

**Earth Explorer
Mission CFI Software**

**EXPLORER_LIB
SOFTWARE USER MANUAL**

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Issue	Change Description	Date	Approval
1.0	New document	08/11/01	
1.1	Updated Time Transformation functions	04/02/02	
1.2	Updated the following functions: xl_change_cart_cs, xl_geod_to_cart, xl_cart_to_geod, xl_kepl_to_cart, xl_cart_to_kepl, xl_sun, xl_moon, xl_planet, xl_star_radec, xl_geod_distance, xl_time_ref_init_file, xl_time_ref_close. The xl_attitude_cs function has been removed and replaced by xp_attitude in the EXPLORER_POINTING library.	15/04/02	
1.3	Added xl_time_get_leap_second_info	19/07/02	
2.0	Maintenance release. See change bars.	29/11/02	
2.1	Maintenance release. See change bars.	13/05/03	
2.2	Added xl_default_sat_init function.	30/09/03	
3.0	New initialisation strategy and interfaces	21/07/04	
3.1	Maintenance Release. New functions: xl_get_rotation_angles, xl_get_rotated_vectors, xl_position_on_orbit	13/10/04	
3.2	Maintenance release. See change bars.	15/11/04	
3.3	Maintenance release. New features: - Changes for dealing with the new library explorer_datan_handling - Identifier accessors. - OBT to UTC conversion for ADM and SMOS - Support for ENVISAT ASCII files removed	11/07/05	
3.4	Maintenance release. New function xl_default_sat_close.	18/11/05	

Issue	Change Description	Date	Approval
3.5	Maintenance release. New features for xl_time_ref_init_file. New features for xl_change_cart_cs New functions prototypes: - xl_cart_to_radec - xl_radec_to_cart - xl_star_catalog - xl_topocentric_to_ef - xl_ef_to_topocentric	26/05/06	
3.6	Maintenance release. New features: - xl_change_cart_cs - SMOS UTC proteus time format - Parameters for SENTINEL-1 New functions implemented: - xl_euler_to_matrix and xl_matrix_to_euler - xl_cart_to_radec and xl_radec_to_cart - xl_star_catalog - xl_topocentric_to_ef and xl_ef_to_topocentric	24/11/06	
3.7	<ul style="list-style-type: none"> • Maintenance release • New features: <ul style="list-style-type: none"> - Function expcfi_check_libs - Library version for MAC OS X on Intel (32 and 64-bits) 	13/07/07	
3.7.2	<ul style="list-style-type: none"> • Maintenance release • New features: <ul style="list-style-type: none"> - Parameters for SENTINEL-2, SENTINEL-3 and SEOSAT - Generic Satellite 	31/07/08	
3.7.3	<ul style="list-style-type: none"> • Maintenance release • New features: <ul style="list-style-type: none"> - Time initialization with list of files - Time initialization with OSF 	07/05/10	
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1 SCOPE

The EXPLORER_LIB Software User Manual provides a detailed description of usage of the CFI functions included within the EXPLORER_LIB CFI software library.

2 ACRONYMS AND NOMENCLATURE

2.1 Acronyms

ANX	Ascending Node Crossing
AOCS	Attitude and Orbit Control Subsystem
ASCII	American Standard Code for Information Interchange
BOM	Beginning Of Mission
CFI	Customer Furnished Item
EOM	End Of Mission
ESA	European Space Agency
ESTEC	European Space Technology and Research Centre
GPL	GNU Public License
GPS	Global Positioning System
IERS	International Earth Rotation Service
I/F	Interface
LS	Leap Second
OBT	On-board Binary Time
OSF	Orbit Scenario File
SRAR	Satellite Relative Actual Reference
SUM	Software User Manual
TAI	International Atomic Time
UTC	Coordinated Universal Time
UT1	Universal Time UT1
WGS[84]	World Geodetic System 1984

2.2 Nomenclature

<i>CFI</i>	A group of CFI functions, and related software and documentation. that will be distributed by ESA to the users as an independent unit
<i>CFI function</i>	A single function within a CFI that can be called by the user
<i>Library</i>	A software library containing all the CFI functions included within a CFI plus the supporting functions used by those CFI functions (transparently to the user)

3 APPLICABLE AND REFERENCE DOCUMENTS

3.1 Applicable Documents

[GEN_SUM] Earth Explorer Mission CFI Software. General Software User Manual. EE-MA-DMS-GS-0002. Issue 3.7.4 11/01/2011

3.2 Reference Documents

[MCD] Earth Explorer Mission CFI Software. Conventions Document. EE-MA-DMS-GS-0001. Issue 1.0 27/10/09.

[MSC] Earth Explorer Mission CFI Software. Mission Specific Customizations. EE-MA-DMS-GS-0018. Issue 1.0 27/10/09.

[F_H_SUM] Earth Explorer Mission CFI Software. EXPLORER_FILE_HANDLING Software User Manual. EE-MA-DMS-GS-0008. Issue 3.7.4 11/01/2011.

[D_H_SUM] Earth Explorer Mission CFI Software. EXPLORER_DATA_HANDLING Software User Manual. EE-MA-DMS-GS-0007. Issue 3.7.4 11/01/2011.

[IERS] <http://www.iers.org/iers/publications/bulletins/>

4 INTRODUCTION

4.1 Functions Overview

This software library contains all low-level generic routines, supporting all the other CFI functions. The following CFI functions are included:

4.1.1 Time Computations

All time time computations are performed internally using the continuous TAI time reference. Therefore the input and output parameters are converted internally to the adequate time reference.

4.1.1.1 Time Reference Transformations Initialization

- **xl_time_ref_init_file**: initializes time correlations between TAI, UTC, UT1 and GPS times from reference data files.
- **xl_time_ref_init**: initializes time correlations between TAI, UTC, UT1 and GPS times from input reference times.
- **xl_time_close**: cleans up any memory allocation performed by the initialization functions.
- **xl_time_get_leap_second_info**: retrieves the leap second location (if any) in the initialised time range.

4.1.1.2 Time Format and Reference Transformations

- **xl_time_ascii_to_ascii**: transforms a time expressed in a given ASCII format and reference (TAI, UTC, UT1 or GPS) into a time in a different ASCII format and/or reference (TAI, UTC, UT1 or GPS).
- **xl_time_ascii_to_transport**: transforms a time expressed in a given ASCII format and reference (TAI, UTC, UT1 or GPS) into a time in a Transport format, performing a reference transformation if necessary (to TAI, UTC, UT1 or GPS).
- **xl_time_ascii_to_processing**: transforms a time expressed in a given ASCII format and reference (TAI, UTC, UT1 or GPS) into a time in Processing format, performing a reference transformation if necessary (to TAI, UTC, UT1 or GPS).
- **xl_time_processing_to_ascii**: transforms a time expressed in Processing format and a given reference (TAI, UTC, UT1 or GPS) into a time in an ASCII format, performing a reference transformation if necessary (to TAI, UTC, UT1 or GPS).
- **xl_time_processing_to_transport**: transforms a time expressed in Processing format and a given reference (TAI, UTC, UT1 or GPS) into a time in a Transport format, performing a reference transformation if necessary (to TAI, UTC, UT1 or GPS).
- **xl_time_processing_to_processing**: transforms a time expressed in Processing format and a given reference (TAI, UTC, UT1 or GPS) into a time in Processing format with a different reference (TAI, UTC, UT1 or GPS).
- **xl_time_transport_to_ascii**: transforms a time expressed in a given Transport format and reference (TAI, UTC, UT1 or GPS) into a time in an ASCII format, performing a reference transformation if necessary (to TAI, UTC, UT1 or GPS).
- **xl_time_transport_to_transport**: transforms a time expressed in a given Transport format and reference (TAI, UTC, UT1 or GPS) into a time in a different Transport format and/or reference (TAI, UTC, UT1 or GPS).

- **xl_time_transport_to_processing**: transforms a time expressed in a given Transport format and reference (TAI, UTC, UT1 or GPS) into a time in Processing format, performing a reference transformation if necessary (to TAI, UTC, UT1 or GPS).

4.1.1.3 Operation between Dates

- **xl_time_add**: adds a duration to a TAI, UTC, UT1 or GPS time expressed in Processing format.
- **xl_time_diff**: subtracts two TAI, UTC, UT1 or GPS times expressed in Processing format.

4.1.1.4 Transformations from/to On-board Times

- **xl_time_obt_to_time**: transforms an On-board Time (OBT) into a TAI, UTC, UT1 or GPS time in Processing format.
- **xl_time_time_to_obt**: transforms a TAI, UTC, UT1 or GPS time expressed in Processing format into an On-board Time (OBT).

4.1.2 Coordinate Systems Transformations

4.1.2.1 Reference Frames Transformations

- **xl_change_cart_cs**: transforms a state vector between different coordinate systems.
- **xl_topocentric_to_ef**: transforms a state vector from topocentric coordinates to the Earth Fixed CS.
- **xl_ef_to_topocentric**: transforms a state vector from the Earth Fixed CS to topocentric coordinates.

4.1.2.2 Attitude-related Computations

- **xl_euler_to_matrix**: computes the elements of the coordinate transformation matrix with respect to the attitude frame given the corresponding Euler rotation vector in the roll, pitch and yaw sequence.
- **xl_matrix_to_euler**: derives the Euler rotation vector with respect to the attitude frame in the roll, pitch and yaw sequence given the corresponding coordinate transformation matrix.
- **xl_get_rotation_angles**: calculates the rotation angles between two sets of orthonormal right-handed unit vectors expressed wrt an identical coordinate frame.
- **xl_get_rotated_vectors**: calculates the rotated unit vectors given a set of unit vectors and the rotation angles expressed wrt an identical coordinate frame.
- **xl_quaternions_to_vectors**: calculates the orthonormal unit vectors from a given set of quaternions.
- **xl_vectors_to_quaternions**: calculates the set of quaternions that correspond to a set of orthonormal unit vectors.

4.1.2.3 Coordinates Transformations

- **xl_geod_to_cart**: transforms from Geodetic to Cartesian coordinates.
- **xl_cart_to_geod**: transforms from Cartesian to Geodetic coordinates.
- **xl_cart_to_radec**: transforms from a cartesian vector to right ascension and declination.
- **xl_radec_to_cart**: transforms from right ascension and declination to a cartesian vector.

4.1.2.4 State Vector Transformations

- **xl_kepl_to_cart**: transforms from Keplerian to Cartesian coordinates.
- **xl_cart_to_kepl**: transforms from Cartesian to Keplerian coordinates.

4.1.2.5 Position on orbit calculations

- **xl_position_on_orbit**: calculates a value describing the position of the satellite within the orbit, using as input a Cartesian orbit state vector.

4.1.3 Other Basic Computations

- **xl_sun**: calculates the position and velocity of the Sun in the Earth Fixed coordinate system
- **xl_moon**: calculates the Moon position and velocity in the Earth Fixed coordinate system
- **xl_planet**: calculates the position and velocity of a selected planet in the Earth Fixed coordinate system
- **xl_star_radec**: calculates the right ascension and declination of a star in the True of Date coordinate system.
- **xl_geod_distance**: calculates the geodesic distance between two points that lay on the same ellipsoid, and the azimuth of the related geodesic line at both points.
- **xl_star_catalog**: calculates the star coordinates in a star catalogue reference frame.

4.2 Time Reference Transformations Calling Sequence

Time reference transformations, and other functions with time as input, requires the user to initialise correlations between the different allowed time references, i.e. TAI, UTC, UT1 and GPS time. In order to accomplish such correlations, two possible strategies can be used:

- Initialisation from a single or multiple orbit files (**xl_time_ref_init_file**).
- Initialisation from a given set of time references (**xl_time_ref_init**).

The correlations are stored in a data structure, and the software returns a pointer to it, in addition to the validity range of the initialisation. This structure is referred to as the *timeId*.

Once the initialisation has been performed, the user is able to transform any date expressed in one of the allowed time references to another, through the Time Format / Reference Transformation functions. The *timeId* has to be provided to each of these functions. The process can be repeated as needed without initialising the time correlations each time.

After finalising the transformations, the *timeId* must be freed (**xl_time_close**).

A complete view of the time reference transformations sequence is presented in figure 1.

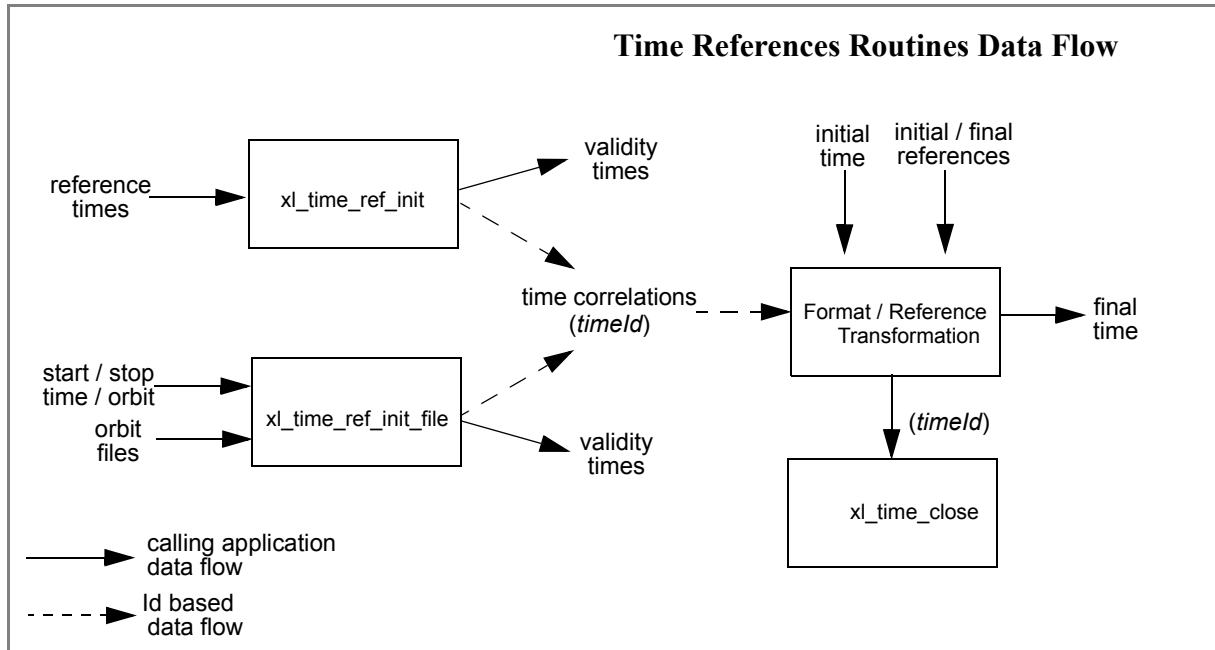


Figure 1: Time reference transformations sequence

There is a second way of calling the functions that require a *timeId* as input.

