaning of paramter zero.

8.1.7 Two Face Field-Check

A field check is a control process of the Compensation parameters. It checks the condition of the Leica Tracker, with respect to predefined parameters. It does not, however, provide for compensatory corrections.

Periodicity

If the tracker is used in a stationary position, conduct the field check on a weekly basis. If the field check results show no change, over a period of six weeks, carry out field checks at least once a month.

If the tracker has been moved, always carry out a field check before taking measurements.

Compensations and field checks must be carried out in normal working conditions, under which the measurements are taken.

Field check two face Measurement

Two face measurements with 4 to 5 reflector positions, distributed over the whole object range, will indicate whether the Tracker compensation is within specifications. To achieve a 2-sigma accuracy, 95 % of the measurements must be within the specification.

Client Routine

The Tracker Server Programming Interface does not have a specific two face measurement mode. A client routine is required, which can use the basic functionality provided.

See chapter 'Procedure – Measurement'.

Procedure - Preparation

The procedure requires the following three setups:

1 Two measurements on a straight line.

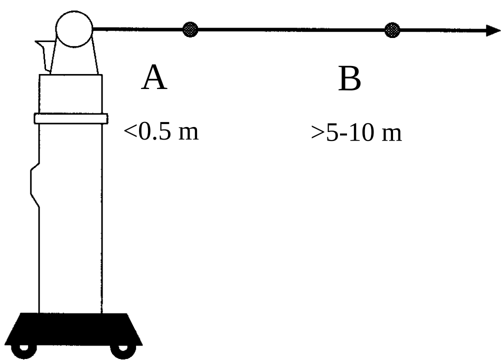
2 One measurement set on a vertical line.

3 One measurement plus or minus 90° to the vertical line.

Measurements on a Straight Line

1. The two measurements must be taken on a straight line (ray) at the same level as the as the Tilting mirror of the Tracker. Point A <0.5 m and Point B within 5-l0 m.

1.

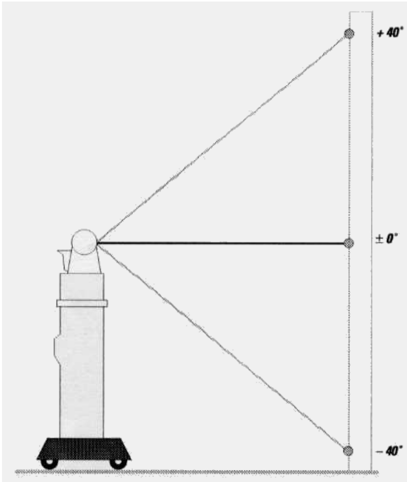


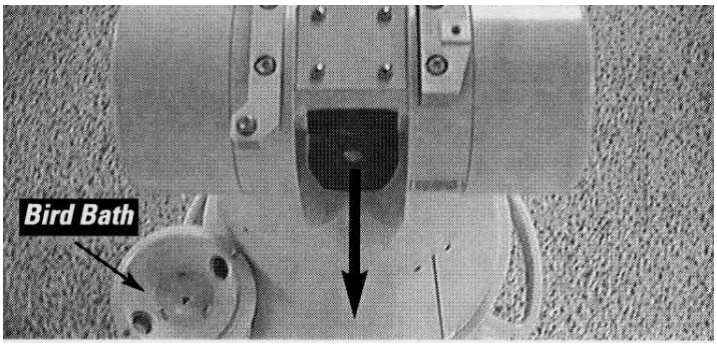
Measurements on a Vertical Line

2. All 3 measurements should be taken in a vertical line.
   1. Mid point 0° at Tracker head height.
   2. Upper measurement at +40° deg.

3. Lower measurement at -40° deg.

During measurements, the Birdbath should not point in the direction of measurement.





Measurement ± 90° to the Vertical Line.

3. Setup the tripod at 90°, as shown in the graphic below.

The Tracker is setup such that it can turn to the 90° position, without running into stop.

Procedure - Measurement

1. Set up the tracker.

2. Set the coordinate system type to spherical clock wise, SCW,
   TPI command: SetCoordinateSystemType.
3. Set the Stationary Measurement Mode.
   TPI command: SetMeasurementMode
4. Set the Stationary measurement parameter.
   MeasTime to 10000ms
   TPI command: SetStationaryModeParams
5. Attach the reflector to the target location.
6. Point the tracker to the target location.
   TPI command: e.g. GoPostion. This is only possible when the coordinates of the point are known within ± 2mm, otherwise track the reflector manually from the Bird bath.
7. Execute the Stationary Measurement in Face I and save it.
   TPI command: StartMeasurement
8. Execute the command Change Face, which puts the Laser Tracker from Face I to Face II.
   The pointing to a fixed reflector position from a station should be the same in both faces.
   TPI command: ChangeFace
9. Execute the Stationary Measurement in Face II and save it.
   TPI command: StartMeasurement.
10. Execute the command Change face, which puts the Laser Tracker from Face II to Face I.
    TPI command: ChangeFace.
11. Repeat the steps 5 - 10 for all target locations.

Procedure - Calculation

Dev_{vt} = vertical angle Face I – vertical angle Face II

Dev_h = horizontal angle Face I – horizontal angle Face II

Both measurements are in Face I representation. Face II measurements are represented in Face I.

Example

Dev_{vt} = 90.7289893– 90.7287338 = 0.0003 Deg
Dev_h = 269.9877001– 269.9879985 = -0.0003 Deg

Tolerances

The recommended tolerances of the deviations are:

Vertical angle = ±13cc (0.0012 Deg)

Horizontal angle = ±13cc (0.0012 Deg)

When the tolerance is exceeded, an Intermediate Compensation is recommended.

9 Mathematics

9.1 Point accuracy

Throughout Emscon point coordinates are stored together with a 3x3 *covariance matrix*. It is a symmetric 3x3 matrix with the squares of the respective *standard deviations* on the diagonal:

$$\begin{pmatrix} stdDev_1^2 & covar_{12} & covar_{13} \\ covar_{12} & stdDev_2^2 & covar_{23} \\ covar_{13} & covar_{23} & stdDev_3^2 \end{pmatrix}$$

The *error ellipsoid* of the point is defined by the eigenvectors and eigenvalues of the covariance matrix. If the covariance matrix is diagonal, the axes of the error ellipsoid are parallel to the coordinate axes. The *correlations*

$$\rho_{ij} = \frac{covar_{ij}}{stdDev_i * stdDev_j}$$

satisfy the relations

$$-1 \le \rho_{ij} \le 1 .$$

At the TPI point coordinates together with the covariance matrix are passed in the following non-redundant form:

Coord1,*Coord2*,*Coord3*,
StdDev1,*StdDev2*,*StdDev3*,
Covar12,*Covar13*,*Covar23*.

9.1.1 A priori accuracy

For continuous measurements, the *a priori* covariance matrix of a point measurement is calculated according to the tracker accuracy. Emscon adapts the following model:

$$StdDevH = \max(1.25\text{E-5/d}, 5\text{E-6})$$
$$StdDevV = \max(1.25\text{E-5/d}, 5\text{E-6})$$
$$StdDevD = \sqrt{1\text{E-10} + (1.25\text{E-6} \cdot \text{d})^2}$$

where d denotes the measured distance in meters. H and V denotes the horizontal and vertical angle in radians. This formula applies in the case of IFM measurements initialized at bird bath distance. The angle accuracy is constant beyond 2.5m and slightly poorer at close range. Simplified homogeneous models are $StdDevXYZ = \max(10\text{E-6} \cdot \text{d}, 25\mu)$ or even simpler $StdDevXYZ = 50\mu$. The a priori accuracy includes unresolved systematic errors and indicates the reliability of a measurement. This kind of accuracy should be used as input to any further calculation.

9.1.2 A posteriori accuracy

For single point measurements (stationary, sphere center, circle center) also the *a posteriori* or *repeatability* covariance is calculated from the actual statistical variation of the many shots. It gives an indication on the stability of the measurement environment disregarding systematic effects. We recommend not using this accuracy for any other purpose.

9.1.3 Transformation of covariance matrices

In the (spherical) tracker coordinate system the a priori covariance matrix of a tracker measurement is diagonal (see formulas above). Conversion to Cartesian coordinates results in a full matrix. Transformation to other coordinate systems using orientation and/or transformation parameters (Section 9.2 below) again transforms the covariance matrix. However, at any stage the standard deviations, i.e. the square roots of the diagonal entries provide a reasonable estimate on the accuracy of the respective coordinate triple.

9.2 Orientation and Transformation

The orientation takes the instrument coordinate system to the world coordinate system and the transformation takes the world coordinate system to an object coordinate system. The two are used either by them selves or together to show coordinates in the required coordinate system.

See Section 8.1.5 for a survey on the TPI commands used to calculate orientation or transformation parameters. The major input to these calculations are the coordinates of a set of reference points together with the corresponding measured coordinates. The result of the calculation is a seven parameter transformation of the measured points onto the reference points.

9.2.1 Orientation

Orientation refers to the alignment of a tracker with respect to a *world coordinate system* (WCS). The world coordinate system may be defined by the principal measurement station (Fig. 1) or by a CAD model (Fig. 2). The coordinates of a point with respect to the principal station or CAD model respectively are called *nominal* or *reference* coordinates. The coordinates as measured by the active station are called *actual* coordinates.

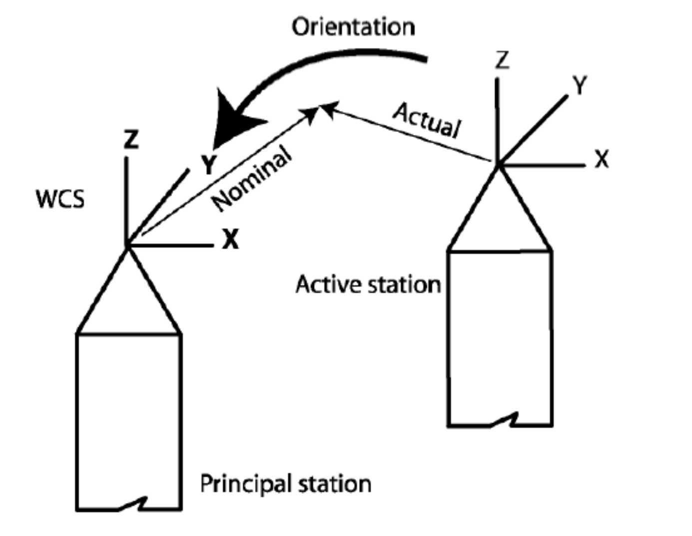


Fig. 1

Setting the calculated parameters as orientation parameters with the `SetStationOrientationParams` command and re-measurement of the reference points yields actual coordinates approximately equal to the nominal coordinates.

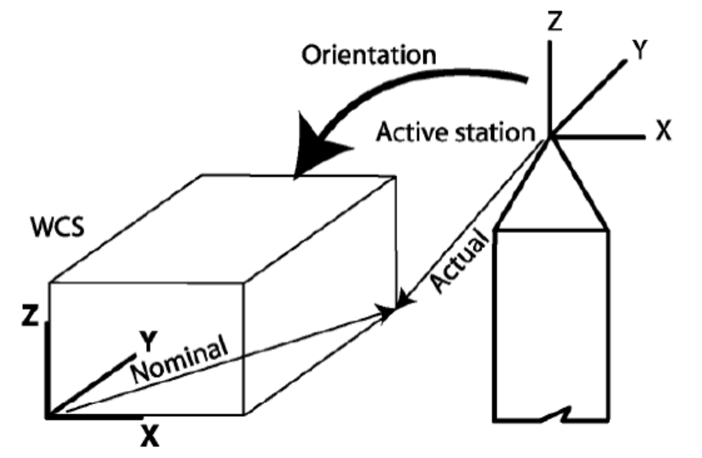


Fig. 2

9.2.2 Transformation

A *transformation* defines a local *object coordinate system*. In this case the object coordinates play the role of nominals. (Fig. 3). Activating the calculated transformation parameters and re-measurement yields actual coordinates approximately equal to the nominal coordinates.