Similar initialisation functions exist in other CFI libraries, resulting in various *Ids* being generated. It is possible to group different *Ids* into a single entity called *runId*. Using this method, a single *runId* can be passed to all functions across the different libraries, instead of passing several *Ids* through the interface.

In this case, the first step would be to create the *timeId*. Then, a *runId* can be generated using as input the *timeId*. This *runId* is then passed through the interface to equivalent functions to those described before (ending in “_run”).

A detailed description of each function is provided in section 7.

Please refer also to:

- [MCD] for a detailed description of the time references and formats, coordinate systems, parameters and models used in this document.
- [GEN_SUM] for a complete overview of the CFI, and in particular the detailed description of the *Id* concept and the error handling functions.

5 LIBRARY INSTALLATION

For a detailed description of the installation of any CFI library, please refer to [GEN_SUM].

6 LIBRARY USAGE

Note that to use the EXPLORER_LIB software library, the following other CFI software libraries are required:

- EXPLORER_FILE_HANDLING (See [F_H_SUM]).
- EXPLORER_DATA_HANDLING[F_H_SUM]

It is also needed to have properly installed in the system the following external GPL library:

- LIBXML2 (see [GEN_SUM]).

and the POSIX thread library:

- libpthread.so (pthread.lib for WINDOWS)

To use the EXPLORER_LIB software library in a user application, that application must include in its source code:

- explorer_lib.h (for a C application)

To link correctly this application, the user must include in his linking command flags like (assuming *cfi_lib_dir* and *cfi_include_dir* are the directories where respectively all CFI libraries and include files have been installed, see [GEN_SUM] for installation procedures):

- SOLARIS/LINUX:

```
-Icfi_include_dir -Lcfi_lib_dir -lexplorer_lib
-lexplorer_data_handling -lexplorer_file_handling
-lxml2 -lpthread
```

- WINDOWS:

```
/I "cfi_include_dir" /libpath:"cfi_lib_dir" libexplorer_lib.lib
libexplorer_data_handling.lib
libexplorer_file_handling.lib
libxml2.lib pthread.lib
```

- MacOS:

```
-Icfi_include_dir -Lcfi_lib_dir -lexplorer_lib
-lexplorer_data_handling
-lexplorer_file_handling
-lpthread
-framework libxml
-framework libiconv
```

All functions described in this document have a name starting with the prefix `xl_`

To avoid problems in linking a user application with the EXPLORER_LIB software library due to the existence of names multiple defined, the user application should avoid naming any global software item beginning with either the prefix `XL_` or `xl_`.

It is possible to call the following CFI functions from a user application.

Table 1: CFI functions included within EXPLORER_LIB library

Function Name	Enumeration value	Long
Main CFI Functions		
xl_time_transport_to_ascii	XL_TIME_TRANSPORT_TO_ASCII_ID	0
xl_time_transport_to_transport	XL_TIME_TRANSPORT_TO_TRANSPORT_ID	1
xl_time_transport_to_processing	XL_TIME_TRANSPORT_TO_PROCESSING_ID	2
xl_time_processing_to_ascii	XL_TIME_PROCESSING_TO_ASCII_ID	3
xl_time_processing_to_transport	XL_TIME_PROCESSING_TO_TRANSPORT_ID	4
xl_time_processing_to_processing	XL_TIME_PROCESSING_TO_PROCESSING_ID	5
xl_time_ascii_to_ascii	XL_TIME_ASCII_TO_ASCII_ID	6
xl_time_ascii_to_transport	XL_TIME_ASCII_TO_TRANSPORT_ID	7
xl_time_ascii_to_processing	XL_TIME_ASCII_TO_PROCESSING_ID	8
xl_time_add	XL_TIME_ADD_ID	9
xl_time_diff	XL_TIME_DIFF_ID	10
xl_time_obt_to_time	XL_TIME_OBT_TO_TIME_ID	11
xl_time_time_to_obt	XL_TIME_TIME_TO_OBT_ID	12
xl_time_ref_init_file	XL_TIME_REF_INIT_FILE_ID	13
xl_time_ref_init	XL_TIME_REF_INIT_ID	14
xl_time_ref_close	XL_TIME_CLOSE_ID	15
xl_change_cart_cs	XL_CHANGE_CART_CS_ID	16
xl_geod_to_cart	XL_GEOD_TO_CART_ID	17
xl_cart_to_geod	XL_CART_TO_GEOD_ID	18
xl_kepl_to_cart	XL_KEPL_TO_CART_ID	19
xl_cart_to_kepl	XL_CART_TO_KEPL_ID	20
xl_sun	XL_SUN_ID	21
xl_moon	XL_MOON_ID	22
xl_planet	XL_PLANET_ID	23
xl_star_radec	XL_STAR_RADEC_ID	24
xl_geod_distance	XL_GEOD_DISTANCE_ID	25
xl_time_get_leap_second_info	XL_TIME_GET_LEAP_SECOND_INFO_ID	26
xl_default_sat_init	XL_DEFAULT_SAT_INIT_ID	27
xl_run_init	XL_RUN_INIT_ID	28

Function Name	Enumeration value	Long
xl_get_rotation_angles	XL_GET_ROTATION_ANGLES_ID	29
xl_get_rotated_vectors	XL_GET_ROTATED_VECTORS_ID	30
xl_position_on_orbit	XL_POSITION_ON_ORBIT	31
xl_quaternions_to_vectors	XL_QUATERNIONS_TO_VEC_ID	32
xl_vectors_to_quaternions	XL_VEC_TO_QUATERNIONS_ID	33
xl_star_catalog	XL_STAR_CATALOG_ID	34
xl_cart_to_radec	XL_CART_TO_RADEC_ID	35
xl_radec_to_cart	XL_RADEC_TO_CART_ID	36
xl_topocentric_to_ef	XL_TOPOCENTRIC_TO_EF_ID	37
xl_ef_to_topocentric	XL_EF_TO_TOPOCENTRIC_ID	38
Error Handling Functions		
xl_verbose	not applicable	
xl_silent		
xl_get_code		
xl_get_msg		
xl_print_msg		

Notes about the table:

- To transform the extended status flag returned by a CFI function to either a list of error codes or a list of error messages, the enumeration value (or the corresponding long value) described in the table must be used
- The error handling functions have no enumerated values

Whenever available **it is strongly recommended to use enumeration values rather than integer values.**

6.1 Usage hints

The runtime performances of few of the CFI functions are improved to a large extent if they are called two consecutive times keeping constant some of their inputs:

- xl_change_cart_cs:time (reference and value).
- xl_planet: time (reference and value).
- xl_star_radec: time (reference and value).

In fact, the time, position, velocity and acceleration vectors do not need to keep exactly constant as long as the difference between two consecutive calls lays within the following thresholds:

- TAI/UT1/UTC time: 0.0864 microseconds
- GPS time: TBD microseconds

Furthermore, the same runtime improvement is achieved in other CFI functions that, although the user may

not need to call two consecutive times with the same inputs, are called internally by other higher level CFI functions in those conditions, and thus improving the runtime performances of the latter. This is the case of the following CFI functions:

- `x1_cart_to_geod`: position, velocity and acceleration vectors
- `x1_sun`: time (reference and value)
- `x1_moon`: time (reference and value)

With the following thresholds:

- Position vector: $0.6e-3$ m
- Velocity vector: $0.6e-6$ m/s
- Acceleration vector: $0.6e-9$ m/s²

Every CFI function has a different length of the Error Vector, used in the calling I/F examples of this SUM and defined at the beginning of the library header file. In order to provide the user with a single value that could be used as Error Vector length for every function, a generic value has been defined (`XL_ERR_VECTOR_MAX_LENGTH`) as the maximum of all the Error Vector lengths. This value can therefore be safely used for every call of functions of this library.

6.2 General Enumerations

The aim of the current section is to present the enumeration values that can be used rather than integer parameters for some of the input parameters of the `EXPLORER_LIB` routines, as shown in the table below. The enumerations presented in `[GEN_SUM]` are also applicable.

Table 2: Enumerations within `EXPLORER_LIB` library

Input	Description	Enumeration value	Long
Time reference	Undefined	<code>XL_TIME_UNDEF</code>	-1
	TAI	<code>XL_TIME_TAI</code>	0
	UTC	<code>XL_TIME_UTC</code>	1
	UT1	<code>XL_TIME_UT1</code>	2
	GPS	<code>XL_TIME_GPS</code>	3
Processing format	Standard	<code>XL_PROC</code>	0
Transport time format	Standard	<code>XL_TRANS_STD</code>	0
	Envisat Ground Segment	<code>XL_TRANS_ENVI_GS</code>	11
	CryoSat Ground Segment	<code>XL_TRANS_CRYO_GS</code>	21
	CryoSat General Telemetry	<code>XL_TRANS_CRYO_TM</code>	22
	CryoSat SIRAL Telemetry	<code>XL_TRANS_CRYO_TM_SIRAL</code>	23
	SMOS transport time format	<code>XL_TRANS_SMOS_TM</code>	31
ASCII time format	Undefined	<code>XL_ASCII_UNDEF</code>	-1
	Standard	<code>XL_ASCII_STD</code>	11
	Standard with reference	<code>XL_ASCII_STD_REF</code>	12
	Standard with microsecs	<code>XL_ASCII_STD_MICROSEC</code>	13
	Standard with reference and microsecs	<code>XL_ASCII_STD_REF_MICROSEC</code>	14

Table 2: Enumerations within EXPLORER_LIB library

Input	Description	Enumeration value	Long
	Compact	XL_ASCII_COMPACT	21
	Compact with reference	XL_ASCII_COMPACT_REF	22
	Compact with microseconds	XL_ASCII_COMPACT_MICROSEC	23
	Compact with reference and microseconds	XL_ASCII_COMPACT_REF_MICROSEC	24
	Envisat	XL_ASCII_ENVI	31
	Envisat with reference	XL_ASCII_ENVI_REF	32
	Envisat with microseconds	XL_ASCII_ENVI_MICROSEC	33
	Envisat with reference and microseconds	XL_ASCII_ENVI_REF_MICROSEC	34
	CCSDS-A	XL_ASCII_CCSDSA	41
	CCSDS-A with reference	XL_ASCII_CCSDSA_REF	42
	CCSDS-A with microseconds	XL_ASCII_CCSDSA_MICROSEC	43
	CCSDS-A with reference and microseconds	XL_ASCII_CCSDSA_REF_MICROSEC	44
	CCSDS-A compact	XL_ASCII_CCSDSA_COMPACT	51
	CCSDS-A compact with reference	XL_ASCII_CCSDSA_COMPACT_REF	52
	CCSDS-A compact with microseconds	XL_ASCII_CCSDSA_COMPACT_MICROSEC	53
	CCSDS-A compact with reference and microseconds	XL_ASCII_CCSDSA_COMPACT_REF_MICROSEC	54
Time Initialization Mode	Initialization from file (data-driven)	XL_SEL_FILE	0
	Initialization within a time range	XL_SEL_TIME	1
	Initialization within a range of orbits	XL_SEL_ORBIT	2
	(not used in LIB)	XL_SEL_DEFAULT	3
Time Initialization Model	Select the file type automatically	XL_TIMEMOD_AUTO	-2
	User defined	XL_TIMEMOD_USER	-1
	None	XL_TIMEMOD_NONE	0
	IERS Bulletin B - Table 1 (Predicted)	XL_TIMEMOD_IERS_B_PREDICTED	1
	IERS Bulletin B - Table 2 (Restituted)	XL_TIMEMOD_IERS_B_RESTITUTED	2
	FOS Predicted Orbit File	XL_TIMEMOD_FOS_PREDICTED	3
	FOS Restituted Orbit File	XL_TIMEMOD_FOS_RESTITUTED	4
	DORIS Preliminary Orbit	XL_TIMEMOD_DORIS_PRELIMINARY	5
	DORIS Precise Orbit	XL_TIMEMOD_DORIS_PRECISE	6
	DORIS Navigator	XL_TIMEMOD_DORIS_NAVIGATOR	7
	Orbit Scenario File	XL_TIMEMOD_OSF	8
Reference frame	Barycentric Mean of 2000	XL_BM2000	1
	Heliocentric Mean of 2000	XL_HM2000	2
	Geocentric Mean of 2000	XL_GM2000	3