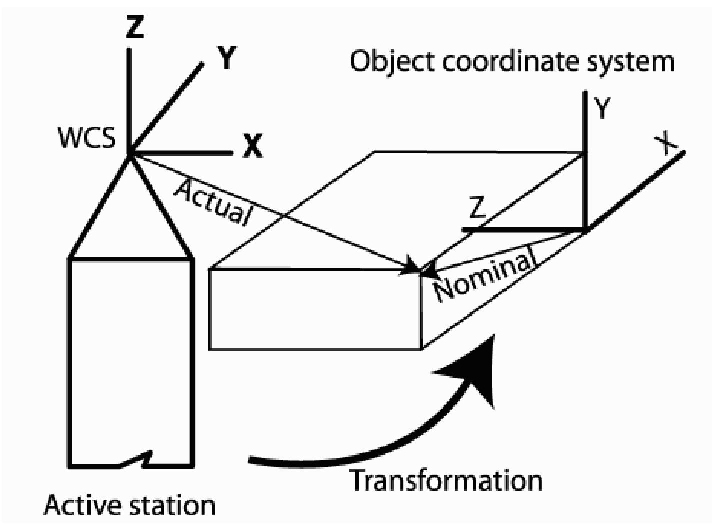


Fig 3

9.2.3 Nominal and actual coordinates

The role of nominal, actual, and world coordinates in the orientation and transformation calculation are summarized in Table 1.

	Nominal/reference	Actual	World
Orientation w.r.t. CAD	CAD coordinates	Measured by active station	Nominal
Orientation w.r.t. 1st station	Measured by 1st station	Measured by active station	Nominal
Transformation	Object coordinates	Measured by active station	Actual

Table 1

9.2.4 Orientation parameters

Orientation and transformation are both *seven parameter transformations* consisting of three translation, three rotation, and one scale parameter. They describe a mapping of a given set of actual points onto a given set of reference points. The mapping is calculated such as to minimize the deviation between the *transformed points* and the corresponding reference points in a least squares sense. Typically the scale is close to one, e.g. when describing a temperature dependent dilation. In the orientation case the map assumes the form:

$$T(x) = t + Rx / s$$

with

t = 3D translation vector
R = 3x3 rotation matrix
s = scale

The corresponding residuals are:

$$residual = T(actual) - nominal$$

The map T can be interpreted as a *coordinate system* with its origin at *t* and the axes given by the columns of *R*. In terms of the *rotation angles* *xAngle, yAngle, zAngle* the rotation matrix assumes the form

$$R = \begin{pmatrix} \mathrm{cz} \cdot \mathrm{cy} & \text{-sz} \cdot \mathrm{cy} & \mathrm{sy} \\ \mathrm{sz} \cdot \mathrm{cx}+\mathrm{cz} \cdot \mathrm{sy} \cdot \mathrm{sx} & \mathrm{cz} \cdot \mathrm{cx}\text{-}\mathrm{sz} \cdot \mathrm{sy} \cdot \mathrm{sx} & \text{-cy} \cdot \mathrm{sx} \\ \mathrm{sz} \cdot \mathrm{sx}\text{-}\mathrm{cz} \cdot \mathrm{sy} \cdot \mathrm{cx} & \mathrm{cz} \cdot \mathrm{sx}+\mathrm{sz} \cdot \mathrm{sy} \cdot \mathrm{cx} & \mathrm{cy} \cdot \mathrm{cx} \end{pmatrix}$$

where

$$cx = \cos(xAngle)$$
$$sx = \sin(xAngle)$$

and similarly for the other angles.

9.2.5 Transformation parameters

Transformation and orientation equations are the inverse form to each other as mappings. For transformations the map assumes the form:

$$T(x) = sR^{-1}(x-t).$$

9.2.6 Input to transformation computation

Orientation or transformation

In the orientation/transformation procedure the first parameter of the `SetTransformationInputParams` command is chosen as `ES_TR_AsOrientation/ ES_TR_AsTransformation` respectively.

Nominal points

Nominal points are added as in the following example:

```
AddNominalPoint(1.0, 2.0, 3.0, ES_FixedStdDev, ES_UnknownStdDev,
ES_ApproxStdDev, 0.0, 0.0, 0.0);
```

The parameters are the three coordinates together with their standard deviations and covariances (see Section 9.1 above). We recommend using the following predefined standard deviations (see also Section 3.3.1):

Coordinate accuracy	Symbol	Value
Fixed (exactly known)	`ES_FixedStdDev`	0.0
Unknown (free)	`ES_UnknownStdDev`	1.0E35
Approximately known (reasonable)	`ES_ApproxStdDev`	1.0E15

Coordinate accuracy	Symbol	Value
Weighted		> 0.0, < 1.0E10

Approximately known coordinates are used to calculate an initial approximation of the orientation or transformation parameters. In a minimum configuration, the solution would be ambiguous without this additional information.

Actual points

Actual points are added in the following form:

```
AddActualPoint(-12.487, -5.79687, 5.49683, 0.0001, 0.0001,
0.0001, 0.0, 0.0, 0.0);
```

The number and order of actual points must agree with that of the corresponding set of nominal points. Typically, actual points are obtained from single point measurements. We recommend using the a priori accuracy (Section 9.1.1) in particular when using fixed nominal values. Using fixed nominals together with the a posteriori accuracy provided by tracker measurements would lead to over weighting of residuals in laser direction. The reason is that tracker measurements are much more accurate in the laser direction than perpendicular to it.

Parameter constraints

If any of the seven orientation or transformation parameters are known prior to the calculation, their value can be fixed. Frequently the scale is fixed to be 1.0 and the other parameters are free as in the following example:

```
SetInputParams(0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 1.0,
ES_UnknownStdDev, ES_UnknownStdDev, ES_UnknownStdDev,
ES_UnknownStdDev, ES_UnknownStdDev, ES_UnknownStdDev,
ES_FixedStdDev);
```

The values of unknown parameters can be set arbitrarily. Parameter constraints are not used to reduce the required number of known nominal coordinates. They are not taken into account for the initial approximation. To fix some or all components of the translation vector the coordinate type must be one of Cartesian RHR or LHR.

9.2.7 Output of transformation computation

Transformation parameters

The command `CallTransformation` returns a structure `CallTransformationRT` containing the seven parameters of the transformation (translation, rotation angles, scale) together with their standard deviations. The standard deviation of a fixed parameter is zero.

Transformed points and residuals

The command `GetTransformedPoint` returns a list of structures, each containing a transformed point together with its covariance matrix and the three coordinates of the *residual* vector

$$residual = nominal - transformed$$

The covariance matrix of the transformed point takes into account the covariance matrix of the actual point and the 7 by 7 covariance matrix of the transformation calculated. The covariance matrix of the residual is obtained by adding those of the nominal and the transformed point.

Statistics

The command `CallTransformation` also returns the

- RMS of residuals
- Maximum deviation
- Variance factor

RMS of residuals

The *RMS of residuals* is defined as

$$RMS = \sqrt{\frac{\sum_{i=1}^{n} |residual|_i^2}{noEquations}}$$

where the *number of equations* is the number of fixed or weighted nominal coordinates.

Maximum deviation

The maximum deviation is defined as

$$maxDev = max_{i=1..n} \left|residual\right|_i$$

where fixed and weighted nominal coordinates are taken into account.

Weighted residual square sum

The transformation algorithm determines the values of the transformation parameters *in the weighted least squares sense*. This means that the following target functional is minimized:

$$RSS = \sum_{i=1}^{n} residual_i^T \, weightMatrix_i \; residual_i$$

This functional is called the *weighted residual square sum*. The *weight matrix* is the inverse of the covariance matrix of the residual. For constraints the residual and the weight matrix are scalars.

Variance factor

The *variance factor* (Axyz: *mean error*) is related to the residual square sum through:

$$varianceFactor = \frac{RSS}{redundancy}$$

It is dimensionless, i.e. it does not depend on the length or angle units. Its value may vary considerably depending on the accuracy of the input and the *model error*, i.e. the size of the residuals. If the residuals are systematically bigger than the standard deviations of the actual coordinates, the variance factor exceeds one. Otherwise, it is less than one.

Redundancy

The *redundancy* is an integer defined as

$$redundancy = noEquations - noParameters \, .$$

If the redundancy is zero the variance factor is undefined. Such cases are called *minimum configurations*. If the redundancy is negative, the solution is non-unique. More fixed nominal coordinates or parameter constraints are needed to determine a unique solution.

9.2.8 Examples

Standard case with 3 points

```
AddNominalPoint(1, 2, 3, Fixed, Fixed, Fixed, 0, 0, 0);
AddNominalPoint(2, 3, 4, Fixed, Fixed, Fixed, 0, 0, 0);
AddNominalPoint(0, -4, 2, Fixed, Fixed, Fixed, 0, 0, 0);
SetInputParams(0, 0, 0, 0, 0, 0, 1, Unknown, Unknown, Unknown,
Unknown, Unknown, Unknown, Unknown);
```

In this example

$$redundancy = 3 \cdot noPoints - 7 = 2 .$$

Pure dilation

```
AddNominalPoint(1, 1, 0, Fixed, Fixed, Fixed, 0, 0, 0);
AddNominalPoint(-1, 1, 0, Fixed, Fixed, Fixed, 0, 0, 0);
AddNominalPoint(1, -1, 0, Fixed, Fixed, Fixed, 0, 0, 0);
AddNominalPoint(-1, -1, 0, Fixed, Fixed, Fixed, 0, 0, 0);

AddActualPoint(1.1, 1.1, 0, 0.001, 0.001, 0.001, 0, 0, 0);
AddActualPoint(-1.1, 1.1, 0, 0.001, 0.001, 0.001, 0, 0, 0);
AddActualPoint(1.1, -1.1, 0, 0.001, 0.001, 0.001, 0, 0, 0);
AddActualPoint(-1.1, -1.1, 0, 0.001, 0.001, 0.001, 0, 0, 0);

SetInputParams(0, 0, 0, 0, 0, 0, 1, Unknown, Unknown, Unknown,
Unknown, Unknown, Unknown, Fixed);
```

In this example the desired transformation is the identity with parameters 0, 0, 0, 0, 0, 0, 1. The length of all residuals is $0.1\sqrt{2}$. Their covariance matrix is

$$covar = \begin{pmatrix} 10^{-6} & 0 & 0 \\ 0 & 10^{-6} & 0 \\ 0 & 0 & 10^{-6} \end{pmatrix}$$

The weight matrix is

$$weight = \begin{pmatrix} 10^{6} & 0 & 0 \\ 0 & 10^{6} & 0 \\ 0 & 0 & 10^{6} \end{pmatrix}$$

Thus

$$RSS = 4 * 10^6 * \left(0.1\sqrt{2}\right)^2 = 80000$$

$$redundancy = 12 - 6 = 6$$

$$varianceFactor = \frac{80000}{6} = 13333.$$

Weighting

To illustrate the influence of nominal or actual standard deviations consider the following example.

```
AddNominalPoint(1.1, 1, 0, 0.002, Fixed, Fixed, 0, 0, 0);
AddNominalPoint(1.1, -1, 0, 0.002, Fixed, Fixed, 0, 0, 0);
AddNominalPoint(-1.1, 1, 0, 0.001, Fixed, Fixed, 0, 0, 0);
AddNominalPoint(-1.1, -1, 0, 0.001, Fixed, Fixed, 0, 0, 0);

AddActualPoint(1, 1, 0, 1.0E-35, 1.0E-35, 1.0E-35, 0, 0, 0);
AddActualPoint(1, -1, 0, 1.0E-35, 1.0E-35, 1.0E-35, 0, 0, 0);
AddActualPoint(-1, 1, 0, 1.0E-35, 1.0E-35, 1.0E-35, 0, 0, 0);
AddActualPoint(-1, -1, 0, 1.0E-35, 1.0E-35, 1.0E-35, 0, 0, 0);
```

The resulting orientation has translation (-0.06, 0, 0) and no rotation. The residual vectors are (-0.16, 0, 0), (-0.16, 0, 0) , (0.04, 0, 0) , (0.04, 0, 0). The weighted residuals (divide by square of standard deviation) have equal length 40000.