Table 2: Enumerations within EXPLORER_LIB library

Input	Description	Enumeration value	Long
	Mean of Date	XL_MOD	4
	True of Date	XL_TOD	5
	Earth Fixed	XL_EF	6
	Barycentric Mean of 1950	XL_BM1950	7
	Galactic Coordinates	XL_GALACTIC	8
Extended reference frames	Barycentric Mean of 2000.0	BAR_MEAN_2000	1
	Heliocentric Mean of 2000.0	HEL_MEAN_2000	2
	Geocentric Mean of 2000.0	GEO_MEAN_2000	3
	Mean of date	MEAN_DATE	4
	True of date	TRUE_DATE	5
	Earth Fixed	EARTH_FIXED	6
	Barycentric Mean of 1950	BAR_MEAN_1950	7
	Galactic Coordinates	GALACTIC	8
	Satellite relative actual reference cs	SAT_ACT_REF	9
	Quasi-Mean of Date	QUASI_MEAN_DATE	10
	Pseudo-True of Date	PSE_TRUE_DATE	11
	Quasi-True of Date	QUASI_TRUE_DATE	12
	Topocentric coordinate system	TOPOCENTRIC	13
	Satellite reference frame	SAT_REF	14
	Satellite relative reference frame	SAT_REL_REF	15
Kepler OSV mode	Mean Kepler State Vector	XL_KEPLER_MEAN	1
	Osculating Kepler State Vector	XL_KEPLER_OSC	2
Planet ID	Mercury	XL_MERCURY	1
	Venus	XL_VENUS	2
	Earth-Moon barycenter	XL_EM_BAR	3
	Mars	XL_MARS	4
	Jupiter	XL_JUPITER	5
	Saturn	XL_SATURN	6
	Uranus	XL_URANUS	7
	Neptune	XL_NEPTUNE	8
Calculation mode	Position	XL_CALC_POS	1
	Position and velocity	XL_CALC_POS_VEL	2
	Position, velocity and acceleration	XL_CALC_POS_VEL_ACC	3

Table 2: Enumerations within EXPLORER_LIB library

Input	Description	Enumeration value	Long
AOCS mode	Default Cx, Cy, Cz values	XL_AOCS_DEFAULT	0
	User defined Cx, Cy, Cz values	XL_AOCS_USER	1
	Geocentric pointing	XL_AOCS_GPM	2
	Local normal pointing	XL_AOCS_LNP	3
	Yaw steering + local normal pointing	XL_AOCS_YSM	4
Angle Type	True Latitude (TOD)	XL_ANGLE_TYPE_TRUE_LAT_TOD	1
	Mean Latitude (TOD)	XL_ANGLE_TYPE_MEAN_LAT_TOD	2
Derivatives	No derivative	XL_NO_DER	0
	First derivative is also calculated	XL_DER_1ST	1
	First and second derivative.	XL_DER_2ND	2
Type of <i>Ids</i>	Unknown	XL_INIT_UNKNOWN	0
	<i>runId</i>	XL_INIT_RUN	1
	<i>timeId</i>	XL_INIT_TIME	2
	<i>orbitId</i> (not used in LIB)	XO_INIT_ORBIT	3
	<i>propagId</i> (not used in LIB)	XO_INIT_PROPAG	4
	<i>interpollId</i> (not used in LIB)	XO_INIT_INTERPOL	5
	<i>sat_nom_att_Id</i> (not used in LIB)	XP_INIT_SAT_NOM_ATT	6
	<i>sat_att_Id</i> (not used in LIB)	XP_INIT_SAT_ATT	7
	<i>instr_att_Id</i> (not used in LIB)	XP_INIT_INSTR_ATT	8
	<i>attitudeId</i> (not used in LIB)	XP_INIT_ATTITUDE	9
	<i>atmosId</i> (not used in LIB)	XP_INIT_ATMOS	10
	<i>demId</i> (not used in LIB)	XP_INIT_DEM	11
	<i>targetId</i> (not used in LIB)	XP_INIT_TARGET	12
Boolean values	False	XL_FALSE	0
	True	XL_TRUE	1
Star Catalogues	FK4 Star catalogue	XL_FK4	0
	FK5 Star catalogue	XL_FK5	1
Vector mode flag	Point location	XL_MODE_FLAG_LOCATION	0
	Direction vector	XL_MODE_FLAG_DIRECTION	1

The use of the previous enumeration values could be restricted by the particular usage within the different CFI functions. The actual range to be used is indicated within a dedicated reference named **allowed range**. When there are not restrictions to be mentioned, the allowed range column is populated with the label **complete**.

The meanings and units of the different array elements from the Transport time strongly depend upon the selected Transport format (by means of the Transport format ID). The table below shows the choices:

Table 3: Transport time formats

Input	Array Element	Unit (Format)	Allowed Range
XL_TRANS_STD	[0]	Integer days	[-18262,36524]
	[1]	Integer seconds	[0,86399]
	[2]	Integer microseconds	[0,999999]
XL_TRANS_ENVI_GS	[0]	Integer days	[-18262,36524]
	[1]	Integer seconds	[0,86399]
	[2]	Integer microseconds	[0,999999]
XL_TRANS_CRYO_GS	[0]	Integer days	[-18262,36524]
	[1]	Integer seconds	[0,86399]
	[2]	Integer microseconds	[0,999999]
XL_TRANS_CRYO_TM	[0]	Integer days	[-18262,36524]
	[1]	Integer milliseconds	[0,86399999]
	[2]	Integer microseconds	[0,999]
XL_TRANS_CRYO_TM_SIRAL	[0]	Integer days	[-18262,36524]
	[1]	Integer milliseconds	[0,86399999]
	[2]	Integer microseconds	[0,999]
	[3]	SIRAL extra counter	[0,1745454545]
XL_TRANS_SMOS_TM	[0]	Week number	[-1566, 6260]
	[1]	Seconds of week	[0, 604799]
	[2]	Fraction of seconds	[0, 65535]

The string characteristics of the ASCII time formats depends strongly upon the selected ASCII format (by means of the ASCII format ID). The tables below show the available choices:

Note that the value of 86400 for seconds (and 86400000 for milliseconds) is accepted only for UTC in case a leap second is being introduced. This may happen only at 23:59 minutes and only on four days of the year (31/03, 30/06, 30/09, 31/12). The decision to introduce a leap second in UTC is the responsibility of the International Earth Rotation Service (IERS). See [IERS] for further details.

For further details on the SIRAL extra counter for the Cryosat mission please see [MCD].

Table 4: Basic ASCII time formats

Input	String format
XL_ASCII_UNDEF	-
XL_ASCII_STD	"yyyy-mm-dd_hh:nn:ss"
XL_ASCII_COMPACT	"yyyymmdd_hhnnss"
XL_ASCII_ENVI	"dd-mmm-yyyy hh:nn:ss"
XL_ASCII_CCSDSA	"yyyy-mm-ddThh:nn:ss"
XL_ASCII_CCSDSA_COMPACT	"yyyymmddThhnnss"

Table 5: Derived ASCII time formats

Input	String format
XL_ASCII_STD_REF	"RRR=yyyy-mm-dd_hh:nn:ss"
XL_ASCII_STD_MICROSEC	"yyyy-mm-dd_hh:nn:ss.uuuuuu"
XL_ASCII_STD_REF_MICROSEC	"RRR=yyyy-mm-dd_hh:nn:ss.uuuuuu"
XL_ASCII_COMPACT_REF	"RRR=yyyymmdd_hhnnss"
XL_ASCII_COMPACT_MICROSEC	"yyyymmdd_hhnnssuuuuuu"
XL_ASCII_COMPACT_REF_MICROSEC	"RRR=yyyymmdd_hhnnssuuuuuu"
XL_ASCII_ENVI_REF	"RRR=dd-mmm-yyyy hh:nn:ss"
XL_ASCII_ENVI_MICROSEC	"dd-mmm-yyyy hh:nn:ss.uuuuuu"
XL_ASCII_ENVI_REF_MICROSEC	"RRR=dd-mmm-yyyy hh:nn:ss.uuuuuu"
XL_ASCII_CCSDSA_REF	"RRR=yyyy-mm-ddThh:nn:ss"
XL_ASCII_CCSDSA_MICROSEC	"yyyy-mm-ddThh:nn:ss.uuuuuu"
XL_ASCII_CCSDSA_REF_MICROSEC	"RRR=yyyy-mm-ddThh:nn:ss.uuuuuu"
XL_ASCII_CCSDSA_COMPACT_REF	"RRR=yyyymmddThhnnss"
XL_ASCII_CCSDSA_COMPACT_MICROSEC	"yyyymmddThhnnssuuuuuu"
XL_ASCII_CCSDSA_COMPACT_REF_MICROSEC	"RRR=yyyymmddThhnnssuuuuuu"

where:

- *yyyy* stands for the year
- *mm* stands for the month expressed as a numerical count, i.e. 01 for January, etc
- *mmm* stands for the month expressed in abbreviations, i.e. JAN, MAR, etc
- *dd* stands for the day of month
- *ddd* stands for the day of the year
- *hh* stands for the hour in the day
- *nn* stands for the minutes within a hour
- *ss* stands for the seconds within a minute
- *uuuuuu* stands for the microseconds within a second
- *RRR* stands for the time reference (TAI, UTC, UT1 or GPS)

In ASCII formats two values are defined, by convention, as Beginning of Mission (BOM) and End of Mission (EOM). These values are listed, for the various ASCII time formats, in table 6 and table 7.

Usually a date with all zeros is seen as EOM, and a date with all nines is considered EOM. The only exception are the ENVISAT-specific formats, which use as EOM the date December 31st, 2078 at 23:59:59.999999.

Format transformations of BOM and EOM between ASCII format is allowed.

Time reference is not considered in BOM or EOM, thus any time reference is accepted (TAI, UTC, UT1 or GPS) for the values in table 6 and table 7.

BOM and EOM do not have an equivalent in Processing or Transport formats, so if the user tries to convert them from ASCII to another non-ASCII format an error will occur.

Table 6: Definition of BOM and EOM for basic ASCII time formats

ASCII format	Beginning of Mission	End of Mission
XL_ASCII_UNDEF	-	-
XL_ASCII_STD	"0000-00-00_00:00:00"	"9999-99-99_99:99:99"
XL_ASCII_COMPACT	"00000000_000000"	"99999999_999999"
XL_ASCII_ENVI	"00-000-0000_00:00:00"	"31-DEC-2078 23:59:59"
XL_ASCII_CCSDSA	"0000-00-00T00:00:00"	"9999-99-99T99:99:99"
XL_ASCII_CCSDSA_COMPACT	"00000000T000000"	"99999999T999999"

Table 7: Definition of BOM and EOM for derived ASCII time formats

ASCII format	Beginning of Mission	End of Mission
XL_ASCII_STD_REF	"RRR=0000-00-00_00:00:00"	"RRR=9999-99-99_99:99:99"
XL_ASCII_STD_MICROSEC	"0000-00-00_00:00:00.000000"	"9999-99-99_99:99:99.999999"
XL_ASCII_STD_REF_MICROSEC	"RRR=0000-00-00_00:00:00.000000"	"RRR=9999-99-99_99:99:99.999999"
XL_ASCII_COMPACT_REF	"RRR=00000000_000000"	"RRR=99999999_999999"
XL_ASCII_COMPACT_MICROSEC	"00000000_000000000000"	"99999999_999999999999"
XL_ASCII_COMPACT_REF_MICROSEC	"RRR=00000000_000000000000"	"RRR=99999999_999999999999"
XL_ASCII_ENVI_REF	"RRR=00-000-0000_00:00:00"	"RRR=31-DEC-2078 23:59:59"
XL_ASCII_ENVI_MICROSEC	"00-000-0000_00:00:00.000000"	"31-DEC-2078 23:59:59.999999"
XL_ASCII_ENVI_REF_MICROSEC	"RRR=00-000-0000_00:00:00.000000"	"RRR=31-DEC-2078 23:59:59.999999"
XL_ASCII_CCSDSA_REF	"RRR=0000-00-00T00:00:00"	"RRR=9999-99-99T99:99:99"
XL_ASCII_CCSDSA_MICROSEC	"0000-00-00T00:00:00.000000"	"9999-99-99T99:99:99.999999"
XL_ASCII_CCSDSA_REF_MICROSEC	"RRR=0000-00-00T00:00:00.000000"	"RRR=9999-99-99T99:99:99.999999"
XL_ASCII_CCSDSA_COMPACT_REF	"RRR=00000000T000000"	"RRR=99999999T999999"
XL_ASCII_CCSDSA_COMPACT_MICROSEC	"00000000T000000000000"	"99999999T999999999999"
XL_ASCII_CCSDSA_COMPACT_REF_MICROSEC	"RRR=00000000T000000000000"	"RRR=99999999T999999999999"

where:

- *RRR* stands for the time reference (TAI, UTC, UT1 or GPS)

6.3 Data Structures

The aim of the current section is to present the data structures that are used in the EXPLORER_LIB library. The structures are currently used for the CFI Identifiers accessor functions. The following table show the structures with their names and the data that contain:

Table 8: EXPLORER_LIB structures

Structure name	Data		
	Variable Name	C type	Description
xl_par_der	deriv	XL_Deriv_enum	Flag to indicate if the 1st and 2nd derivatives are defined
	p	double	The parameter, expressed in the appropriate units
	pd	double	1st time derivative of the parameter
	p2d	double	2nd time derivative of the parameter
xl_cord	cs	XL_CS_rl_enum	Coordinate reference frame
	deriv	XL_Deriv_enum	Flag to indicate if the 1st and 2nd derivatives are defined
	v	double [3]	Vector
	vd	double [3]	Vector rate
	v2d	double [3]	Vector rate-rate
xl_cs_tra	azel_flag	XL_Boolean	Flag to indicate if an azimuth/elevation definition has been provided.
	azel_def	xl_az_el_definition	Azimuth/elevation definition.
	ref_i	XL_CS_rl_enum	Initial reference frame
	ref_f	XL_Attitude_fr_enum	final reference frame
	amb_flag	XL_Boolean	Ambiguity flag
	deriv	XL_Deriv_enum	Flag to indicate if the 1st and 2nd derivatives are defined
	v	double [3]	Translation vector from ref_i to ref_f
	vd	double [3]	Translation rate vector from ref_i to ref_f
	v2d	double [3]	Translation rate-rate vector from ref_i to ref_f
	m	double [3][3]	Rotation matrix from ref_i to ref_f
	md	double [3][3]	Rotation matrix rate from ref_i to ref_f
	m2d	double [3][3]	Rotation matrix rate-rate from ref_i to ref_f

Table 8: EXPLORER_LIB structures

Structure name	Data		
	Variable Name	C type	Description
xl_time_correlations	tai_time	double	TAI time
	ut1_time	double	UT1 time
	tai_utc	double	difference between TAI and UTC
	tai_ut1	double	difference between TAI and UT1
	tai_gps	double	difference between TAI and GPS
xl_leap_second	flag	long	XL_TRUE if the leap second exists
	utc_time	double	UTC time for the leap second
xl_time_id_data	num_lines	long	Number of records in the array with the time correlations
	time_str	xl_time_correlations*	Array with the time correlations
	leap_sec	xl_leap_second	Leap second information
xl_az_el_definition	az_0_axis	long	Azimuth 0° axis (one of the values in XL_Axis_enum)
	az_90_axis	long	Azimuth 90° axis (one of the values in XL_Axis_enum)
	el_90_axis	long	Elevation 90° axis (one of the values in XL_Axis_enum)

7 CFI FUNCTIONS DESCRIPTION

The following sections describe each CFI function.

The calling interfaces are described for C users.

Input and output parameters of each CFI function are described in tables, where C programming language syntax is used to specify:

- Parameter types (e.g. long, double)
- Array sizes of N elements (e.g. param[N])
- Array element M (e.g. [M])

7.1 xl_time_ref_init_file

7.1.1 Overview

The **xl_time_ref_init_file** CFI function initializes time correlations between TAI, UTC, UT1 and GPS times from reference data files. The correlations provided by the different input files can be found in the following table.

Table 9: Time reference correlations from reference files

	TAI	UTC	UT1	GPS	orbit
FOS Predicted Orbit File	X	X	X	(x)	X
FOS Restituted Orbit File	X	X	X	(x)	X
DORIS Preliminary Orbit	X	X	X	(x)	X
DORIS Precise Orbit	X	X	X	(x)	X
DORIS Navigator File	X	X	X	(x)	X
IERS Bulletin B format1980	X	X	X	(x)	
IERS Bulletin B format2010	X	X	X	(x)	
Orbit Scenario File	X	X	X	(x)	

Normally a single Predicted or DORIS Orbit file is sufficient to have all correlations needed (the (x) mark indicates that the GPS time correlation, although is not present within the file, can be simulated since it is always a fixed delta from TAI). The last updated IERS Bulletin B can be downloaded from IERS bulletins web page ([IERS]).

When using an Orbit Scenario File, it must be taken into account that, since one orbital change can be far away from the following one, leap seconds could be calculated wrongly if there is more than one of the four possible leap second insertion points (end of March, end of June, end of September and end of December) between them.

In case multiple files are used for the time correlations initializations, the files should be time ordered.

For Orbit Scenario File, only one file is admitted. If more files are introduced a warning is raised and the computations are performed only with the first OSF introduced.

All other input files are ESA-provided. These initialization files could even be generated by the users by means of EXPLORER_FILE_HANDLING and EXPLORER_GEN_FILES CFI libraries.

A complete calling sequence of the time reference computations is presented in section 4.2.

7.1.2 Calling interface

The calling interface of the **xl_time_ref_init_file** CFI function is the following (input parameters are underlined>):

```
#include <explorer_lib.h>
{
    long time_model, n_files, time_init_mode, time_ref;
    long orbit0, orbit1;
```

```

char **time_file;
double time0, time1, val_time0, val_time1;
xl_time_id time_id = {NULL};
long ierr[XL_NUM_ERR_TIME_REF_INIT_FILE], status;

status = xl_time_ref_init_file (&time_model, &n_files,
                               time_file, &time_init_mode,
                               &time_ref, &time0, &time1,
                               &orbit0, &orbit1,
                               &val_time0, &val_time1,
                               &time_id, ierr);
}

```

7.1.3 Input parameters

The `xl_time_ref_init_file` CFI function has the following input parameters:

Table 10: Input parameters of `xl_time_ref_init_file` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
time_model	long *	-	Time model ID	-	Complete except XL_TIMEMOD_USER <u>Note:</u> When the input file is an IERS Bulletin B format 1980 file and the time mode is XL_TIMEMOD_AUTO, then the time model is set automatically to XL_TIMEMOD_IERS_B_RES TITUTED <u>Note:</u> When the input file is an IERS Bulletin B format 2010, the time models XL_TIMEMOD_IERS_B_RES TITUTED and XL_TIMEMOD_IERS_B_PRE DICTED coincide.
n_files	long *	-	Number of reference data files	-	> 0
time_file	char**	-	Filenames of the reference data files	-	-

Table 10: Input parameters of xl_time_ref_init_file function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
time_init_mode	long *	-	Flag for selecting the time range of the initialisation: It could be the whole file (<i>XL_SEL_FILE</i>), the orbit range given by orbit0-orbit1 (<i>XO_SEL_ORBIT</i>) or the time range given by time0-time1 (<i>XO_SEL_TIME</i>)	-	Select either: <ul style="list-style-type: none"> · <i>XL_SEL_FILE</i> · <i>XL_SEL_ORBIT</i> · <i>XL_SEL_TIME</i> - <i>XL_SEL_ORBIT</i> is not allowed for IERS Bulletins (any format) nor DORIS Navigator files - <i>XL_SEL_ORBIT</i> and <i>XL_SEL_TIME</i> are not enabled for OSF
time_ref	long *	-	Time reference ID	-	Complete. If the input file is a DORIS Navigator file and the time_init_mode is <i>XL_SEL_TIME</i> , then only time_ref allowed is <i>XL_TIME_UTC</i> .
time0	double*	-	If: <i>time_init_mode=XL_SEL_TIME</i> Start of the time range defined by [time0,time1]	Decimal days (Processing format)	[-18262.0,36524.0]
time1	double*	-	If: <i>time_init_mode=XL_SEL_TIME</i> End of the time range defined by [time0,time1]	Decimal days (Processing format)	[-18262.0,36524.0] > time0
orbit0	long*	-	If: <i>time_init_mode=XL_SEL_ORBIT</i> Absolute orbit number corresponding to the start of the time range defined by [<i>ANX_{orbit0}</i> , <i>ANX_{orbit1+1}</i>]	-	>= 0
orbit1	long*	-	If: <i>time_init_mode=XL_SEL_ORBIT</i> Absolute orbit number corresponding to the end of the time range defined by [<i>ANX_{orbit0}</i> , <i>ANX_{orbit1+1}</i>]	-	>orbit0

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Time model ID: time_model. See [GEN_SUM].
- Time reference ID: time_ref. See [GEN_SUM].
- Time range initialisation flag: time_init_mode. See current document, section 6.2.

7.1.4 Output parameters

The output parameters of the `xl_time_ref_init_file` CFI function are:

Table 11: Output parameters of `xl_time_ref_init_file` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_time_ref_init_file</code>	long	-	Status flag	-	-
<code>val_time0</code>	double*	-	Validity start time of the initialization	Decimal days (Processing format)	[-18262.0,36524.0]
<code>val_time1</code>	double*	-	Validity end time of the initialization	Decimal days (Processing format)	[-18262.0,36524.0]
<code>time_id</code>	<code>xl_time_id*</code>	-	Structure that contains the time correlations.	-	-
<code>ierr</code>	long	-	Error vector	-	-

Note that `val_time0` and `val_time1` can define a validity range different to that requested by the user. This range gives the maximum coverage provided by the input files within the margins selected by the user.

It has to be remarked that if the input time is outside the range of initialization, transformations are performed anyway, using the closest correlation data. However a warning is returned, since there is no guarantee that the correlation is correct.

7.1.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_time_ref_init_file` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the error vector returned by the `xl_time_ref_init_file` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 12: Error messages of `xl_time_ref_init_file` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Time model ID is not correct	No calculation performed	<code>XL_CFI_TIME_REF_INIT_F ILE_TIME_MODEL_ERR</code>	0
ERR	Non-positive number of data files	No calculation performed	<code>XL_CFI_TIME_REF_INIT_F ILE_N_FILES_ERR</code>	1
ERR	Incorrect file names	No calculation performed	<code>XL_CFI_TIME_REF_INIT_F ILE_FILE_NAMES_ERR</code>	2
ERR	Time init mode ID is not correct	No calculation performed	<code>XL_CFI_TIME_REF_INIT_F ILE_INIT_MODE_ERR</code>	3

Table 12: Error messages of xl_time_ref_init_file function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Time reference ID is not correct	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_TIME_ERR	4
ERR	Reference start time out of limits	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_DAY_0_ERR	5
ERR	Reference end time out of limits	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_DAY_1_ERR	6
ERR	Wrong reference time range	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_DAY_RANGE_ERR	7
ERR	Reference start orbit is negative	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_ORB_0_ERR	8
ERR	Reference end orbit is negative	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_ORB_1_ERR	9
ERR	Wrong reference orbit range	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_ORB_RANGE_ERR	10
ERR	File does not exist	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_FILE_ERR	11
ERR	Time table is empty or has wrong format	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_TABLE_ERR	12
ERR	Time range from file is outside input range	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_TIME_OUTSIDE_RANGE_ERR	13
ERR	Orbit range from file is outside input range	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_ORB_OUTSIDE_RANGE_ERR	14
ERR	Memory allocation error	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_MEMORY_ERR	15
ERR	Error in reading file	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_READ_FILE_ERR	16
ERR	Time reference ID is already initialized	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_STATUS_ERR	17
ERR	Could not find out the input file types	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_DETECT_FILE_ERR	18
ERR	The input file type is not correct	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_WRONG_FILE_TYPE_ERR	19
ERR	Input time reference should be UTC for DORIS Navigator files	No calculation performed	XL_CFI_TIME_REF_INIT_FILE_TIME_REF_FOR_DORIS_ERR	20
WARN	Only one OSF file is admitted	Calculation performed using first OSV file introduced	XL_CFI_TIME_REF_INIT_FILE_ONLY_FIRST_OSF_WARN	21
WARN	Time init mode option not currently enabled for file	Calculation performed with XL_SEL_FILE	XL_CFI_TIME_REF_INIT_FILE_INIT_MODE_WARN	22

7.1.6 Runtime performances

The following runtime performances have been measured (reading an IERS Bulletin B) for a serie of calls to `xl_time_ref_init_file` + `xl_time_close`.

Table 13: Runtime performances of `xl_time_ref_init_file` + `xl_time_close` function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
25.6	6.4	16.1	2.9

7.2 xl_time_ref_init

7.2.1 Overview

The `xl_time_ref_init` CFI function initializes time correlations between TAI, UTC, UT1 and GPS times from input reference times for time ranges from -18262.0 and +36524.0 decimal days.

A complete calling sequence of the time reference computations is presented in section 4.2.