3-2-1 Alignment

```
AddNominalPoint(1, 2, 3, Fixed, Fixed, Approx, 0, 0, 0);
AddNominalPoint(2, 3, 4, Fixed, Fixed, Fixed, 0, 0, 0);
AddNominalPoint(0, -4, 2, Approx, Fixed, Approx, 0, 0, 0);

SetInputParams(0, 0, 0, 0, 0, 0, 1, Unknown, Unknown, Unknown,
Unknown, Unknown, Unknown, Fixed);
```

This is a minimum configuration since

$$redundancy = 2 + 3 + 1 - 6 = 0.$$

The approximate coordinates are necessary to select a unique solution from the eight possible solutions. This fact can be easily observed in the following example:

```
AddNominalPoint(0, 0, 0, Fixed, Fixed, Fixed, 0, 0, 0);
AddNominalPoint(1, 0, 0, Unknown, Fixed, Fixed, 0, 0, 0);
AddNominalPoint(1, 1, 0, Unknown, Unknown, Fixed, 0, 0, 0);
```

Here each of the rotation angles can be 0 or π. The scale must be fixed in 3-2-1 situations.

Box corner

The corner of a box is defined by three mutually perpendicular planes. In the subsequent example each plane contains two measured points. Only the nominal coordinate defining the plane is exactly known.

```
AddNominalPoint(0, 1, 1, Fixed, Approx, Approx, 0, 0, 0);
AddNominalPoint(0, 2, 2, Fixed, Approx, Approx, 0, 0, 0);
AddNominalPoint(1, 0, 1, Approx, Fixed, Approx, 0, 0, 0);
AddNominalPoint(1, 0, 2, Approx, Fixed, Approx, 0, 0, 0);
AddNominalPoint(1, 1, 0, Approx, Approx, Fixed, 0, 0, 0);
AddNominalPoint(2, 2, 0, Approx, Approx, Fixed, 0, 0, 0);
```

Again, this is a minimum configuration provided the scale is fixed.

Orientation using Nivel measurement

Suppose the horizontal angles xAngle and yAngle have been obtained from a 'Nivel' measurement. To complete the orientation of the station use a number of reference points together with:

```
SetInputParams(0, 0, 0, xAngle, yAngle, 0, 1, Unknown, Unknown,
Unknown, Fixed, Fixed, Unknown, Fixed);
```

9.3 T-Probe

The coordinate system of the T-Probe is defined as in Figure 1 with the z-axis pointing roughly towards the camera and the y-axis opposite to mount 1. Thus the y coordinate of a tip vector at mount 1 is negative.

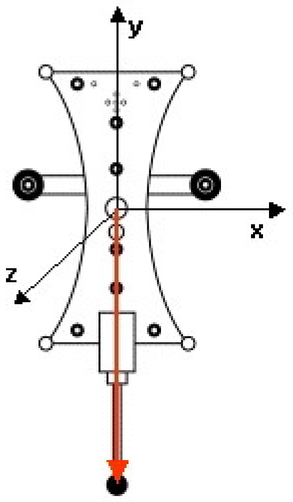


Figure 1

The tip position and probe orientation is returned with respect to the user coordinate system (transformation parameters). The *probe orientation* is described by the rotation angles (xAngle, yAngle, zAngle) or the quaternion (q0, q1, q2, q3). In terms of rotation angles the rotation matrix R is defined as in Section 9.2.4 . In terms of the quaternion it is given by

$Rxx = q0 \cdot q0+q1 \cdot q1-q2 \cdot q2-q3 \cdot q3$

$Rxy=2(q1 \cdot q2-q0 \cdot q3)$

$Rxz=2(q1 \cdot q3+q0 \cdot q2)$

$Ryx=2(q1 \cdot q2+q0 \cdot q3)$

$Ryy=q0 \cdot q0-q1 \cdot q1+q2 \cdot q2-q3 \cdot q3$

$Ryz=2(q2 \cdot q3-q0 \cdot q1)$

$Rzx=2(q1 \cdot q3-q0 \cdot q2)$

$Rzy=2(q3 \cdot q2+q0 \cdot q1)$

$Rzz=q0*q0-q1*q1-q2*q2+q3*q3$

This matrix is used to transform directions from the probe coordinate system to the user system through:

$$directionUser = R * directionProbe.$$

EmScon 3.0 TPI Programmers Manual - Revision: May 26, 2008

10 Appendices

10.1 Tracker Trigger Interface [A]

Appendix A: A detailed description of Trigger- issues of the Tracker / emScon.

10.2 Server Error Numbers [B]

Appendix B: This listing comprises the error numbers (and partly symbols) an emScon programmer may encounter for the 'ResultStatus' of TPI commands and/or TPI Error Events. It is meant as a Summary / Quick- Reference for information already documented in the main sections of the manual (but spread among several chapters). This listing applies to TPI errors that originate on the emScon server (i.e. not on Controller/Tracker Firmware)

10.3 Tracker / TP Error Numbers [C]

Appendix C: This listing comprises the error numbers an emScon programmer may encounter for the 'ResultStatus' of TPI commands and/or TPI Error Events. The errors listed here originate at the Tracker or Tracker- Processor. (In contrast to those listed in Appendix B, which originate on the emScon server). Thus Appendix C extends the listing of Appendix B.

10.4 T-Cam / T-Probe Error Numbers [D]

Appendix D: This listing continues and extends the list of Appendix C. While the list under Appendix C was related to Tracker/TP hardware only, this list covers 'Extension-Hardware', such as T-Cam and T-Probe.

10.5 AIFM Error Numbers [E]

Appendix E: This listing continues and extends the list of Appendix C. It contains new error numbers specific to emScon 3.0. These numbers are related to the new AIFM (Absolute Interferometer) hardware of AT- Tracker series.

Tracker Trigger Interface

1. Introduction

The **LT CONTROLLER plus** and **base** as well as the **AT Controller 900** provides a trigger input interface to enable external triggering and synchronization of the tracker measurement.

With emScon version 2.3 or higher the trigger interface of the Laser Tracker gets a feature enrichment. There are now two major categories of external trigger modes:

- Realtime Triggers -> take measurements triggered by an external clock signal
- Event Message Triggers -> do not really measure, they only use the same hardware Interface. It will send an event message to the application. It's up to the application software then to take any action (e.g. start a stationary measurement).

The hardware trigger interface of the LT Controller allows a flexible setup. The interface can be configured to:

- Differential RS422 or single wired TTL input signal (defined by a jumper on the connector).
- Single event or continual clock trigger mode
- Trigger event on negative or positive transition of the clock signal
- A minimal time delay between measurements

2. Hardware Interface

The trigger input connector can be found on the rear side of the LT Controller plus or base. Currently the trigger card in the LT Controller supports only a trigger input interface.

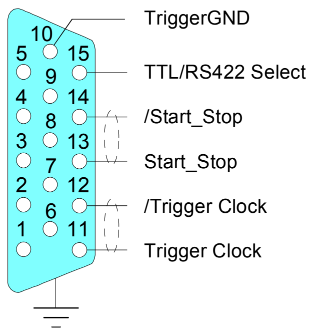
The trigger interface contains 2 input signals:

- Clock input
- Start / Stop signal input
- An additional line selects between TTL or RS422 interface

To prevent any difficulties with ground loops all inputs are optically isolated to the rest of the Controller electronics.

2.1 Trigger Input Connector

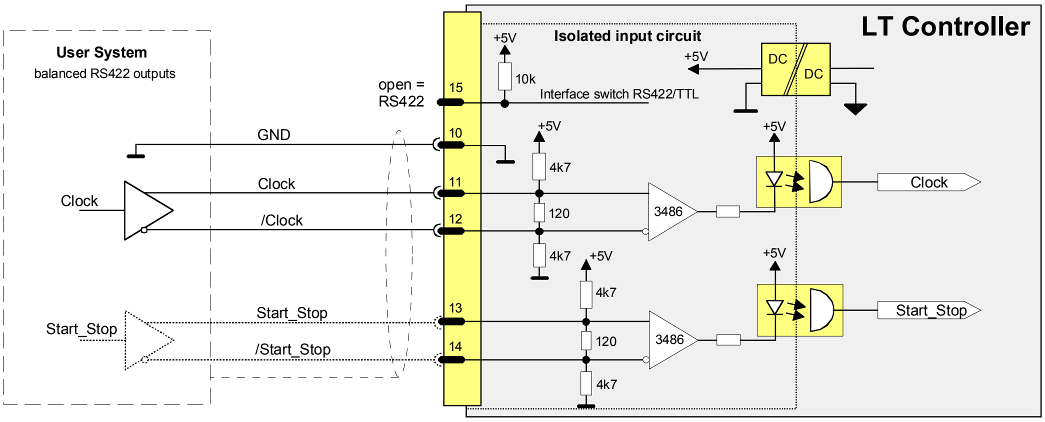
The picture shows the pins of the 15pin female high density DSUB connector (view from solder side).



Only pin 10...15 are used for the external trigger interface.
The remaining pins 1...9 are reserved for future use and should not be connected.

2.2 Differential RS422 Signal Input

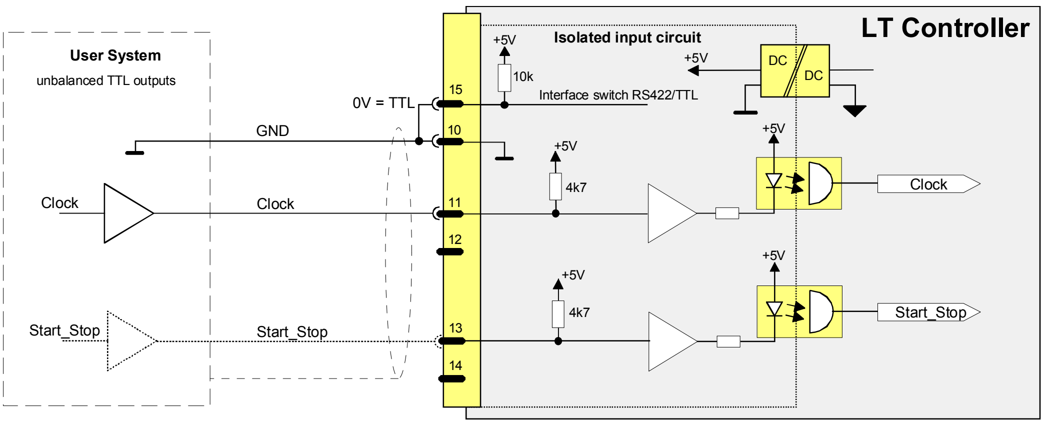
The drawing shows a principal interface circuit of the LT Controller trigger interface configured for balanced RS422 input signals.



The Start/Stop inputs can be left unconnected in cases were only the clock signal is used for event triggering.
For improved noise immunity in an industrial environment the use of differential signals is strongly recommended.

2.3 Single wired TTL Signal Input

The drawing shows a principal interface circuit of LT Controller trigger interface using unbalanced TTL signals. With pin 15 tied to GND the interface switches for TTL inputs.