7.2.2 Calling interface

The calling interface of the `xl_time_ref_init` CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long orbit_num;
    double time[4], anx_time, orbit_duration;
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_TIME_REF_INIT], status;

    status = xl_time_ref_init (time, &orbit_num, &anx_time,
                             &orbit_duration, &time_id, ierr);
}
```

Note that input time vector must be indexed using the existing enumeration for time references.

The `XL_NUM_ERR_TIME_REF_INIT` constant is defined in the file *explorer_lib.h*.

7.2.3 Input parameters

The `xl_time_ref_init` CFI function has the following input parameters:

Table 14: Input parameters of `xl_time_ref_init` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
time	double[4]	[0]	TAI input time	Decimal days (Processing format)	[-18262.0,36524.0]
		[1]	UTC input time	Decimal days (Processing format)	[-18262.0,36524.0]
		[2]	UT1 input time	Decimal days (Processing format)	[-18262.0,36524.0]
		[3]	GPS input time	Decimal days (Processing format)	[-18262.0,36524.0]
orbit_num	long*	-	Absolute orbit number at the reference time	-	>=0
anx_time	double*	-	Time since Ascending node crossing at the reference time	Seconds	[0,orbit_duration]
orbit_duration	double*	-	Duration of the orbit containing the reference time	Seconds	>0

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Time vector can be accessible by means of enumeration values, as defined in [GEN_SUM].

7.2.4 Output parameters

The output parameters of the `xl_time_ref_init` CFI function are:

Table 15: Output parameters of `xl_time_ref_init` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_time_ref_init	long	-	Status flag	-	-
time_id	xl_time_id*	-	Structure that contains the time correlations.	-	-
ierr	long	-	Error vector	-	-

7.2.5 Warnings and errors

Next table lists the possible error messages that can be returned by the **xl_time_ref_init** CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library **xl_get_msg** (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained by translating the error vector returned by the **xl_time_ref_init** function by calling the function of the EXPLORER_LIB software library **xl_get_code** (see [GEN_SUM]).

Table 16: Error messages of xl_time_ref_init function

Error type	Error message	Cause and impact	Error code	Error No
ERR	TAI time is out of range	No calculation performed	XL_CFI_TIME_REF_INIT_TAI_ERR	0
ERR	UTC time is out of range	No calculation performed	XL_CFI_TIME_REF_INIT_UTC_ERR	1
ERR	UT1 time is out of range	No calculation performed	XL_CFI_TIME_REF_INIT_UT1_ERR	2
ERR	GPS time is out of range	No calculation performed	XL_CFI_TIME_REF_INIT_GPS_ERR	3
ERR	Absolute orbit number is negative	No calculation performed	XL_CFI_TIME_REF_INIT_ORBNUM_ERR	4
ERR	Elapsed time since ANX is negative	No calculation performed	XL_CFI_TIME_REF_INIT_ANXTIME_ERR	5
ERR	Orbit duration is negative	No calculation performed	XL_CFI_TIME_REF_INIT_ORBDUR_ERR	6
ERR	ANX time is bigger than orbit duration	No calculation performed	XL_CFI_TIME_REF_INIT_COMP_ERR	7
ERR	Memory allocation error	No calculation performed	XL_CFI_TIME_REF_INIT_MEMORY_ERR	8
ERR	Time reference ID is already initialized	No calculation performed	XL_CFI_TIME_REF_INIT_STATUS_ERR	9

7.2.6 Runtime performances

The following runtime performances have been measured for a serie of calls to **xl_time_ref_init** + **xl_time_close**.

Table 17: Runtime performances of xl_time_ref_init + xl_time_close function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.0344	0.0043	0.0054	0.0007

7.3 xl_time_close

7.3.1 Overview

The `xl_time_close` CFI function cleans up any memory allocation performed by the initialization functions. A complete calling sequence of the time reference computations is presented in section 4.2.

7.3.2 Calling interface

The calling interface of the `xl_time_close` CFI function is the following:

```
#include <explorer_lib.h>
{
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_TIME_CLOSE], status;
    status = xl_time_close (&time_id, ierr);
}
```

7.3.3 Input parameters

The `xl_time_close` CFI function has the following input parameters:

Table 18: Input parameters of xl_time_close function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
time_id	xl_time_id*	-	Structure that contains the time correlations.	-	-

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Satellite ID: `sat_id`. See [GEN_SUM].

7.3.4 Output parameters

The output parameters of the `xl_time_close` CFI function are:

Table 19: Output parameters of xl_time_close function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_time_close	long	-	Status flag	-	-
ier	long	-	Error vector	-	-

7.3.5 Warnings and errors

Next table lists the possible error messages that can be returned by the **xl_time_close** CFI function after translating the returned extended status flag into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library **xl_get_msg** (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the extended status flag returned by the **xl_time_close** function by calling the function of the EXPLORER_LIB software library **xl_get_code** (see [GEN_SUM])

Table 20: Error messages of xl_time_close function

Error type	Error message	Cause and impact	Error code	Error No
ERR	The Time Id is not initialized or it could be in use by another Id.	No calculation performed	XL_CFI_TIME_CLOSE_WRONG_ID_ERR	0

7.3.6 Runtime performances

Runtime is smaller than CPU clock and it is not possible to perform loops for measuring it.

7.4 xl_time_get_id_data

7.4.1 Overview

The `xl_time_get_id_data` CFI function returns a data structure containing the data used for the time initialisation.

7.4.2 Calling interface

The calling interface of the `xl_time_get_id_data` CFI function is the following:

```
#include <explorer_lib.h>
{
    xl_time_id time_id;
    xl_time_id_data data;
    long status;
    status = xl_time_get_id_data (&time_id, &data);
}
```

7.4.3 Input parameters

The `xl_time_get_id_data` CFI function has the following input parameters:

Table 21: Input parameters of xl_time_get_id_data function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
time_id	xl_time_id*	-	Structure that contains the time correlations.	-	-

7.4.4 Output parameters

The output parameters of the `xl_time_get_id_data` CFI function are:

Table 22: Output parameters of xl_time_get_id_data function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_time_get_id_data	long	-	Status flag	-	-
data	xl_time_id_data	-	Time ID data	-	-

The data structure `xl_time_id_get_id_data` can be seen in table 8.

7.4.5 Warnings and errors

This function does not return any error/warning code. Only the status of the function indicates if the execution was correct or not.

The possible causes of error are:

- The time_id was not initialised.

7.4.6 Runtime performances

The following runtime performances have been estimated.

Table 23: Runtime performances of xl_time_get_id_data function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.00124	0.00053	0.00071	0.00007

7.5 xl_time_set_id_data

7.5.1 Overview

The `xl_time_set_id_data` CFI function changes the time correlations that are stored within a `time_id`.

7.5.2 Calling interface

The calling interface of the `xl_time_set_id_data` CFI function is the following:

```
#include <explorer_lib.h>
{
    xl_time_id time_id;
    xl_time_id_data data;
    long status;
    status = xl_time_set_time_id (&time_id, &data);
}
```

7.5.3 Input parameters

The `xl_time_set_id_data` CFI function has the following input parameters:

Table 24: Input parameters of xl_time_set_id_data function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
time_id	xl_time_id*	-	Structure that contains the time correlations (input/output parameter)	-	-

7.5.4 Output parameters

The output parameters of the `xl_time_set_id_data` CFI function are:

Table 25: Output parameters of xl_time_set_id_data function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_time_set_id_data	long	-	Status flag	-	-
time_id	xl_time_id*	-	Structure that contains the time correlations (input/output parameter)	-	-

Table 25: Output parameters of xl_time_set_id_data function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
data	xl_time_id_data	-	Time ID data	-	-

The data structure `xl_time_set_id_data` can be seen in table 8.

7.5.5 Warnings and errors

This function does not return any error/warning code. Only the status of the function indicates if the execution was correct or not.

The possible causes of error are:

- The `time_id` was not initialised.

7.5.6 Runtime performances

The following runtime performances have been estimated.

Table 26: Runtime performances of xl_time_set_id_data function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.00115	0.00049	0.00064	0.00008

7.6 xl_run_init

7.6.1 Overview

The **xl_run_init** CFI function groups into a single *id* the *satellite Id* and the *time Id*, creating a *run Id*.

7.6.2 Calling interface

The calling interface of the **xl_run_init** CFI function is the following:

```
#include <explorer_lib.h>
{
    long sat_id, run_id;
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_RUN_INIT], status;
    status = xl_run_init (&sat_id, &time_id, &run_id, ierr);
}
```

7.6.3 Input parameters

The **xl_run_init** CFI function has the following input parameters:

Table 27: Input parameters of xl_run_init function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long *	-	Satellite ID	-	Complete
time_id	xl_time_id*	-	Structure that contains the time correlations.	-	-

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Satellite ID: sat_id. See [GEN_SUM].

7.6.4 Output parameters

The output parameters of the **xl_run_init** CFI function are:

Table 28: Output parameters of xl_run_init function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_run_init	long	-	Status flag	-	-
run_id	long *	-	Run ID	-	>=0

Table 28: Output parameters of xl_run_init function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
ierr	long	-	Error vector	-	-

7.6.5 Warnings and errors

Next table lists the possible error messages that can be returned by the **xl_run_init** CFI function after translating the returned extended status flag into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library **xl_get_msg** (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the extended status flag returned by the **xl_run_init** function by calling the function of the EXPLORER_LIB software library **xl_get_code** (see [GEN_SUM])

Table 29: Error messages of xl_run_init function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Maximum number of initializations reached	No calculation performed	XL_CFI_RUN_INIT_MAX_INIT_ERR	0
ERR	Satellite ID is not correct	No calculation performed	XL_CFI_RUN_INIT_SAT_ERR	1
ERR	Time ID is not initialized	No calculation performed	XL_CFI_RUN_INIT_TIME_INIT_ERR	2
ERR	Memory allocation error	No calculation performed	XL_CFI_RUN_INIT_MEMORY_ERR	3
ERR	Inconsistency between Ids within the run_id	No calculation performed	XL_CFI_RUN_INIT_INCONSISTENCY_ERR	4

7.6.6 Runtime performances

Runtime is smaller than CPU clock and it is not possible to perform loops for measuring it.

7.7 xl_run_get_ids

7.7.1 Overview

The **xl_run_get_ids** CFI function returns the *ids* being used..

7.7.2 Calling interface

The calling interface of the **xl_run__get_ids** CFI function is the following:

```
#include <explorer_lib.h>
{
    long sat_id, run_id;
    xl_time_id time_id = {NULL};
    xl_run_get_ids (&run_id, &time_id);
}
```

7.7.3 Input parameters

The **xl_run_get_ids** CFI function has the following input parameters:

Table 30: Input parameters of xl_run_get_ids function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
run_id	long *	-	Run ID	-	>=0

7.7.4 Output parameters

The output parameters of the **xl_run_close** CFI function are:

Table 31: Output parameters of xl_run_get_ids function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_run_get_ids	void	-	-	-	-
time_id	xl_time_id*	-	Structure that contains the time correlations.	-	-

7.7.5 Warnings and errors

Next table lists the possible error messages that can be returned by the **xl_run_get_ids** CFI function after translating the returned extended status flag into the equivalent list of error messages by calling the function

of the EXPLORER_LIB software library **xl_get_msg** (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (**WARN**) or an error (**ERR**), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the extended status flag returned by the **xl_run_get_ids** function by calling the function of the EXPLORER_LIB software library **xl_get_code** (see [GEN_SUM])

TBW

7.7.6 Runtime performances

Runtime is smaller than CPU clock and it is not possible to perform loops for measuring it.

7.8 xl_run_close

7.8.1 Overview

The **xl_run_close** CFI function cleans up any memory allocation performed by the initialization functions.

7.8.2 Calling interface

The calling interface of the **xl_run_close** CFI function is the following:

```
#include <explorer_lib.h>
{
    long run_id;
    xl_run_close (&run_id);
}
```

7.8.3 Input parameters

The **xl_run_close** CFI function has the following input parameters:

Table 32: Input parameters of xl_run_close function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
run_id	long *	-	Run ID	-	>=0

7.8.4 Output parameters

The output parameters of the **xl_run_close** CFI function are:

Table 33: Output parameters of xl_run_close function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_run_close	void	-	-	-	-

7.8.5 Warnings and errors

No errors have been envisaged for **xl_run_close**.

7.8.6 Runtime performances

Runtime is smaller than CPU clock and it is not possible to perform loops for measuring it.

7.9 xl_time_ascii_to_ascii

7.9.1 Overview

The **xl_time_ascii_to_ascii** CFI function transforms a time expressed in a given ASCII format and reference (TAI, UTC, UT1 or GPS) into a time in a different ASCII format and/or reference (TAI, UTC, UT1 or GPS).

7.9.2 Calling Interface

The calling interface of the **xl_time_ascii_to_ascii** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long ascii_id_in, ascii_id_out;
    long time_ref_in, time_ref_out;
    char ascii_in[XL_TIME_ASCII_DIM_MAX];
    char ascii_out[XL_TIME_ASCII_DIM_MAX];
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_ASCII_ASCII], status;

    status = xl_time_ascii_to_ascii(&time_id, &ascii_id_in,
                                   &time_ref_in, &ascii_in, &ascii_id_out,
                                   &time_ref_out, ascii_out, ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_time_ascii_to_ascii_run(&run_id, &ascii_id_in,
                                        &time_ref_in, &ascii_in, &ascii_id_out,
                                        &time_ref_out, ascii_out, ierr);
}
```

The **XL_TIME_ASCII_DIM_MAX** and **XL_NUM_ERR_ASCII_ASCII** constants are defined in the file *explorer_lib.h*.

7.9.3 Input Parameters

The `xl_time_ascii_to_ascii` CFI function has the following input parameters:

Table 34: Input parameters of `xl_time_ascii_to_ascii` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>time_id</code>	<code>xl_time_id*</code>	-	Structure that contains the time correlations.	-	-
<code>ascii_id_in</code>	<code>long *</code>	-	ASCII format ID	-	Complete
<code>time_ref_in</code>	<code>long *</code>	-	Time reference ID	-	Complete
<code>ascii_in</code>	<code>char</code>	See table 4 and table 5	Time in ASCII format	See table 4 and table 5	See table 4 and table 5
<code>ascii_id_out</code>	<code>long *</code>	-	ASCII format ID	-	Complete
<code>time_ref_out</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>

It is possible to use enumeration values rather than integer values for some of the input arguments:

- ASCII format ID: `ascii_id_in` and `ascii_id_out`. Current document, section 6.2.
- Time reference ID: `time_ref_in` and `time_ref_out`. See [GEN_SUM].

It is important to point out the usage of the **`time_ref_in`** parameter in the frame of the current function:

- If **`time_ref_in`** input parameter is defined, it shall be used by the function.
- If **`time_ref_in`** input parameter is undefined, it shall be used the time reference part from the `ascii` format string. In case this is omitted, an error shall be returned.

Note that for the function to work correctly, the time references should be properly initialised before calling the function (see section 4.2 for details), unless `time_ref_in = time_ref_out`.

7.9.4 Output Parameters

The output parameters of the `xl_time_ascii_to_ascii` CFI function are:

Table 35: Output parameters of `xl_time_ascii_to_ascii`

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_time_ascii_to_ascii</code>	long	-	Status flag	-	-
<code>ascii_out</code>	char	See table 4 and table 5	Time in ASCII format	See table 4 and table 5	See table 4 and table 5
<code>ierr</code>	long	-	Error vector	-	-

7.9.5 Warnings and Errors

Next table lists the possible error messages that can be returned by the `xl_time_ascii_to_ascii` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained by translating the error vector returned by the `xl_time_ascii_to_ascii` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 36: Error messages of `xl_time_ascii_to_ascii` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input ascii format ID is not correct	No calculation performed	XL_CFI_TIME_ASCII_ASCII_ASCII_IN_ERR	0
ERR	Input time reference ID is not correct	No calculation performed	XL_CFI_TIME_ASCII_ASCII_TIME_IN_ERR	1
ERR	Satellite ID and input format ID are not compatible	No calculation performed	XL_CFI_TIME_ASCII_ASCII_COMP_IN_ERR	2
ERR	Input ascii format is not correct	No calculation performed	XL_CFI_TIME_ASCII_ASCII_FORMAT_IN_ERR	3
ERR	Input time reference inconsistent with the time reference in the date	No calculation performed	XL_CFI_TIME_ASCII_ASCII_REF_INC_IN_ERR	4
ERR	Output ascii format ID is not correct	No calculation performed	XL_CFI_TIME_ASCII_ASCII_ASCII_OUT_ERR	5
ERR	Output time reference ID is not correct	No calculation performed	XL_CFI_TIME_ASCII_ASCII_TIME_OUT_ERR	6

Table 36: Error messages of xl_time_ascii_to_ascii function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Satellite ID and output format ID are not compatible	No calculation performed	XL_CFI_TIME_ASCII_ASCII_COMP_OUT_ERR	7
ERR	Input ascii year is out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_YEAR_IN_ERR	8
ERR	Input ascii month is out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_MONTH_IN_ERR	9
ERR	Input ascii day is out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_DAY_IN_ERR	10
ERR	Input ascii hour is out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_HOUR_IN_ERR	11
ERR	Input ascii minutes are out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_MIN_IN_ERR	12
ERR	Input ascii seconds are out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_SEC_IN_ERR	13
ERR	Input ascii microseconds are out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_MICROSEC_IN_ERR	14
ERR	Internal error: Input Gregorian date to MJD transformation failed	No calculation performed	XL_CFI_TIME_ASCII_ASCII_MJD_IN_ERR	15
ERR	Internal error: Output ascii MJD is out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_MJD_OUT_ERR	16
ERR	Internal error: Output ascii year is out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_YEAR_OUT_ERR	17
ERR	Internal error: Output ascii month is out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_MONTH_OUT_ERR	18
ERR	Internal error: Output ascii day is out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_DAY_OUT_ERR	19
ERR	Internal error: Output ascii hour is out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_HOUR_OUT_ERR	20
ERR	Internal error: Output ascii minutes are out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_MIN_OUT_ERR	21
ERR	Internal error: Output ascii seconds are out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_SEC_OUT_ERR	22
ERR	Internal error: Output ascii microseconds are out of range	No calculation performed	XL_CFI_TIME_ASCII_ASCII_MICROSEC_OUT_ERR	23
ERR	Internal error: Output ascii format is not correct	No calculation performed	XL_CFI_TIME_ASCII_ASCII_FORMAT_OUT_ERR	24
ERR	Time reference not initialised	No calculation performed	XL_CFI_TIME_ASCII_ASCII_REF_INIT_ERR	25

Table 36: Error messages of xl_time_ascii_to_ascii function

Error type	Error message	Cause and impact	Error code	Error No
WARN	Time out of initialization range	Calculation performed. A message informs the user.	XL_CFI_TIME_ASCII_ASCII_REF_INIT_WARN	26

7.9.6 Runtime Performances

The following runtime performances have been measured.

Table 37: Runtime performances of xl_time_ascii_to_ascii function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.10864	0.01823	0.03868	0.00658

7.10 xl_time_ascii_to_processing

7.10.1 Overview

The **xl_time_ascii_to_processing** CFI function transforms a time expressed in a given ASCII format and reference (TAI, UTC, UT1 or GPS) into a time in Processing format, performing a reference transformation if necessary (to TAI, UTC, UT1 or GPS).

User should be aware that the use of UTC in Processing format is not encouraged, due to the discontinuity that is caused by the introduction of leap seconds. See [IERS] for further details.

7.10.2 Calling Interface

The calling interface of the **xl_time_ascii_to_processing** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long ascii_id_in, proc_id_out;
    long time_ref_in, time_ref_out;
    char ascii_in[XL_TIME_ASCII_DIM_MAX];
    double processing_out;
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_ASCII_PROC], status;

    status = xl_time_ascii_to_processing(&time_id, &ascii_id_in,
                                       &time_ref_in, ascii_in, &proc_id_out,
                                       &time_ref_out, &processing_out, ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_time_ascii_to_processing_run(&run_id, &ascii_id_in,
                                           &time_ref_in, ascii_in, &proc_id_out,
                                           &time_ref_out, &processing_out, ierr);
}
```

The `XL_TIME_ASCII_DIM_MAX` and `XL_NUM_ERR_ASCII_PROC` constants are defined in the file `explorer_lib.h`.

7.10.3 Input Parameters

The `xl_time_ascii_to_processing` CFI function has the following input parameters:

Table 38: Input parameters of `xl_time_ascii_to_processing` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>time_id</code>	<code>xl_time_id*</code>	-	Structure that contains the time correlations.	-	-
<code>ascii_id_in</code>	<code>long *</code>	-	ASCII format ID	-	Complete
<code>time_ref_in</code>	<code>long *</code>	-	Time reference ID	-	Complete
<code>ascii_in</code>	<code>char</code>	See table 4 and table 5	Time in ASCII format	See table 4 and table 5	See table 4 and table 5
<code>proc_id_out</code>	<code>long *</code>	-	Processing format ID	-	Complete
<code>time_ref_out</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>

It is possible to use enumeration values rather than integer values for some of the input arguments:

- ASCII format ID: `ascii_id_in`. Current document, section 6.2.
- Time reference ID: `time_ref_in` and `time_ref_out`. See [GEN_SUM].
- Processing format ID: `proc_id_out`. Current document, section 6.2

It is important to point out the usage of the **time_ref_in** parameter in the frame of the current function:

- If **time_ref_in** input parameter is defined, it shall be used by the function.
- If **time_ref_in** input parameter is undefined, it shall be used the time reference part from the ascii format string. In case this is omitted, an error shall be returned.

Note that for the function to work correctly, the time references should be properly initialised before calling the function (see section 4.2 for details), unless `time_ref_in = time_ref_out`.

7.10.4 Output Parameters

The output parameters of the `xl_time_ascii_to_processing` CFI function are:

Table 39: Output parameters of `xl_time_ascii_to_processing`

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_time_ascii_to_processing</code>	long	-	Status flag	-	-
<code>processing_out</code>	double*	-	Time in Processing Format	Decimal days, MJD2000 (Processing)	[-18262.0,36524.0]
<code>ierr</code>	long	-	Error vector	-	-

7.10.5 Warnings and Errors

Next table lists the possible error messages that can be returned by the `xl_time_ascii_to_processing` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained by translating the error vector returned by the `xl_time_ascii_to_processing` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 40: Error messages of `xl_time_ascii_to_processing` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input ascii format ID is not correct	No calculation performed	XL_CFI_TIME_ASCII_PRO C_ASCII_IN_ERR	0
ERR	Input time reference ID is not correct	No calculation performed	XL_CFI_TIME_ASCII_PRO C_TIME_IN_ERR	1
ERR	Satellite ID and input format ID are not compatible	No calculation performed	XL_CFI_TIME_ASCII_PRO C_COMP_IN_ERR	2
ERR	Input format is not correct	No calculation performed	XL_CFI_TIME_ASCII_PRO C_FORMAT_IN_ERR	3
ERR	Input time reference inconsistent with the time reference in the date	No calculation performed	XL_CFI_TIME_ASCII_PRO C_REF_INC_IN_ERR	4
ERR	Output processing format ID is not correct	No calculation performed	XL_CFI_TIME_ASCII_PRO C_PROC_OUT_ERR	5
ERR	Output time reference ID is not correct	No calculation performed	XL_CFI_TIME_ASCII_PRO C_TIME_OUT_ERR	6
ERR	Year is out of range	No calculation performed	XL_CFI_TIME_ASCII_PRO C_YEAR_ERR	7

Table 40: Error messages of xl_time_ascii_to_processing function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Month is out of range	No calculation performed	XL_CFI_TIME_ASCII_PRO C_MONTH_ERR	8
ERR	Day is out of range	No calculation performed	XL_CFI_TIME_ASCII_PRO C_DAY_ERR	9
ERR	Hour is out of range	No calculation performed	XL_CFI_TIME_ASCII_PRO C_HOUR_ERR	10
ERR	Minutes are out of range	No calculation performed	XL_CFI_TIME_ASCII_PRO C_MIN_ERR	11
ERR	Seconds are out of range	No calculation performed	XL_CFI_TIME_ASCII_PRO C_SEC_ERR	12
ERR	Microseconds are out of range	No calculation performed	XL_CFI_TIME_ASCII_PRO C_MICROSEC_ERR	13
ERR	Internal Error: Input Gregorian date to MJD transformation failed	No calculation performed	XL_CFI_TIME_ASCII_PRO C_MJD_ERR	14
ERR	Time reference not initialised	No calculation performed	XL_CFI_TIME_ASCII_PRO C_REF_INIT_ERR	15
WARN	Time out of initialization range	Calculation performed. A message informs the user.	XL_CFI_TIME_ASCII_PRO C_REF_INIT_WARN	16

7.10.6 Runtime Performances

The following runtime performances have been measured.

Table 41: Runtime performances of xl_time_ascii_to_processing

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.13652	.002128	0.04180	0.00693

7.11 xl_time_ascii_to_transport

7.11.1 Overview

The **xl_time_ascii_to_transport** CFI function transforms a time expressed in a given ASCII format and reference (TAI, UTC, UT1 or GPS) into a time in a Transport format, performing a reference transformation if necessary (to TAI, UTC, UT1 or GPS).

7.11.2 Calling Interface

The calling interface of the **xl_time_ascii_to_transport** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long ascii_id_in, trans_id_out;
    long time_ref_in, time_ref_out;
    char ascii_in[XL_TIME_ASCII_DIM_MAX];
    long transport_out[XL_TIME_TRANS_DIM_MAX];
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_ASCII_TRANS], status;

    status = xl_time_ascii_to_transport(&time_id, &ascii_id_in,
                                       &time_ref_in, &ascii_in, &trans_id_out,
                                       &time_ref_out, transport_out, ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_time_ascii_to_transport_run(&run_id, &ascii_id_in,
                                           &time_ref_in, &ascii_in, &trans_id_out,
                                           &time_ref_out, transport_out, ierr);
}
```

The `XL_TIME_TRANS_DIM_MAX`, `XL_TIME_ASCII_DIM_MAX`, `XL_NUM_ERR_ASCII_TRANS` constants are defined in the file *explorer_lib.h*.

7.11.3 Input Parameters

The `xl_time_ascii_to_transport` CFI function has the following input parameters:

Table 42: Input parameters of `xl_time_ascii_to_transport` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>time_id</code>	<code>xl_time_id*</code>	-	Structure that contains the time correlations.	-	-
<code>ascii_id_in</code>	<code>long *</code>	-	ASCII format ID	-	Complete
<code>time_ref_in</code>	<code>long *</code>	-	Time reference ID	-	Complete
<code>ascii_in</code>	<code>char</code>	See table 4 and table 5	Time in ASCII format	See table 4 and table 5	See table 4 and table 5
<code>trans_id_out</code>	<code>long *</code>	-	Transport format ID	-	Complete
<code>time_ref_out</code>	<code>long *</code>	-	Time reference ID	-	Any except XL_TIME_UNDEF

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Satellite ID: `sat_id`. See [GEN_SUM].
- ASCII format ID: `trans_id_in`. Current document, section 6.2.
- Time reference ID: `time_ref_in` and `time_ref_out`. See [GEN_SUM].
- Transport format ID: `trans_id_out`. Current document, section 6.2.

It is important to point out the usage of the **time_ref_in** parameter in the frame of the current function:

- If **time_ref_in** input parameter is defined, it shall be used by the function.
- If **time_ref_in** input parameter is undefined, it shall be used the time reference part from the ascii format string. In case this is omitted, an error shall be returned.

Note that for the function to work correctly, the time references should be properly initialised before calling the function (see section 4.2 for details), unless `time_ref_in = time_ref_out`.