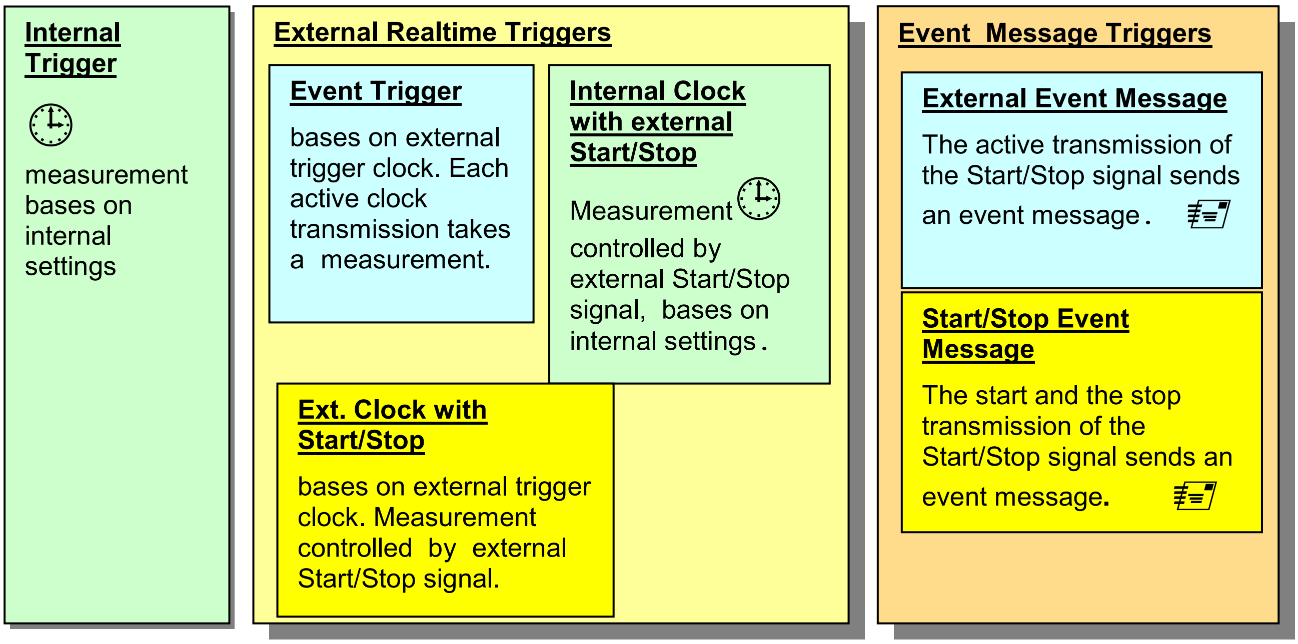


The Start/Stop input can be left unconnected in cases were only the clock signal is used for event triggering.
For improved noise immunity in an industrial environment the use of **differential RS422 signals** is strongly recommended as shown above §2.2.

3. Trigger Modes

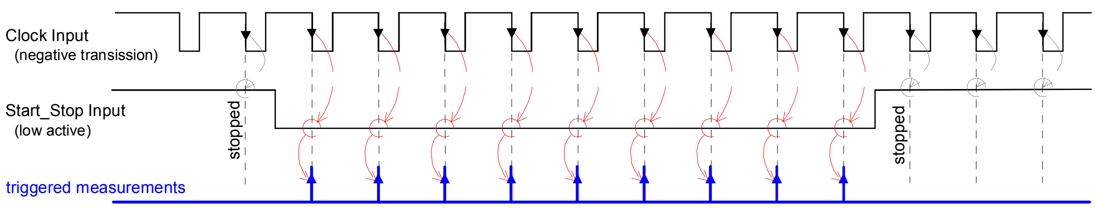
There are tree major categories of trigger modes:

- Internal -> takes measurements based on internal settings without any external conditions.
- Realtime Triggers -> take measurements triggered by external signals.
- Event Message Triggers -> do not really measure, they just send an event message to the application. It's up to the application software then to take any action (e.g. start a stationary measurement).



3.1 Realtime Trigger Modes:

- **External Clock with Start/Stop signal**
  The measurement will be controlled by a start/stop signal on the trigger board. One transition of the clock signal (positive or negative depends on the configuration) triggers a measurement if the start/stop signal is active.



- **Realtime Event Trigger**
  In the event trigger mode each positive or negative transition (depending on the configuration) of the clock signal will take a measurement. In event trigger mode the start/Stop signal will be ignored.

- **Internal clock with external start/stop signal**
  The measurement will be controlled by the external Start/Stop signal on the trigger board. The continuous measurement then will be taken regarding internal settings and is not synchronized to an external signal.

3.2 Event Message Trigger Modes:

They do not start a measurement, just the hardware interface of the trigger card is used to receive the events. Since the idea of **Event Message Triggers** are single incidents they will send up to maximal 3 messages per second. Faster incidents will be simply ignored, realtime triggers are the better choice therefore.

- **<u>Event Trigger</u>**
  The positive or negative transition (depending on the configuration) of the Start/Stop signal will send a trigger event message. It does not start a measurement. It's up to the application software to take any action like starting a stationary measurement etc.

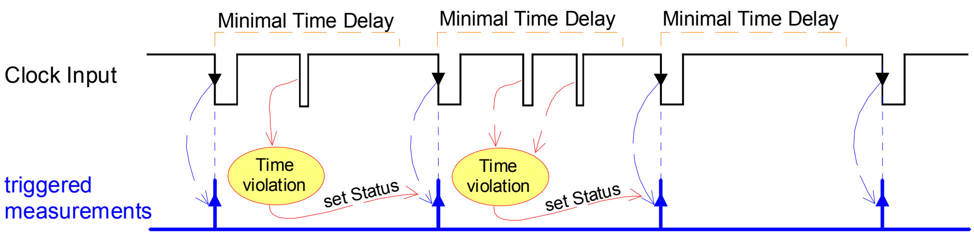
- **<u>Start/Stop Event Trigger</u>**
  The both transition of the Start/Stop signal will send depending on the configuration a start or a stop event message. It does not start a measurement. It's up to the application software to take any action.

3.3 Configuration of the Trigger Input Signals:

- **<u>Clock Signal</u>**
  The clock signal can be configured to work either with the positive or the negative clock transmission. Default is negative transmission.

- **<u>Start/Stop Signal</u>**
  The start/stop signal can be either low or high active (low active means low = start condition). Default is low active.

- **<u>Minimal Delay Time</u>**
  While using a realtime trigger mode based on external clock the maximal data rate (minimal delay between 2 points) can be defined.



Trigger clocks that violate the minimal time delay are ignored and do not trigger a measurement. The time violation flag will be set in the status of the next delivered measurement point.

4. Time Information

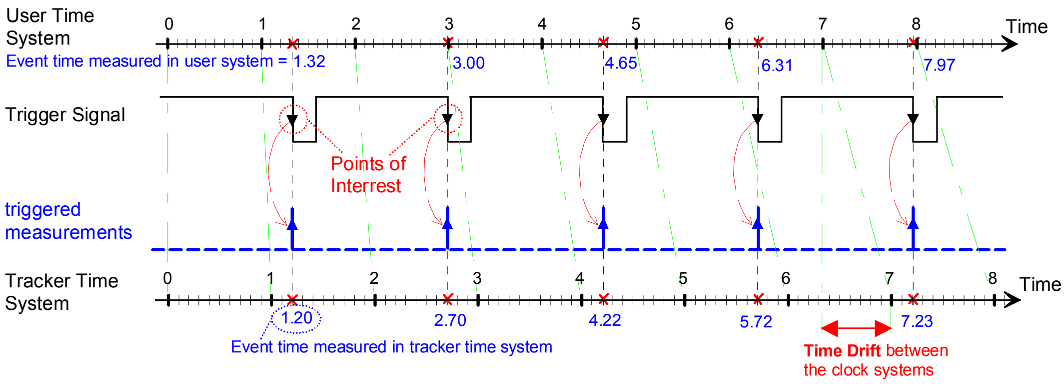
4.1 Timestamp and Clock Drift

A timestamp is supplied with each measurement from tracker. The time bases on the internal clock of the tracker controller with microsecond resolution.

As it lies in the nature of subject internal clocks of several computers may slightly differ. Even when initially set accurately, real clocks will differ after some amount of time due to drift, caused by clocks counting time at slightly different rates.

The tracker controller captures the trigger event (point of interest) in its own time system. Then a measurement is interpolated to exactely that point. The timestamp captured with the trigger event will be sent together with the measurement.

The time of the first measurement after the measurement start command or a the external start signal will always be set to 0.



The drawing above shows the effect of the drift between the 2 time systems. The measurement is taken in the exact point of interest but the time measured in the tracker may differ from a reference time taken externally.

A drift of 10-20 microseconds per second is not unusual. (As an example: 10microsec/second is equal to a drift of about 1 second in a day).

4.2 Time and Trigger Accuracy

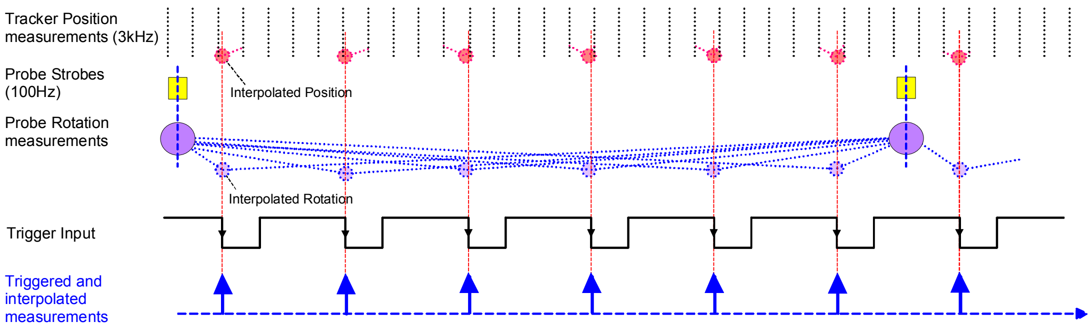
The internal clock bases on a cristall osillator with an overall stability of **±100ppm**, including temperature changes within operating range, shock and vibration, aging of 1.year, etc.

Catching a measurement with an external trigger signal has an accuracy of **±5µsec**, including acquisition of the trigger signal and several components of a measurement.

5. Generation of triggered Measurement Results

The external trigger signal does not directely influence the raw measureing process in the tracker. While the angle and distance reading runs at a fix rate of 3kHz the T-Cam and probe devices capture rotation measurements with 100Hz. Each measurement component is captured together with a timestamp based on the internal tracker clock running at 1MHz (gives a resolution of 1 µsec).

In the same way the timestamps of events from external trigger are captured. With the knowledge of the time of all occurances it is possible to interpolate a measurement to the exact point of interest without a time lag.



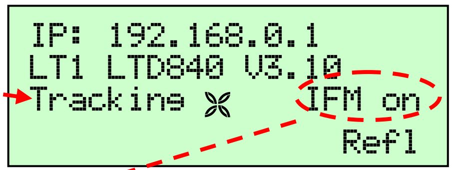
The drawing shows the way as 6D Probe measurements are captured and interpolated. For 3D it works the same way but using only the tracker position measurement

6. External Triggers on the Tracker Controller Status Display

The 3. line of the LCD display shows the status and operation of the tracker .

6.1 Tracking and Measurements:

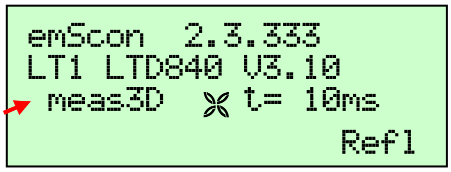
Just tracking no Measurements sent



Status shown in 3. line:

- " " (empty) interferometer not locked
- DMmeas ADM measurement in progress
- IFM on interferometer locked, tracker ready to measure

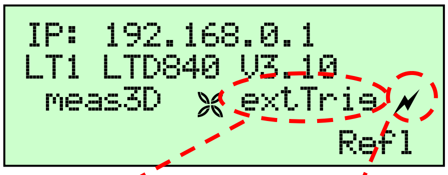
Measurements based on internal Clock



- meas3D t=1ms 3D measurement with a rate of 1000 points/sec, delay of 1ms
- mDisp3D IFM on only 3D reflector display data running but not a measurement
- meas6D t=5ms 6D measurement with a rate of 200 points/sec, delay of 5ms
- mDisp6D IFM on only 6D reflector display data running but not a measurement

6.2 External Realtime Trigger:

trigger mode set to external trigger



- External Trigger Mode with Start/Stop
  Display swapping between extTrig and minimal time delay of e.g. t>=5ms

Trigger Status

- _ Start/Stop line inactive (stop condition)
- □ Start/Stop line active, waiting for trigger events
- ϟ Trigger activity, events take measurements
- x Time violation, pulses faster then then minimal delay

- External Trigger, Event Mode
  Display swapping between extTrig and minimal time delay of e.g. t>=5ms

Trigger Status

- E Tracker ready, waiting for trigger events
- ϟ Trigger activity, events take measurements
- x Time violation, pulses faster then the minimal delay

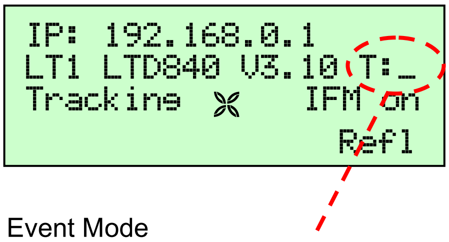
6.3 External Start/Stop Trigger:

- External Start/Stop Trigger, measurements based on internal clock
  Display swapping between
  extStart and measurement
  time delay of e.g. ti=1ms

  Trigger Status
  - _ Start/Stop line inactive (stop condition)
  - M Measurements taken based on internal clock

6.4 Message Event Triggers:

Since message event triggers do not take measurements they only send an event message to the client. Therefore the trigger status is displayed on the 2. line and not on the operation line in the LCD display.



- Event Message Trigger, Event Mode
  Display in 2. line shows
  T:e (T: stay for trigger)

  Trigger Status
  - e Tracker ready, waiting for an trigger event
  - ϟ Trigger activity, event message sent

- Event Message Trigger, Start/Stop Mode
  Display in 2. line shows
  T: and the start/stop
  line status

  Trigger Status
  - _ Start/Stop line inactive (stop condition)
  - □ Start/Stop line active

Appendix B

EMSCON SERVER ERROR NUMBERS

This appendix describes error numbers (plus some warnings) that originate on the emScon server. These numbers are returned as status values for failed TPI command calls (except zero- values and documented warnings, which apply to successful calls).
The listing below is presented in a Quick- Reference style. For additional information see the chapter 'ES_ResultStatus' in the section of the manual where 'enum' values are described (while the formal definition - including symbolic names for use in applications - can be found in the 'ES_C_API_Def.h' include file). Note that symbols are available only for those errors defined as enum values (i.e. those with prefix ES_RS_), since only these are publicly defined in the API include file.
Most of these errors are shared among multiple commands. As an example, the error 'ES_RS_ServerBusy' may appear with virtually every command, while 'ES_RS_WrongParameter' may occur with every command that takes any input parameters. Some errors, however, may even be unique to a specific single command.
Furthermore, error groups specific to certain special commands (those executed as sub-processes by the server), such as 'CallTransformation' or 'CallOrientToGravity' exist. These errors typically are in a range between 20000 and 29999. Their (internal) symbols are not available to application programmers (although partly listed in the sections below).
Finally, errors in the range between 1000 and 9999 originate on the controller/hardware. They are listed in appendices C and D (i.e. not in this appendix). Only numbers; no symbols exist for these at all.

B1: TPI status values defined in enum 'ES_ResultStatus'

Number	**Symbol (without 'ES_RS_' prefix)**	**Comments (as far as symbol not self-explaining)**
0	AllOK	Default status in case of command succeeded
1	ServerBusy	Previously issued command still pending; Retry later!
2	NotImplemented	Command not implemented (server version not up to date?)
3	WrongParameter	Any of the provided parameters is invalid
4	WrongParameter1	First parameter is invalid (error)
5	WrongParameter2	2nd parameter is invalid (error)
6	WrongParameter3	**...**
7	WrongParameter4	**...**
8	WrongParameter5	**...**
9	WrongParameter6	**...**
10	WrongParameter7	**...**
11	Parameter1OutOfRangeOK	Warning: First parameter is out of recommended range (but still accepted, command succeeded)
12	Parameter1OutOfRangeNOK	Error: First parameter is out of range (not accepted, command failed)
13	Parameter2OutOfRangeOK	Warning: 2nd parameter is out of recommended range (but still accepted, command succeeded)
14	Parameter2OutOfRangeNOK	Error: 2nd parameter is out of range (not accepted)
15	Parameter3OutOfRangeOK	**…**
16	Parameter3OutOfRangeNOK	**…**

17	Parameter4OutOfRangeOK	**…**
18	Parameter4OutOfRangeNOK	**…**
19	Parameter5OutOfRangeOK	**…**
20	Parameter5OutOfRangeNOK	**…**
21	Parameter6OutOfRangeOK	**…**
22	Parameter6OutOfRangeNOK	**…**
23	WrongCurrentReflector	Current Reflector type is not suitable in current context
24	NoCircleCenterFound	Applies to Circle Center measurement modes only. Failed to calculate the center (usually bad or not enough measurements)
25	NoSphereCenterFound	Applies to Sphere Center measurement modes only. Failed to calculate the center (usually bad or not enough measurements)
26	NoTPFound	Tracker Processor (Controller) not detected. Missing cable?
27	NoWeathermonitorFound	Tried to query meteo data from (missing or disabled) external meteo device
28	NoLastMeasuredPoint	Applies to command 'GoLastMeasuredPoint' only. No point has been measured yet since last system start.
29	NoVideoCamera	Tried to access Video functionality, but there is no overview video camera
30	NoAdm	Tried to access ADM functionality, but tracker is not equipped with an ADM
31	NoNivel	Tried to access Level functionality, while no inclination sensor (Nivel) is attached/enabled
32	WrongTPFirmware	Current firmware is not suitable for actual tracker/controller
33	DataBaseNotFound	Fatal installation problem on emScon server (SQL server not running or no DB attached)
34	LicenseExpired	The copy-protection Dongle has expired
35	UsageConflict	The issued command does not make sense in current context
36	Unknown	An unknown / not specified error has occurred
37	NoDistanceSet	Tried to measure HVD while IFM distance not set - use 'GoBirdBath' or 'GoPosition'/'FindReflector'
38	NoTrackerConnected	Tracker not recognized (cable connection problem?)
39	TrackerNotInitialized	Any command that throws this error requires the tracker being initialized first. Issue 'Initialize' command first.
40	ModuleNotStarted	Applies to a child-process: Transformation, OrientToGravity… Should normally not happen (hanging process?) System may require a reboot
41	ModuleTimedOut	Applies to a child-process: No response within reasonable time
42	ErrorReadingModuleDb	Fatal database failure (database file corrupt?)
43	ErrorWritingModuleDb	Fatal database failure (disk full?)
44	NotInCameraPosition	Video Camera cannot deliver image due wrong (mirror) position - use

		'ActivateCameraView'
45	TPHasServiceFirmware	Controller has service firmware loaded - system needs reboot
46	TPExternalControl	Controller is under external control, issued command currently not supported (reboot!)
47	WrongParameter8	8th parameter is invalid (not accepted, command failed)
48	WrongParameter9	**...**
49	WrongParameter10	**...**
50	WrongParameter11	**...**
51	WrongParameter12	**...**
52	WrongParameter13	**...**
53	WrongParameter14	**...**
54	WrongParameter15	**...**
55	WrongParameter16	**...**
56	NoSuchCompensation	Tried to set a compensation that does not exist. Use 'GetCopensations' to get list of valid/existing IDs
57	MeteoDataOutOfRange	Provided meteo data (temp, pressure, humidity) is out of accepted range
58	InCompensationMode	Command not allowed while system is in compensation mode
59	InternalProcessActive	Waiting for termination of a sub-process, similar to 'ServerBusy', try again later
60	NoCopyProtectionDongleFound	System requires a copy protection key (Dongle)
61	ModuleNotActivated	Current module not activated on Dongle
62	ModuleWrongVersion	Version of current module is not suitable / not up to date. Re-install server software
63	DemoDongleExpired	Get a new demo license or use a non-demo Dongle
64	ParameterImportFromProbeFailed	Probe attached (cable?) and power ON?
65	ParameterExportToProbeFailed	Probe attached (cable?) and power ON?
66	TrkCompMeasCameraMismatch	Selected Mechanical tracker compensation relates to a compensation with camera, but no one is mounted, or vice versa
67	NoMeasurementCamera	Tried to access 6DoF (T-Cam) functionality without having a camera mounted or recognized
68	NoActiveMeasurementCamera	6DoF camera (T-Cam) is not active
69	NoMeasurementCamerasInDb	(Selected) T-Cam is not present in Database (fatal error). Remove camera and remount it, then Re- Initialize
70	NoCameraToTrackerCompSet	The system has no active CameraToTracker compensation, use 'SetTCamToTrackerCompensation'
71	NoCameraToTrackerCompInDb	TCamToTracker compensation missing; import a suitable one, or perform a TCamToTracker compensation
72	ProblemStoringCameraToTrackerFactorySet	T-Cam hardware information not recognized ('plug and play') (fatal error)
73	ProblemWithCameraInternalCalibration	Something is wrong with camera calibration (fatal error, hardware problem?)

74	CommunicationWithMeasurementCameraFailed	Is the camera mounted correctly?
75	NoMeasurementProbe	The issued command relates to Probe functionality, but none is connected or online (Probe power on?)
76	NoActiveMeasurementProbe	The issued command relates to Probe functionality, but none is active
77	NoMeasurementProbesInDb	Probe hardware information not found ('plug and play') (fatal error). Try removing Probe and reconnect it.
78	NoMeasurementProbeCompSet	The system has no active Probe compensation, use 'SetProbeCompensation'
79	NoMeasurementProbeCompInDb,	Probe compensation missing; import a suitable one, or perform a Probe compensation
80	ProblemStoringProbeFactorySet	Hardware communication problem or database error (fatal error)
81	WrongActiveMeasurementProbeCompInDb	The available probe compensation does not match the attached probe
82	CommunicationWithMeasurementProbeFailed	Communication problem with probe (sometimes due to bad Illumination conditions)
83	NoMeasurementTip	Issued command requires a Tip/Stylus mounted to the probe
84	NoActiveMeasurementTip	The mounted Tip is not active (Perform a TipToProbe compensation?)
85	NoMeasurementTipsInDb	Tip/Stylus hardware information not found ('plug and play') (fatal error)
86	NoMeasurementTipCompInDb	Tip/Stylus compensation is missing; import a suitable one, or perform a TipToProbe/Stylus compensation
87	NoMeasurementTipCompSet	The issued command relates to Tip/Stylus functionality, but none is active
88	ProblemStoringTipAssembly	Hardware communication or database error (fatal error)
89	ProblemReadingCompensationDb	Database reading error (fatal)
90	NoDataToImport	Import (Probe) parameters: imported file does not contain suitable data
91	ProblemSettingTriggerSource	Hardware problem, or system is not equipped with trigger-board
92	6DModeNotAllowed	System is in a condition/configuration where 6DoF modes are not supported
93	Bad6DResult	System is able to measure 6DoF, but results are unreliable (Tilt angle excess of Probe, or not enough LEDs visible)
94	NoTemperatureFromWM	Tried to query a temperature value from external meteo station, but no response - is temperature sensor connected?)
95	NoPressureFromWM	Tried to query a pressure value from external meteo station, but no response - rarely happens since pressure device is integrated and cannot be removed)
96	NoHumidityFromWM	Tried to query a humidity value from external meteo station, but no response - there may be no humidity sensor connected)
97	6DMeasurementFace2NotAllowed	6DoF measurements by convention are only allowed in Face I; Use 'ChangeFace'

98	InvalidInputData	Similar to 'WrongParameter', but cannot exactly determine what's wrong
99	NoTriggerBoard	Tried to access Trigger Board features, but the system is not equipped with a Trigger board
10001	NoMeasurementShankCompSet	If we are in 'Shank' mode, measurements without shank compensation are not allowed
10002	NoValidADMCompensation	The issued command is not available without having a valid ADM compensation; import or perform a mechanical tracker compensation
10003	PressureSensorProblem	Pressure difference (from 2 internal sensors) too big
10004	MeasurementStatusNotReady	Tried to trigger a measurement while status was not (yet) ready

Remark: Range 100..9999 is reserved for Controller/Sensor Firmware errors (as listed in Appendices C and D), hence the gap between error #99 and #10001.

B2: TPI status values forwarded from special commands (sub- processes)

Remark: Not all of the errors listed below may be relevant to application programmers. The occurrence of some may be very unlikely. Note that symbols (other than those in section B1) are not available to application programmers by including certain files; they are listed for information only (in addition to comments)
Errors marked with 'F' are unanticipated fatalities and should not occur under normal conditions.
All the listed errors are **additional** errors to the ones listed in the section above; that is, any of the shared errors from section B1 might also apply to the special commands mentioned here.