7.11.4 Output Parameters

The output parameters of the `xl_time_ascii_to_transport` CFI function are:

Table 43: Output parameters of `xl_time_ascii_to_transport`

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_time_ascii_to_transport</code>	long	-	Status flag	-	-
<code>transport_out[dim]</code>	long	See table 3	Time in Transport format	See table 3	See table 3
<code>ierr</code>	long	-	Error vector	-	-

7.11.5 Warnings and Errors

Next table lists the possible error messages that can be returned by the `xl_time_ascii_to_transport` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained by translating the error vector returned by the `xl_time_ascii_to_transport` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 44: Error messages of `xl_time_ascii_to_transport` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input ascii format ID is not correct	No calculation performed	XL_CFI_TIME_ASCII_TRANS_ASCII_IN_ERR	0
ERR	Input time reference ID is not correct	No calculation performed	XL_CFI_TIME_ASCII_TRANS_TIME_IN_ERR	1
ERR	Satellite ID and input format ID are not compatible	No calculation performed	XL_CFI_TIME_ASCII_TRANS_COMP_IN_ERR	2
ERR	Input format is not correct	No calculation performed	XL_CFI_TIME_ASCII_TRANS_FORMAT_IN_ERR	3
ERR	Input time reference inconsistent with the time reference in the date	No calculation performed	XL_CFI_TIME_ASCII_TRANS_REF_INC_IN_ERR	4
ERR	Output transport format ID is not correct	No calculation performed	XL_CFI_TIME_ASCII_TRANS_TRANS_OUT_ERR	5
ERR	Output time reference ID is not correct	No calculation performed	XL_CFI_TIME_ASCII_TRANS_TIME_OUT_ERR	6

Table 44: Error messages of xl_time_ascii_to_transport function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Satellite ID and output format ID are not compatible	No calculation performed	XL_CFI_TIME_ASCII_TRANS_COMP_OUT_ERR	7
ERR	Year is out of range	No calculation performed	XL_CFI_TIME_ASCII_TRANS_YEAR_ERR	8
ERR	Month is out of range	No calculation performed	XL_CFI_TIME_ASCII_TRANS_MONTH_ERR	9
ERR	Day is out of range	No calculation performed	XL_CFI_TIME_ASCII_TRANS_DAY_ERR	10
ERR	Hour is out of range	No calculation performed	XL_CFI_TIME_ASCII_TRANS_HOUR_ERR	11
ERR	Minutes are out of range	No calculation performed	XL_CFI_TIME_ASCII_TRANS_MIN_ERR	12
ERR	Seconds are out of range	No calculation performed	XL_CFI_TIME_ASCII_TRANS_SEC_ERR	13
ERR	Microseconds are out of range	No calculation performed	XL_CFI_TIME_ASCII_TRANS_MICROSEC_ERR	14
ERR	Internal Error: Input Gregorian date to MJD transformation failed	No calculation performed	XL_CFI_TIME_ASCII_TRANS_MJD_ERR	15
ERR	Time reference not initialised	No calculation performed	XL_CFI_TIME_ASCII_TRANS_REF_INIT_ERR	16
WARN	Time out of initialization range	Calculation performed. A message informs the user.	XL_CFI_TIME_ASCII_TRANS_REF_INIT_WARN	17

7.11.6 Runtime Performances

The following runtime performances have been measured.

Table 45: Runtime performances of xl_time_ascii_to_transport

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.06622	0.01033	0.02035	0.00343

7.12 xl_time_processing_to_ascii

7.12.1 Overview

The **xl_time_processing_to_ascii** CFI function transforms a time expressed in Processing format and a given reference (TAI, UTC, UT1 or GPS) into a time in an ASCII format, performing a reference transformation if necessary (to TAI, UTC, UT1 or GPS).

User should be aware that the use of UTC in Processing format is not encouraged, due to the discontinuity that is caused by the introduction of leap seconds. See [IERS] for further details.

7.12.2 Calling Interface

The calling interface of the **xl_time_processing_to_ascii** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long proc_id_in, ascii_id_out;
    long time_ref_in, time_ref_out;
    double processing_in;
    char ascii_out[XL_TIME_ASCII_DIM_MAX];
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_PROC_ASCII], status;

    status = xl_time_processing_to_ascii(&time_id, &proc_id_in,
                                        &time_ref_in, &processing_in, &ascii_id_out,
                                        &time_ref_out, ascii_out, ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_time_processing_to_ascii_run(&run_id, &proc_id_in,
                                           &time_ref_in, &processing_in, &ascii_id_out,
                                           &time_ref_out, ascii_out, ierr);
}
```

7.12.3 Input Parameters

The `xl_time_processing_to_ascii` CFI function has the following input parameters:

Table 46: Input parameters of `xl_time_processing_to_ascii` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>time_id</code>	<code>xl_time_id*</code>	-	Structure that contains the time correlations.	-	-
<code>proc_id_in</code>	<code>long *</code>	-	Processing format ID	-	Complete
<code>time_ref_in</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>
<code>processing_in</code>	<code>double*</code>	-	Time in Processing Format	Decimal days, MJD2000 (Processing)	[-18262.0,36524.0]
<code>ascii_id_out</code>	<code>long *</code>	-	ASCII format ID	-	Complete
<code>time_ref_out</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Processing format ID: `proc_id_in`. Current document, section 6.2.
- Time reference ID: `time_ref_in` and `time_ref_out`. See [GEN_SUM].
- ASCII format ID: `ascii_id_out`. Current document, section 6.2.

Note that for the function to work correctly, the time references should be properly initialised before calling the function (see section 4.2 for details), unless `time_ref_in = time_ref_out`.

7.12.4 Output Parameters

The output parameters of the `xl_time_processing_to_ascii` CFI function are:

Table 47: Output parameters of `xl_time_processing_to_ascii`

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_time_processing_to_ascii</code>	long	-	Status flag	-	-
<code>ascii_out</code>	char	See table 4 and table 5	Time in ASCII format	See table 4 and table 5	See table 4 and table 5
<code>ierr</code>	long	-	Error vector	-	-

7.12.5 Warnings and Errors

Next table lists the possible error messages that can be returned by the `xl_time_processing_to_ascii` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained by translating the error vector returned by the `xl_time_processing_to_ascii` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 48: Error messages of `xl_time_processing_to_ascii` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input processing format ID is not correct	No calculation performed	<code>XL_CFI_TIME_PROC_ASCII_PROC_IN_ERR</code>	0
ERR	Input time reference ID is not correct	No calculation performed	<code>XL_CFI_TIME_PROC_ASCII_TIME_IN_ERR</code>	1
ERR	Input days out of range	No calculation performed	<code>XL_CFI_TIME_PROC_ASCII_DAY_ERR</code>	2
ERR	Output ascii format ID is not correct	No calculation performed	<code>XL_CFI_TIME_PROC_ASCII_ASCII_OUT_ERR</code>	3
ERR	Output time reference ID is not correct	No calculation performed	<code>XL_CFI_TIME_PROC_ASCII_TIME_OUT_ERR</code>	4
ERR	Satellite ID and output format ID are not compatible	No calculation performed	<code>XL_CFI_TIME_PROC_ASCII_COMP_OUT_ERR</code>	5
ERR	Internal error: Output ascii MJD is out of range	No calculation performed	<code>XL_CFI_TIME_PROC_ASCII_ASCII_MJD_ERR</code>	6

Table 48: Error messages of xl_time_processing_to_ascii function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Internal error: Output ascii year is out of range	No calculation performed	XL_CFI_TIME_PROC_ASCII_ASCII_YEAR_ERR	7
ERR	Internal error: Output ascii month is out of range	No calculation performed	XL_CFI_TIME_PROC_ASCII_ASCII_MONTH_ERR	8
ERR	Internal error: Output ascii day is out of range	No calculation performed	XL_CFI_TIME_PROC_ASCII_ASCII_DAY_ERR	9
ERR	Internal error: Output ascii hour is out of range	No calculation performed	XL_CFI_TIME_PROC_ASCII_ASCII_HOUR_ERR	10
ERR	Internal error: Output ascii minutes are out of range	No calculation performed	XL_CFI_TIME_PROC_ASCII_ASCII_MIN_ERR	11
ERR	Internal error: Output ascii seconds are out of range	No calculation performed	XL_CFI_TIME_PROC_ASCII_ASCII_SEC_ERR	12
ERR	Internal error: Output ascii microseconds are out of range	No calculation performed	XL_CFI_TIME_PROC_ASCII_ASCII_MICROSEC_ERR	13
ERR	Internal error: Output ascii format is not correct	No calculation performed	XL_CFI_TIME_PROC_ASCII_FORMAT_OUT_ERR	14
ERR	Time reference not initialised	No calculation performed	XL_CFI_TIME_PROC_ASCII_REF_INIT_ERR	15
WARN	Time out of initialization range	Calculation performed. A message informs the user.	XL_CFI_TIME_PROC_ASCII_REF_INIT_WARN	16

7.12.6 Runtime Performances

The following runtime performances have been measured.

Table 49: Runtime performances of xl_time_processing_to_ascii

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.09202	0.01549	0.02768	0.00468

7.13 xl_time_processing_to_processing

7.13.1 Overview

The **xl_time_processing_to_processing** CFI function transforms a time expressed in Processing format and a given reference (TAI, UTC, UT1 or GPS) into a time in Processing format with a different reference (TAI, UTC, UT1 or GPS).

User should be aware that the use of UTC in Processing format is not encouraged, due to the discontinuity that is caused by the introduction of leap seconds. See [IERS] for further details.

7.13.2 Calling Interface

The calling interface of the **xl_time_processing_to_processing** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long proc_id_in, proc_id_out;
    long time_ref_in, time_ref_out;
    double processing_in, processing_out;
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_PROC_PROC], status;

    status = xl_time_processing_to_processing(&time_id, &proc_id_in,
        &time_ref_in, &processing_in, &proc_id_out,
        &time_ref_out, &processing_out, ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_time_processing_to_processing_run(&run_id, &proc_id_in,
        &time_ref_in, &processing_in, &proc_id_out,
        &time_ref_out, &processing_out, ierr);
}
```

The `XL_NUM_ERR_PROC_PROC` constant is defined in the file *explorer_lib.h*.

7.13.3 Input Parameters

The `xl_time_processing_to_processing` CFI function has the following input parameters:

Table 50: Input parameters of `xl_time_processing_to_processing` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>time_id</code>	<code>xl_time_id*</code>	-	Structure that contains the time correlations.	-	-
<code>proc_id_in</code>	<code>long *</code>	-	Processing format ID	-	Complete
<code>time_ref_in</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>
<code>processing_in</code>	<code>double*</code>	-	Time in Processing Format	Decimal days, MJD2000 (Processing)	<code>[-18262.0,36524.0]</code>
<code>proc_id_out</code>	<code>long *</code>	-	Processing format ID	-	Complete
<code>time_ref_out</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Processing format ID: `proc_id_in` and `proc_id_out`. Current document, section 6.2.
- Time reference ID: `time_ref_in` and `time_ref_out`. See `[GEN_SUM]`.

Note that for the function to work correctly, the time references should be properly initialised before calling the function (see section 4.2 for details), unless `time_ref_in = time_ref_out`.

7.13.4 Output Parameters

The output parameters of the `xl_time_processing_to_processing` CFI function are:

Table 51: Output parameters of `xl_time_processing_to_processing`

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_time_processing_to_processing</code>	long	-	Status flag	-	-
<code>processing_out</code>	double*	-	Time in Processing Format	Decimal days, MJD2000 (Processing)	[-18262.0,36524.0]
<code>ierr</code>	long	-	Error vector	-	-

7.13.5 Warnings and Errors

Next table lists the possible error messages that can be returned by the `xl_time_processing_to_processing` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained by translating the error vector returned by the `xl_time_processing_to_processing` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 52: Error messages of `xl_time_processing_to_processing` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input processing format ID is not correct	No calculation performed	<code>XL_CFI_TIME_PROC_PRO C_PROC_IN_ERR</code>	0
ERR	Input time reference ID is not correct	No calculation performed	<code>XL_CFI_TIME_PROC_PRO C_TIME_IN_ERR</code>	1
ERR	Output processing format ID is not correct	No calculation performed	<code>XL_CFI_TIME_PROC_PRO C_PROC_OUT_ERR</code>	2
ERR	Output time reference ID is not correct	No calculation performed	<code>XL_CFI_TIME_PROC_PRO C_TIME_OUT_ERR</code>	3
ERR	Number of days out of range	No calculation performed	<code>XL_CFI_TIME_PROC_PRO C_DAY_ERR</code>	4
ERR	Time reference not initialised	No calculation performed	<code>XL_CFI_TIME_PROC_PRO C_REF_INIT_ERR</code>	5
WARN	Time out of initialization range	Calculation performed. A message informs the user.	<code>XL_CFI_TIME_PROC_PRO C_REF_INIT_WARN</code>	6

7.13.6 Runtime Performances

The following runtime performances have been measured.

Table 53: Runtime performances of xl_time_processing_to_processing

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.05951	0.00789	0.01043	0.00147

7.14 xl_time_processing_to_transport

7.14.1 Overview

The **xl_time_processing_to_transport** CFI function transforms a time expressed in Processing format and a given reference (TAI, UTC, UT1 or GPS) into a time in a Transport format, performing a reference transformation if necessary (to TAI, UTC, UT1 or GPS).

User should be aware that the use of UTC in Processing format is not encouraged, due to the discontinuity that is caused by the introduction of leap seconds. See [IERS] for further details.