B2.1 CallOrientToGravity command (reserved error-range: 20000..20999)

Number	**Symbol** (not exposed)	**Comments**
0	OTG_SUCCESS	Default status in case of command succeeded
20010	OTG_ERR_UNSOLICITED	An unsolicited error occurred
20011	OTG_ERR_INIT_SOCKET	Socket initialization failed (F)
20012	OTG_ERR_OLECOM_INIT	OLE/COM initialization failed (F)
20013	OTG_ERR_RESOURCE_READ	Reading resource string failed (F)
20014	OTG_ERR_SEND_DATA	Error on sending data (F)
20015	OTG_ERR_RECEIVE_DATA	Error on receiving data (F)
20016	OTG_ERR_RESPONSE_TIMEOUT	No answer within reasonable time
20017	OTG_ERR_SAVE_DATA	Error on saving results to database
20018	OTG_ERR_TOO_MANY_RETRIES	Too many retries due unstable Nivel liquid
20019	OTG_ERR_INVALID_SAMPLE_COUNT	Invalid count of samples specified (min 2, max 10) (F)
20020	OTG_ERR_BAD_COMMAND_ANSWER	There was a command answer other than OK
20021	OTG_ERR_OUT_OF_VALID_RANGE	(Some) Nivel results are out of valid range
20022	OTG_ERR_NIVEL_NOT_RESPONDING	No Nivel connected, or Nivel flagged off
20023	OTG_ERR_INVALID_MOUNTING_ARG	/POS270 or /POS90 expected as commandline argument (F)
20024	OTG_ERR_FORCED_TERMINATION	Process terminated from outside

B2.2 CallIntermediateCompensation command (reserved error-range: 23000..23999)

Number	Symbol (not exposed)	Comments
0	IMC_SUCCESS	Default status in case of command succeeded
23010	IMC_ERR_COMPNOTCALC	The intermediate compensation cannot be calculated due to incomplete input data
23011	IMC_ERR_OPEN_ESDB	Open database failed (F)
23012	IMC_ERR_READ_CRT_COMP	Reading current compensation from database failed
23013	IMC_ERR_SAVE_MEAS	Writing measurements to database failed
23014	IMC_ERR_NO_DRVPOINTS	No drive-points in database; Use AddDrivePoint command
23015	IMC_ERR_CREATE_COMP	Creation of compensation failed in database
23016	IMC_ERR_SAVE_COMP	Saving compensation to database failed
23017	IMC_ERR_READ_DRIVEPT	Reading drive points failed
23018	IMC_ERR_FULL_COMP_INWORK	A full compensation is in work - cannot continue
23019	IMC_ERR_DELETE_INWORK	Could not delete In-work compensation
23020	IMC_ERR_MEAS_TIMEOUT	Measurement Timeout
23021	IMC_ERR_SVR_GETTING	Getting tracker parameters failed
23022	IMC_ERR_SVR_SETTING	Setting tracker parameters failed
23023	IMC_ERR_POSITION_TIMEOUT	Timeout in Positioning (no reflector within searched range?)
23030	IMC_ERR_BAD_CMD_ANSWER	There was a command answer other than OK
23031	IMC_ERR_SEND_DATA	Sending data via TCP/IP failed (F)
23032	IMC_ERR_RECEIVE_DATA	Error on receiving data via TCP/IP (F)
23033	IMC_ERR_FORCED_TERMINATION	Process terminated from outside
23501	(no symbol)	At least one of the 3 calculated mechanical parameters is not in the range specified.
23502	(no symbol)	Too few (less than 2) measurements available. Calculation cannot be performed. Either not enough driving points, or not all could be found and/or measured.
23503	(no symbol)	Minimum vertical angle difference not met
23998	IMC_ERR_UNSOLICITED	An unsolicited error occurred
23999	IMC_ERR_UNKNOWN	Unknown error

Warning Flags

Warning flags are a special issue applicable to 'Automated Intermediate Compensation' [IMC] only. Warning flags are available upon a **successful** calculation. The parameter 'lWarningFlags' is a 32-bit integer value to be interpreted as a bit-mask. If the value is zero (none of the bits set), then the intermediate compensation process completed with no warnings at all. Otherwise, each raised bit means a particular warning. There can be more than one warning at a time. Here is the meaning of the particular bits:

Bit	Symbol (not exposed)	Comments
Bit 1 (0x1)	AverageVerticalTwoFaceErrorIsTooHigh	Tracker service (from Leica Geosystems personnel) is required because the vertical index is constantly > 1 Gon. There is currently no way for the user to reset the approximate index.
Bit 2 (0x2)	AtLeastOneVerticalTwoFaceErrorIsTooHigh	If Bit 1 not raised, there is probably a very high error within a single two-face measurement. If Bit 1 is raised too, ignore

		warning Bit 2.
Bit 3 (0x4)	AtLeastOneDistanceIsNotInRange	At least one of the distances is smaller than the minimum or larger than the maximum recommended distance, according to the recommendations.
Bit 4 (0x8)	NotEnoughMeasInTwoOppositeVerticalPlanesWithGoodDiffOfVerticalAngle	This warning covers all (except the range criterion) possible criteria, which are not fulfilled by the measurement configuration, according to the recommendations.
Bit 5 (0x10)	NotAllCorrectedDoubledTwoFaceErrorsAreWithinCompensationTolerance	Not all measurement residuals are within recommended tolerances.
Bit 6 (0x20)	NotAllMechanicalParametersAreInRange	Not all three (3) mechanical parameters calculated are within recommended tolerance (according to hardware specs).

B2.3 CallTransformation command (reserved error-range: 24000..24999)

Number	**Symbol** (not exposed)	**Comments**
0	TRAFO_SUCCESS	Default status in case of command succeeded
24010	TRAFO_ERR_OLECOM_INIT	OLE/COM initialization failed (F)
24011	TRAFO_ERR_RESOURCE_READ	Reading resource string failed (F)
24012	TRAFO_ERR_READ_DATA	Error on reading input data from database (F)
24013	TRAFO_ERR_SAVE_DATA	Error on saving results to database (F)
24020	TRAFO_ERR_FIT_FAILED	Least Square Fit failed
24021	TRAFO_ERR_INITIALFIT_FAILED	Initial approximation for Fit failed
24022	TRAFO_ERR_TOOMANYUNKNOWNNOMINALS	Too many unknown nominals
24023	TRAFO_ERR_MULTIPLESOLUTIONS	Multiple solution

C. TRACKER ERROR NUMBERS

The error numbers that are sent with answers are all a three digit number. The first digit indicates the category of the error condition that is reported. These are:

1XX	System errors.
2XX	Communication errors
3XX	Parameter errors.
4XX	LCP hardware errors.
5XX	ADM hardware errors.
6XX	Hardware error in the TP, repair by service personnel (additional range to 9XX)
7XX	Operation errors.
8XX	Hardware configuration error, repair by user.
9XX	Hardware error in the TP, repair by service personnel.

C.1 System Errors

101	Program too large for BOOT to load.
102	Program failed, reload or reboot.
103	Invalid command.
104	Boot command unable to open file in RAM disk
105	Boot process interrupted by command
110	Calibration not set.
111	Tracker not initialized.
112	reserved
113	Calibration parameters sent to the wrong tracker.
114	Target not defined (target offset for ADM measurement)
115	No Compensation for ADM
116	No Tracker Compensation with T-Cam
121	TP.PGM Software running on a LT Controller
122	LT.PGM Software running on a SMART310 Tracking Processor
123	Boot failed, firmware file has invalid signature for LT Controller plus/base
130	ADM not available
131	Video Camera not available
132	Beam expander lens for radial searching not available
133	Nivel not available
134	TCAM not available
135	Probe not available
136	Probe Tip not available
137	Additional Compensation Tool not available
150	FlashDisk, file creation error
151	FlashDisk, file delete error
152	FlashDisk, disk full
153	FlashDisk, file write error
154	FlashDisk, file read error
199	Command not implemented.

C.2 Communication Errors

201	Overflow of input buffer.
202	Communications timeout, the string is not completed within time period.
203	Frame error, the format of the received string is not correct.

205	LAN communication too slow, TP runs out of recourses (buffers).
206	LAN name conflict (more than one station with equal names online)
207	LAN, no session established between AP and TP
210	Communications between TP and Laser Control Processor (LCP) has failed.
211	Laser Controller/ADM/AIFM communication error
212	Laser Controller/ADM/AIFM communication timeout
213	Laser Controller/ADM/AIFM communication busy, no resources available
221	Communications between TP and ADM has failed
222	Communications between TP and Nivel20 has failed
225	Laser Controller/ADM/AIFM communication, answer buffer too small
231	TCAM communication failed
232	TCAM communication timeout
233	TCAM busy
241	Probe communication failed
242	Probe communication timeout
243	Probe busy
251	Probe Tip communication failed
252	Probe Tip communication timeout
253	Probe Tip busy
261	Additional Compensation Tool communication failed
262	Additional Compensation Tool communication timeout
263	Additional Compensation Tool busy
299	Unknown Device

C.3 Parameter Errors

3xx	Invalid value for parameter xx, where xx is the number of the parameter. The number of the parameter depends on the command.
399	Several parameters are invalid.

C.4 Laser Control Processor HW Errors

401	LCP has no firmware loaded.	
402	Invalid Tracker Serial Number stored on the LCP	
403	Command not supported by the LCP	
404	LCP serial number key failed. Error reading silicon ID number.	
405	LCP serial number key failed. Tracker serial number, tracker model and silicon ID number do not match.	
406	INVALID_COMMAND	(former: 103)
407	NOT_IMPLEMENTED	(former: 199)
408	COMMAND_WRONG_CONTEXT	(former: 104)
409	PARAM_NR_FALSE	(former: 300)
410	INTERNAL_CMD_ERROR	(former: 114)
411	WRITE_ERROR	(Lockbit active: -> write protected)
412	LB_ERROR_ARG1	(Lockbit: unknowm function)
413	TO_MANY_PARAMS_PER_FRAME	
414	WRONG_STORAGE_MODIFIER	
420	COM_FRAME_ERROR	(former: 203)
430	+15 Power Supply failed	
431	On Board +5V digital Power Supply failed	
432	On Board +5V analog Power Supply failed	
433	On Board +3.3V digital Power Supply failed	

434	On Board +4.096V reference Voltage failed
435	Peltier Check failed
436	Single Fault Diode cable not connected
437	Peltier cable not connected
438	Laser Power Supply cable not connected
439	Laser Temperature Sensor is not working
440	Air in Temperature Sensor is not working
441	Heatsink Temperature Sensor is not working
442	Air out Temperature Sensor is not working
449	Unknown hardware error
460	Laser current failed
461	Laser Off-Spike detected
462	Laser Mode Light failed, not enough light
463	Polarisation error to high
464	No minimum light value detected
465	Laser Mode Hopping -> Warmup changed to Temperature Mode
480	TIMEOUT: Laser Modecounting failed
481	TIMEOUT: Laser unable to stabilize
485	TIMEOUT: Looptimer stopped, -> Watchdog
499	Unknown error

C.5 Absolute Distance Meter HW Errors

501	ADM has no firmware loaded.
502	Set frequency not locked.
503	Set frequency, illegal state (internal software error)
504	Measurement cycles exceeded
505	Reserved
506	Illegal state (internal software error)
507	Minimum lost, unstable measurement conditions
508	Reserved
509	Start failed, hardware error
510	Reserved
511	Band scanning failed
512	Frequency unstable
513	No RF current
514	Frequency current error
515	Security timeout, maximal measurement time exceeded
516	Security lock, no light from Interferometer
517	Invalid distance
518	Emergency Power Output Lock,
519	Measurement aborted by user/Application
...	
550	Light polarization during ADM measurement too unstable (happens normally only on large entry angles into prisms)
551	ADM measurement, distance difference of double measurement out of tolerance
552	ADM measurement, invalid temperature
...	
597	ADM communication, frame error
598	ADM –LTC communication, internal software error
599	unknown ADM error

C.6 Hardware Error (additional error numbers to the 9xx group)

600	
601	Motor Amplifier, digital Poti set invalid
602	Motor Amplifier, digital Poti access error
603	Motor Amplifier, I^2C-Bus failed
604	LTCplus/base, front panel cable not connected
605	LTCplus/base, fan cable not connected
606	LTCplus/base, video output cable not connected
607	LTCplus/base, frame grabber video cable not connected (emScon side)
608	LTCplus/base, PC backplane to Motor Amplifier cable not connected
609	Motor Amplifier, motor power (28V) Watchdog has locked
610	Beam expander lens not in parking position (moved out of the beam).
611	Beam expander lens not able to move into the beam.
614	Hardware error, PSD offset measurement misses points
615	Collar reflector measurement, X range error
616	Collar reflector measurement, Y range error
617	Collar reflector measurement, target lost
620	IFM fail signal shows always ok (also in cases where the beam is not on a target)
621	IFM count not stable (counting error during servo control point measurement)
622	Synchronisation line ADM to TP failed
623	Synchronisation line TP to ADM failed
625	Hardware error, no LTC/ATC card found
626	Hardware error, old version of LTC/ATC card
630	Serial port COM1: not available
631	Serial port COM1: hardware failure
632	Serial port COM1: reserved
633	Serial port COM2: not available
634	Serial port COM2: hardware failure
635	Serial port COM2: reserved
636	Serial port COM3: not available
637	Serial port COM3: hardware failure
638	Hardware error, Interrupt of COM Port 3 and 4 not working
639	Hardware error, COM Port 4 not installed
640	No Trigger Card
641	No internal TCAM/Probe cable
642	No internal Trigger I/O cable
643	No Cable Trigger to Mot.Amp.Card
644	Incompatible program on Trigger Card (FPGA)
645	No Packet Driver installed for T-Cam communication
650	Motor Amplifier Card hardware error, incompatible motor amplifier board
651	Motor Amplifier Card hardware error, IDE bus error
652	Motor Amplifier Card hardware error, encoder cable not connected
653	Motor Amplifier Card hardware error, motor phasing error
654	Motor Amplifier Card hardware error, motor phasing timeout
655	Motor Amplifier Card hardware error, no digital poti setting for encoder interface on the motor amplifier card
656	Motor Amplifier Card hardware error, incompatible firmware
657	Motor Amplifier Card hardware error, parameter set not available
658	Motor Amplifier Card hardware error, parameter set invalid
659	Motor Amplifier Card hardware error, parameter set doesn't match with motor topology
660	Motor Amplifier Card hardware error, amplifier over temperature
661	Motor Amplifier Card hardware error, 28V power supply under voltage
662	Motor Amplifier Card hardware error, AZ motor over current
663	Motor Amplifier Card hardware error, EL motor over current
690	AT901x Sensor, Bottom Board cable not connected
691	AT901x Sensor, EL spiral cable not connected

692	AT901x Sensor, Az Axis cable not connected
693	AT901x Sensor, internal NIVEL cable not connected
694	AT901x Sensor, internal Probe cable not connected
699	Sensor/Motor cable length measurement error

C.7 Operation Errors

701	Target lost, tracking has failed.
702	Interferometer has failed, lost count.
703	Azimuth limit has been reached. The tracker head has attempted to go beyond the ±240 degrees.
704	Elevation limit has been reached.
705	Positioning timeout, positioning of the tracker head could not be completed within the timeout period.
706	Abort command.
707	invalid angle on the azimuth axis.
708	invalid angle on the elevation axis.
710	Radial speed is within bounds. (Sent after a speed warning when the speed has returned to acceptable bounds.)
711	Radial speed warning. This is a warning that the movement of the reflector in the radial direction is approaching the speed limit.
712	Radial speed error. This indicates that the radial speed has exceeded the capacity of the interferometer and there is a likely loss of accurate distance setting.
720	Intensity overflow on photosensor. This error occurs, if the intensity value from the photosensor exceeds the range of the A/D converter. The TP will change the A/D range automatically.
721	Laser light mode has jumped. This means the laser control loop wasn't able to stabilize the laser tube. (This can be caused by a fast and large temperature change).
722	Laser stabilization in progress, wait until the laser is stable before tracking.
723	Laser is unable to stabilize.
724	Laser light is switched off.
731	Reflector too close to the Tracker for measuring the distance with the ADM.
732	ADM gets no signal from the reflector
733	ADM measuring timeout, the communication with the ADM is working, but there is no completed measurment within a certain time by the ADM.
734	Target was not stable during the ADM measurement
735	Reflector too far from the Tracker to measure the distance with the ADM.
736	Distance measured by the ADM is invalid, out of range
	reserved
740	3D measurement on 6DoF-Probe not allowed
	reserved
760	TCAM vertical drive not initialized
761	TCAM zoom not initialized
762	TCAM no Synchronization Signal
763	TCAM zoom out of Range (1.5...15m)
764	TCAM overload stop in vertical drive
765	TCAM positioning timeout, didn't get on track in a certain time
766	Probe communication timeout, we see markers but don't get any Info from Probe
767	TCAM frame grabber error
768	TCAM marker identification error
769	Probe during ADM and 6DoF logon process not stable
770	Laser entry angle on Probe out of range for logon with the ADM
771	Probe recognize error from T-Cam
772	Probe model load to T-Cam error
773	Prism model load error in LTC
774	Probe model invalid or unsuitable to device

C.8 Hardware Configuration Errors (user correctable)

801	Power switch from the rack is off.
802	Power switch for tracker motor is off.
810	Cables from TP to the rack are not connected.
811	DA-cable from TP to the rack is not connected.
812	Encoder-cable from TP to the rack is not connected.
813	Communication from the TP to the rack is not connected.
820	Cables from the rack to the sensor tube are not connected.
821	TCAM cable from LTCplus to sensor tube not connected
822	Cable connection error, T-CAM cable connected with an AT901 tracker
831	Azimuth index offset is not suitable for this measuring head.
832	Elevation index offset is not suitable for this measuring head.
841	Azimuth encoder interpolation rate wrong
842	Elevation encoder interpolation rate wrong
843	An new LT/LTD500 Sensor in use with an old SMART310 Controller/TP, not compatible!
844	An old SMART310 Sensor in use with the new LT Controller, it is not compatible.
845	An old SMART310 Sensor cable is in use, it isn't compatible with the new LT Controller and LT/LTD500 Sensor.
846	LTD600/700/800 sensor connected to a classic (LTD500) controller
847	TCAM not compatible with Tracker (LTD7/800 mixed with TCAM8/700)
848	Incompatible T-CAM, LT Controller and/or Tracker combination
850	TCAM on tracker head not locked
851	Incompatible, LT/AT Controller and Tracker combination
852	Incompatible firmware for LT/AT Controller and Tracker
853	Motor amplifier uP in service mode
854	AT901, Quick release open error

C.9 Hardware Error (requires service personnel)

901	Azimuth axis is not working.
902	Elevation axis is not working.
903	Azimuth Tacho signal failed.
904	Elevation Tacho signal failed.
905	Azimuth encoder is not working.
906	Elevation encoder is not working.
907	Azimuth index mark does not respond.
908	Elevation index mark does not respond.
909	Azimuth moving range limited (can not move +/- 240 degrees).
910	Photo sensor is not working properly.
911	Photo sensor does not receive enough light.
912	Photo sensor intensity signal failed
913	Photo sensor X signal failed
914	Photo sensor Y signal failed
915	Calculation error while determining the SERVO CONTROL POINT.
916	No collar reflector found for measuring the servo control point. (or the beam intensity is not strong enough to locate the collar reflector.).
917	Laser unable to stabilize, hardware error on the laser detected.
918	Interferometer is not working properly. (eg, at test into the collar reflector did not work)
919	'Lost counts' signal of the interferometer is not working properly.
921	LAN, Command line switch error.
923	No LANtastic hardware detected.
924	LAN, Shared RAM did not pass tests.

925	LAN Coprocessor did not respond to reset.
927	LAN, Interrupt level error.
930	No encoder board detected.
931	Encoder board, Azimuth counter is not working.
932	Encoder board, Elevation counter is not working.
933	Encoder board, Interferometer counter is not working.
934	Encoder board, Azimuth index pulse failed.
935	Encoder board, Elevation index pulse failed.
936	Encoder board, Latch signal for counters failed.
937	Encoder board, disabling of index pulses failed.
938	Encoder board, cannot switch on the receiver for index pulses.
939	Encoder potentiometer adjustments, invalid.
940	No A/D board detected.
941	A/D board, Unipolar/Bipolar switch is set wrong.
942	A/D board, 8/16 channel switch is set wrong.
943	A/D board, Analog input multiplexor error.
944	A/D board, A/D converter is not working.
945	A/D board, DMA data transfer is not working.
946	A/D board, onboard clock is not working.
947	A/D board, Pacer clock too slow, switch is set wrong.
948	A/D board, Pacer trigger is not working.
949	A/D board, External trigger is not working.
950	A/D board, A/D voltage range switch is not working.
951	A/D board, A/D input offset is out of tolerance.
952	A/D board, DMA transfer synchronization error.
953	A/D board, Ref. Voltage Jumper for DAC in wrong position
954	D/A board, zero point of DAC out of tolerance
955	D/A board, both axes not working.
956	D/A board, Azimuth axis not working.
957	D/A board, Elevation axis not working.
958	Azimuth motor amplifier balance not properly adjusted.
959	Elevation motor amplifier balance not properly adjusted.
960	reserved
961	CPU board, DMA controller failed.
962	CPU board, DMA controller wrap around error
963	reserved
964	CPU board, CPU clock too slow.
968	CPU board, not enough memory for dynamic memory allocation.
969	reserved
970	LTC, internal PSD input cable not connected.
971	LTC, internal Motor I/O cable not connected.
972	LTC Digital I/O cable not connected.
973	LTC, COM1 cable not connected
974	LTC, COM2 cable not connected
975	LTC, Az Encoder Cable not connected
976	LTC, El Encoder cable not connected
977	LTC, Cable between A/D board and LTC card not connected
978	LTC, HW Trigger cable LTC card to Encoder card not connected
979	LTCplus, Encoder Latch Cable, Motor Amplifier to Encoder Card not connected
980	LTC, +5V Power Supply failed
981	LTC, +7V Power Supply failed
982	LTC, +12V Power Supply failed
983	LTC, +28V Power Supply failed
984	LTC, -5V Reference voltage failed
985	LTC, -7V Power Supply failed
986	LTC, -12V Power Supply failed
987	LTC, Inhibit of 28V Power Supply not working
988	LTC, +15V Power Supply failed
989	LTC, -15V Power Supply failed
990	LTC, Tacho Power Supply failed (located in the measuring head)

991	LTC, 2.5/3.3V Supply failed on LTC Card
992	LTCplus, +5V Supply failed on Motor Amplifier
993	LTCplus, +12V Supply failed on Motor Amplifier
994	LTCplus, -12V Supply failed on Motor Amplifier
995	LTCplus, +3.3V Supply failed on Tracker Server (emScon)
996	LTCplus, +12V Supply failed on Tracker Server (emScon)
997	LTCplus, -12V Supply failed on Tracker Server (emScon)
998	LTCplus, Power for FAN's on Front Panel failed
999	Unknown hardware error.

D. T-Cam / T-Probe ERROR NUMBERS

Unique ID	Text
2150	MSGERR: ERROR, message table inconsistent (entry: %d)!
2151	MSGERR: ERROR, attachement ring buffer overrun!
2200	PARMGR: MESSAGE, New parameter initialisation!
2201	PARMGR: ERROR, CRC on parameter table!
2202	PARMGR: ERROR, not allowed range for this parameter!
2203	PARMGR: ERROR, unknown parameter id!
2204	PARMGR: REMARK, parameter table is full!
2205	PARMGR: WARNING, table size defined in code and that saved in flash differs
2206	PARMGR: WARNING, error occure during load!
2207	PARMGR: ERROR, error occure during save!
2208	PARMGR: ERROR, invalid command parameter !
2210	PARTBL: ERROR, flash table not found
2211	PARTBL: ERROR, invalid table block number!
2212	PARTBL: ERROR, invalid table data!
3000	CMDI: ERROR, unknown keyword!
3003	CMDI: ERROR, not allowed command in this mode!
3004	CMDI: ERROR, to long string parameter!
3050	DCSC: ERROR, wrong value for T-Cam mode!
3052	DSPHL: ERROR, timeout during V_INIT command
3054	DSPHL: ERROR, timeout during V_INFO command !
3110	TGT: Command parameter invalid - command not executed
3111	TGT: FGIF data invalid – data block discarded
3112	TGT: Section list overflow – line discarded
3113	TGT: Invalid image item – data item skipped
3114	TGT: Objects per line overflow – further objects discarded
3115	TGT: Objects in total overflow – further objects discarded
3116	TGT: Too many objects surrounding feature - feature not tracked
3117	TGT: Timeout in TGT extraction
3150	VTT: ERROR, invalid angle!
3151	VTT: ERROR, invalid distance!
3153	VTT: ERROR, invalid command parameter!
3154	VTT: ERROR, command not allowed!
3156	VTT: ERROR, timeout command function!
3157	VTT: ERROR, mode changing not possible!
3158	VTT: ERROR, error during V_OFFSET procedure!
3200	DARK: ERROR, timeout while getting image!
3203	DARK: ERROR, timeout of blende command
3204	DARK: ERROR, camera access error !
3205	DARK: ERROR in a state!
3300	DIFF: ERROR, timeout while getting image!
3301	DIFF: ERROR in a state!
4000	COM: WARNING, too many active ethernet clients
4001	COM: WARNING, ethernet client id not found
4010	COM: ERROR, ethernet module already initialized!
4011	COM: ERROR, init of the ethernet module failed!
4012	COM: ERROR, trying to access ethernet module in uninitialized state!
4013	COM: ERROR, receiving error occurred (error code %u)!
4014	COM: ERROR, transmit error occurred (error code %u)!

Unique ID	Text
4015	COM: ERROR, transmit buffer is too big for appending!
4050	FGIF: ERROR, image memory overflow!
4051	FGIF: ERROR, image data not picked up!
4052	FGIF: ERROR, command not allowed!
4053	FGIF: ERROR, invalid command parameter!
4054	FGIF: ERROR, timeout command function!
4055	FGIF: ERROR, 100Hz synchronisation failure!
4056	FGIF: ERROR, FPGA watchdog failure!
4057	FGIF: ERROR, FPGA data overflow error!
4058	FGIF: ERROR, GBPS data failure!
4059	FGIF: ERROR, GBPS synchronisation error!
4060	FGIF: ERROR, mailbox overflow in full picture mode!
4100	MOT: ERROR, encoder failure!
4101	MOT: ERROR, wrong encoder counter direction!
4102	MOT: ERROR, motor controller failure!
4103	MOT: ERROR, motor unit is blocked or braked!
4104	MOT: ERROR, reflexion sensor failure!
4105	MOT: ERROR, unknown error in open loop check!
4106	MOT: ERROR, function call not allowed!
4107	MOT: ERROR, standstill error while closed loop check!
4108	MOT: ERROR, timeout during closed loop check!
4109	MOT: ERROR, timeout during reference search!
4110	MOT: ERROR, no index position found!
4111	MOT: ERROR, no cable feedback signal!
4112	MOT: ERROR, encoder status error!
4113	MOT: ERROR, encoder signal error!
4114	MOT: ERROR, over temperature on sensor 0!
4115	MOT: ERROR, over temperature on sensor 1!
4116	MOT: ERROR, over current on motor 0!
4117	MOT: ERROR, over current on motor 1!
4150	PROBE: ERROR, wrong command parameter!
4200	ZFCI: INFO, zoom controller is connected again to the DSP
4210	ZFCI: ERROR, no zoom controller connected to the DSP!
4211	ZFCI: ERROR, dsp-avr synchronisation error!
4212	ZFCI: ERROR, checksum failure!
4213	ZFCI: ERROR, incorrect flash or eeprom address!
4214	ZFCI: ERROR, flash or eeprom address already written!
4215	ZFCI: ERROR, zoom controller reports an error - command not executed!
4216	ZFCI: ERROR, command may not be executed at the moment!
4217	ZFCI: ERROR, invalid command parameter!
4218	ZFCI: ERROR, wrong ZFC answer!
4250	FLASH: REMARK, space in err/log message sector is running out
4251	FLASH: REMARK, err/log message sector erased successfully
4260	FLASH: ERROR, err/log message sector erase failed!
4261	FLASH: ERROR, writing of a err/log message failed!
4350	SPI: ERROR, Receive timeout occurred!
4351	SPI: ERROR, Transmit channel not ready!
4400	SYNCH: ERROR, No external synch input received!
4450	CCIR: ERROR, invalid command parameter!
4500	FLTABHD: REMARK, parameter table is empty!
4501	FLTABHD: REMARK, recovery of the corresponding table failed!
4502	FLTABHD: WARNING, read parameter table is not valid!

Unique ID	Text
4510	FLTABHD: ERROR, FLASH write error!
4511	FLTABHD: ERROR, FLASH read error!
4512	FLTABHD: ERROR, reset of a parameter table failed!
4513	FLTABHD: ERROR, module initialization failed or was not done!
4514	FLTABHD: ERROR, malloc error occurred!
4515	FLTABHD: ERROR, parameter table write error (crc check was not successful)!
4516	FLTABHD: ERROR, sector erase error!
4550	CAM: ERROR, invalid Z_CAMCOM answer!
4551	CAM: ERROR, no valid camera FPGA version!

E. AIFM Error IDs

Upon an above command the AIFM can report the following errors:

ID	Error Text	Exception Type	Triggered in Module
	general aifm errors	**AifmException**	
7000	no interferometer available	AifmException	CommandOld
7001	unknown spiral-cable state	AifmException	CommandOld
7002	unknown CBL_CHK_NIV state	AifmException	CommandOld
7003	unknown CBL_CHK_PRB state	AifmException	CommandOld
7004	unknown Quick-Release state	AifmException	CommandOld
7005	checksum error	AifmException	CommandOld
7006	invalid temperature	AifmException	CommandOld
7007	undefined feature table request	AifmException	CommandOld
7099	undefined	AdmException	indefinite
	adm errors	**AdmException**	
7100	flap motor failed	AdmException	Flap00
7101	flap not initialized	AdmException	Flap00
7102	flap not initialized, no free resources	AdmException	Flap00
7103	positioning error, flap possibly jammed	AdmException	Flap00
7104	flap positioning error, faulty hardware	AdmException	Flap00
7105	cannot start EOM test, invalid mode	AdmException	Flap00
7106	EOM test in progress or incorrect parameters	AdmException	Flap00
7130	resonator not calibrated	AdmException	Resonator00
7131	calibration flap position timeout	AdmException	Resonator00
7132	flap during flap calibration out of range	AdmException	Resonator00
7133	flap calibration amplitude jump error due to flap vibraions	AdmException	Resonator00
7134	flap calibration amplitude overflow	AdmException	Resonator00
7135	calibration maximum not found	AdmException	Resonator00
7136	calibration frequency-position polynom fit failed	AdmException	Resonator00
7137	calibration position-amplitude polynom fit failed	AdmException	Resonator00
7138	flap position timeout	AdmException	Resonator00
7139	max flap pos too large	AdmException	Resonator00
7140	max flap pos too small	AdmException	Resonator00
7141	flap consistency suspicious	AdmException	Resonator00
7160	error on param initializing: pllFrequency	AdmException	Adm00
7161	error on param initializing: sweepFlap	AdmException	Adm00
7162	error on param initializing: ddsFrequency	AdmException	Adm00
7163	error on param initializing: sweepStart	AdmException	Adm00

7164	error on param initializing: sweepEnd	AdmException	Adm00
7165	flap calibration table initialize error	AdmException	Adm00
7166	invalid argument	AdmException	Adm00
7167	distance invalid	AdmException	Adm00
7168	max loop count exceeded in wobble minimum search	AdmException	Adm00
7169	only one minima found (distance too small)	AdmException	Adm00
7170	no minima found (distance too small)	AdmException	Adm00
7171	flap calibration table read item error	AdmException	Adm00
7172	fine low frequency out of range	AdmException	Adm00
7173	fine high frequency out of range	AdmException	Adm00
7174	*sweep: did not find 2 minimas*	*AdmException*	*Adm00*
7175	sf overflow error	AdmException	Adm00
7176	sf level too small	AdmException	Adm00
7177	read sweep values are not valid --> semaphore error	AdmException	Adm00
7178	no adm signal available	AdmException	Adm00
7179	adm signal too weak	AdmException	Adm00
7180	distance too large (restricted by the system)	AdmException	Adm00
7181	distance too small (restricted by the system)	AdmException	Adm00
7190	laser output level (persistency value) too large	AdmException	Lasercontrol00
7191	laser target sf value (persistency value) too large	AdmException	Lasercontrol00
7199	undefined	AdmException	indefinite
	persistence errors	**PersistException**	
7200	Software error (usually indicates not implemented items)	PersistException	Storage or Stream
7201	Invalid directory name (name longer than 28 char, or contains blanks, or an invalid character [`*\\\|/:\"?<>=])	PersistException	Storage
7202	Invalid file name (name longer than 28 char, or contains blanks, or an invalid character [`*\\\|/:\"?<>=])	PersistException	Storage
7203	Invalid property flags for persist parameter specified	PersistException	Storage
7204	Invalid storage (fatal FS or flash failure)	PersistException	Storage
7205	Invalid stream (fatal FS or flash failure)	PersistException	Storage
7206	Index access violation	PersistException	Storage
7207	Internal to external type- mapping failure	PersistException	Storage
7208	Dynamic memory allocation failure (fatal)	PersistException	Storage
7209	Could not query parameter description	PersistException	Storage
7210	Tried to write a hardcoded parameter to disk	PersistException	Storage
7250	Creation of directory failed (fatal FS or flash failure)	PersistException	Storage
7251	Removing of an (empty!) directory failed (fatal)	PersistException	Storage
7252	Opening file failed	PersistException	Storage

7253	Writing (to previously opened) file failed	PersistException	Stream
7254	Reading (from previously opened) file failed	PersistException	Stream
7255	Creating file failed	PersistException	Storage
7260	Creation of working data (tree) copy failed	PersistException	Storage
7261	Copying working data tree to master tree failed	PersistException	Storage
7262	Packing of Tree into file (for export) failed	PersistException	Storage
7263	Unpacking imported file failed (import)	PersistException	Storage
7270	Thread (for Commit, Rollback, and Reset) did not terminate successfully. Either copying disk- data (Commit, Rollback) or deleting data (Reset) failed; Or reloading parameters after a Rollback failed (most likely for load() methods that contain hardware init stuff). Notice that after a Rollback the load() method of every module is being called!	PersistException	Storage
7271	Tried to start a 2nd thread before already running one was terminated. Only one thread (Commit, Rollback, Reset) is allowed.	PersistException	Storage
7272	Synchronisation (by using semaphore) between main and secondary thread failed	PersistException	Storage
7299	undefined	PersistException	indefinite
	ifm errors	**IfmException**	
7300	gain value too large	IfmException	Interferometer
7301	wrong temperature sensor id	IfmException	Interferometer
7399	undefined	IfmException	indefinite
	devapi errors	**DevApiException**	
7499	undefined	DevApiException	indefinite
	sensor errors	**SensorException**	
7500	can't write the serial number	SensorException	TrackerTypeManager
7501	can't read the serial number	SensorException	TrackerTypeManager
7502	can't access id chip	SensorException	TrackerTypeManager
7503	crc error in id chip	SensorException	TrackerTypeManager
7504	can't write tracker type	SensorException	TrackerTypeManager
7505	can't write tracker type key	SensorException	TrackerTypeManager
7506	can't read tracker type	SensorException	TrackerTypeManager
7507	can't read tracker type key	SensorException	TrackerTypeManager
7508	unknown tracker	SensorException	TrackerTypeManager
7509	invalid file transfer compression	SensorException	FileTransfer
7599	undefined	SensorException	indefinite

Whether building the fastest car, the biggest plane or the most precise tooling, you need exact measurements to improve quality and productivity. So when it has to be right, professionals trust Leica Geosystems metrology products to help collect, analyze and present 3-dimensional (3D) data for industrial measurement.

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