7.14.2 Calling Interface

The calling interface of the **xl_time_processing_to_transport** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long proc_id_in, trans_id_out;
    long time_ref_in, time_ref_out;
    double processing_in;
    long transport_out[XL_TIME_TRANS_DIM_MAX];
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_PROC_TRANS], status;

    status = xl_time_processing_to_transport(&time_id, &proc_id_in,
        &time_ref_in, &processing_in, &trans_id_out,
        &time_ref_out, transport_out, ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_time_processing_to_transport_run(&run_id, &proc_id_in,
        &time_ref_in, &processing_in, &trans_id_out,
        &time_ref_out, transport_out, ierr);
}
```

The `XL_TIME_TRANS_DIM_MAX` and `XL_NUM_ERR_PROC_TRANS` constants are defined in the file *explorer_lib.h*.

7.14.3 Input Parameters

The `xl_time_processing_to_transport` CFI function has the following input parameters:

Table 54: Input parameters of `xl_time_processing_to_transport` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>time_id</code>	<code>xl_time_id*</code>	-	Structure that contains the time correlations.	-	-
<code>proc_id_in</code>	<code>long *</code>	-	Processing format ID	-	Complete
<code>time_ref_in</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>
<code>processing_in</code>	<code>double*</code>	-	Time in Processing Format	Decimal days, MJD2000 (Processing)	[-18262.0,36524.0]
<code>trans_id_out</code>	<code>long *</code>	-	Transport format ID	-	Complete
<code>time_ref_out</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Processing format ID: `proc_id_in`. Current document, section 6.2.
- Time reference ID: `time_ref_in` and `time_ref_out`. See [GEN_SUM].
- Transport format ID: `trans_id_out`. Current document, section 6.2.

Note that for the function to work correctly, the time references should be properly initialised before calling the function (see section 4.2 for details), unless `time_ref_in = time_ref_out`.

7.14.4 Output Parameters

The output parameters of the `xl_time_processing_to_transport` CFI function are:

Table 55: Output parameters of `xl_time_processing_to_transport`

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_time_processing_to_transport</code>	long	-	Status flag	-	-
<code>transport_out[dim]</code>	long	See table 3	Time in Transport format	See table 3	See table 3
<code>ierr</code>	long	-	Error vector	-	-

7.14.5 Warnings and Errors

Next table lists the possible error messages that can be returned by the `xl_time_processing_to_transport` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the error vector returned by the `xl_time_processing_to_transport` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 56: Error messages of `xl_time_processing_to_transport` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input processing format ID is not correct	No calculation performed	XL_CFI_TIME_PROC_TRANS_PROC_IN_ERR	1
ERR	Input time reference ID is not correct	No calculation performed	XL_CFI_TIME_PROC_TRANS_TIME_IN_ERR	2
ERR	Output transport format ID is not correct	No calculation performed	XL_CFI_TIME_PROC_TRANS_TRANS_OUT_ERR	3
ERR	Output time reference ID is not correct	No calculation performed	XL_CFI_TIME_PROC_TRANS_TIME_OUT_ERR	4
ERR	Satellite ID and output format ID are not compatible	No calculation performed	XL_CFI_TIME_PROC_TRANS_COMP_OUT_ERR	5
ERR	Number of days out of range	No calculation performed	XL_CFI_TIME_PROC_TRANS_DAY_ERR	6
ERR	Time reference not initialised	No calculation performed	XL_CFI_TIME_PROC_TRANS_REF_INIT_ERR	7
WARN	Time out of initialization range	Calculation performed. A message informs the user.	XL_CFI_TIME_PROC_TRANS_REF_INIT_WARN	8

7.14.6 Runtime Performances

The following runtime performances have been measured.

Table 57: Runtime performances of xl_time_processing_to_transport

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.05259	0.00723	0.00945	0.00130

7.15 xl_time_transport_to_ascii

7.15.1 Overview

The **xl_time_transport_to_ascii** CFI function transforms a time expressed in a given Transport format and reference (TAI, UTC, UT1 or GPS) into a time in an ASCII format, performing a reference transformation if necessary (to TAI, UTC, UT1 or GPS).

7.15.2 Calling Interface

The calling interface of the **xl_time_transport_to_ascii** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long trans_id_in, ascii_id_out;
    long time_ref_in, time_ref_out;
    long transport_in[XL_TIME_TRANS_DIM_MAX];
    char ascii_out[XL_TIME_ASCII_DIM_MAX];
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_TRANS_ASCII], status;

    status = xl_time_transport_to_ascii(&time_id, &trans_id_in,
                                       &time_ref_in, transport_in, &ascii_id_out,
                                       &time_ref_out, ascii_out, ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_time_transport_to_ascii_run(&run_id, &trans_id_in,
                                           &time_ref_in, transport_in, &ascii_id_out,
                                           &time_ref_out, ascii_out, ierr);
}
```

The `XL_TIME_TRANS_DIM_MAX`, `XL_TIME_ASCII_DIM_MAX`, `XL_NUM_ERR_TRANS_ASCII` constants are defined in the file *explorer_lib.h*.

7.15.3 Input Parameters

The `xl_time_transport_to_ascii` CFI function has the following input parameters:

Table 58: Input parameters of `xl_time_transport_to_ascii` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>time_id</code>	<code>xl_time_id*</code>	-	Structure that contains the time correlations.	-	-
<code>trans_id_in</code>	<code>long *</code>	-	Transport format ID	-	Complete
<code>time_ref_in</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>
<code>transport_in[dim]</code>	<code>long</code>	See table 3	Time in Transport format	See table 3	See table 3
<code>ascii_id_out</code>	<code>long *</code>	-	ASCII format ID	-	Complete
<code>time_ref_out</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Transport format ID: `trans_id_in`. Current document, section 6.2.
- Time reference ID: `time_ref_in` and `time_ref_out`. See [GEN_SUM].
- ASCII format ID: `ascii_id_out`. Current document, section 6.2.

It is important to point out the usage of the **time_ref_out** parameter within the current function:

- If the time reference flag for the output is undefined, an error shall be returned.

Note that for the function to work correctly, the time references should be properly initialised before calling the function (see section 4.2 for details), unless `time_ref_in = time_ref_out`.

7.15.4 Output Parameters

The output parameters of the `xl_time_transport_to_ascii` CFI function are:

Table 59: Output parameters of `xl_time_transport_to_ascii`

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_time_transport_to_ascii</code>	long	-	Status flag	-	-
<code>ascii_out</code>	char	See table 4 and table 5	Time in ASCII format	See table 4 and table 5	See table 4 and table 5
<code>ierr</code>	long	-	Error vector	-	-

7.15.5 Warnings and Errors

Next table lists the possible error messages that can be returned by the `xl_time_transport_to_ascii` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained by translating the error vector returned by the `xl_time_transport_to_ascii` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 60: Error messages of `xl_time_transport_to_ascii` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input transport format ID is not correct	No calculation performed	XL_CFI_TIME_TRANS_ASCII_TRANS_IN_ERR	0
ERR	Input time reference ID is not correct	No calculation performed	XL_CFI_TIME_TRANS_ASCII_TIME_IN_ERR	1
ERR	Satellite ID and input format ID are not compatible	No calculation performed	XL_CFI_TIME_TRANS_ASCII_COMP_IN_ERR	2
ERR	Number of days out of range	No calculation performed	XL_CFI_TIME_TRANS_ASCII_DAY_ERR	3
ERR	Number of seconds out of range	No calculation performed	XL_CFI_TIME_TRANS_ASCII_SEC_ERR	4
ERR	Number of milliseconds out of range	No calculation performed	XL_CFI_TIME_TRANS_ASCII_MILLISEC_ERR	5
ERR	Number of microseconds out of range	No calculation performed	XL_CFI_TIME_TRANS_ASCII_MICROSEC_ERR	6

Table 60: Error messages of xl_time_transport_to_ascii function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Number of SIRAL extra counter ticks out of range	No calculation performed	XL_CFI_TIME_TRANS_ASCII_TICK_ERR	7
ERR	Output ascii format ID is not correct	No calculation performed	XL_CFI_TIME_TRANS_ASCII_ASCII_OUT_ERR	8
ERR	Output time reference ID is not correct	No calculation performed	XL_CFI_TIME_TRANS_ASCII_TIME_OUT_ERR	9
ERR	Satellite ID and output format ID are not compatible	No calculation performed	XL_CFI_TIME_TRANS_ASCII_COMP_OUT_ERR	10
ERR	Internal error: Output ascii MJD is out of range	No calculation performed	XL_CFI_TIME_TRANS_ASCII_ASCII_MJD_ERR	11
ERR	Internal error: Output ascii year is out of range	No calculation performed	XL_CFI_TIME_TRANS_ASCII_ASCII_YEAR_ERR	12
ERR	Internal error: Output ascii month is out of range	No calculation performed	XL_CFI_TIME_TRANS_ASCII_ASCII_MONTH_ERR	13
ERR	Internal error: Output ascii day is out of range	No calculation performed	XL_CFI_TIME_TRANS_ASCII_ASCII_DAY_ERR	14
ERR	Internal error: Output ascii hour is out of range	No calculation performed	XL_CFI_TIME_TRANS_ASCII_ASCII_HOUR_ERR	15
ERR	Internal error: Output ascii minutes are out of range	No calculation performed	XL_CFI_TIME_TRANS_ASCII_ASCII_MIN_ERR	16
ERR	Internal error: Output ascii seconds are out of range	No calculation performed	XL_CFI_TIME_TRANS_ASCII_ASCII_SEC_ERR	17
ERR	Internal error: Output ascii microseconds are out of range	No calculation performed	XL_CFI_TIME_TRANS_ASCII_ASCII_MICROSEC_ERR	18
ERR	Internal error: Output ascii format is not correct	No calculation performed	XL_CFI_TIME_TRANS_ASCII_FORMAT_OUT_ERR	19
ERR	Time reference not initialised	No calculation performed	XL_CFI_TIME_TRANS_ASCII_REF_INIT_ERR	20
WARN	Time out of initialization range	Calculation performed. A message informs the user.	XL_CFI_TIME_TRANS_ASCII_REF_INIT_WARN	21

7.15.6 Runtime Performances

The following runtime performances have been measured.

Table 61: Runtime performances of xl_time_transport_to_ascii

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.08298	0.01391	0.02633	0.00449

7.16 xl_time_transport_to_processing

7.16.1 Overview

The **xl_time_transport_to_processing** CFI function transforms a time expressed in a given Transport format and reference (TAI, UTC, UT1 or GPS) into a time in Processing format, performing a reference transformation if necessary (to TAI, UTC, UT1 or GPS).

User should be aware that the use of UTC in Processing format is not encouraged, due to the discontinuity that is caused by the introduction of leap seconds. See [IERS] for further details.

7.16.2 Calling Interface

The calling interface of the **xl_time_transport_to_processing** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long trans_id_in, proc_id_out;
    long time_ref_in, time_ref_out;
    long transport_in[XL_TIME_TRANS_DIM_MAX];
    double processing_out;
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_TRANS_PROC], status;

    status = xl_time_transport_to_processing(&time_id, &trans_id_in,
                                           &time_ref_in, transport_in, &proc_id_out,
                                           &time_ref_out, &processing_out, ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_time_transport_to_processing_run(&run_id, &trans_id_in,
                                               &time_ref_in, transport_in, &proc_id_out,
                                               &time_ref_out, &processing_out, ierr);
}
```

The `XL_TIME_TRANS_DIM_MAX` and `XL_NUM_ERR_TRANS_PROC` constants are defined in the file *explorer_lib.h*.

7.16.3 Input Parameters

The `xl_time_transport_to_processing` CFI function has the following input parameters:

Table 62: Input parameters of `xl_time_transport_to_processing` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>time_id</code>	<code>xl_time_id*</code>	-	Structure that contains the time correlations.	-	-
<code>trans_id_in</code>	<code>long *</code>	-	Transport format ID	-	Complete
<code>time_ref_in</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>
<code>transport_in[dim]</code>	<code>long</code>	See table 3	Time in Transport format	See table 3	See table 3
<code>proc_id_out</code>	<code>long *</code>	-	Processing format ID	-	Complete
<code>time_ref_out</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Transport format ID: `trans_id_in`. Current document, section 6.2.
- Time reference ID: `time_ref_in` and `time_ref_out`. See [GEN_SUM].
- Processing format ID: `proc_id_out`. Current document, section 6.2

Note that for the function to work correctly, the time references should be properly initialised before calling the function (see section 4.2 for details), unless `time_ref_in = time_ref_out`.

7.16.4 Output Parameters

The output parameters of the `xl_time_transport_to_processing` CFI function are:

Table 63: Output parameters of `xl_time_transport_to_processing`

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_time_transport_to_processing</code>	long	-	Status flag	-	-
<code>processing_out</code>	double*	-	Time in Processing Format	Decimal days, MJD2000 (Processing)	[-18262.0,36524.0]
<code>ierr</code>	long	-	Error vector	-	-

7.16.5 Warnings and Errors

Next table lists the possible error messages that can be returned by the `xl_time_transport_to_processing` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained by translating the error vector returned by the `xl_time_transport_to_processing` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 64: Error messages of `xl_time_transport_to_processing` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input transport format ID is not correct	No calculation performed	XL_CFI_TIME_TRANS_PROC_TRANS_IN_ERR	0
ERR	Input time reference ID is not correct	No calculation performed	XL_CFI_TIME_TRANS_PROC_TIME_IN_ERR	1
ERR	Satellite ID and input format ID are not compatible	No calculation performed	XL_CFI_TIME_TRANS_PROC_COMP_IN_ERR	2
ERR	Output processing format ID is not correct	No calculation performed	XL_CFI_TIME_TRANS_PROC_PROC_OUT_ERR	3
ERR	Output time reference ID is not correct	No calculation performed	XL_CFI_TIME_TRANS_PROC_TIME_OUT_ERR	4
ERR	Number of days out of range	No calculation performed	XL_CFI_TIME_TRANS_PROC_DAY_ERR	5
ERR	Number of seconds out of range	No calculation performed	XL_CFI_TIME_TRANS_PROC_SEC_ERR	6

Table 64: Error messages of xl_time_transport_to_processing function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Number of milliseconds out of range	No calculation performed	XL_CFI_TIME_TRANS_P OC_MILLISEC_ERR	7
ERR	Number of microseconds out of range	No calculation performed	XL_CFI_TIME_TRANS_P OC_MICROSEC_ERR	8
ERR	Number of SIRAL extra counter ticks out of range	No calculation performed	XL_CFI_TIME_TRANS_P OC_TICK_ERR	9
ERR	Time reference not initialised	No calculation performed	XL_CFI_TIME_TRANS_P OC_REF_INIT_ERR	10
WARN	Time out of initialization range	Calculation performed. A message informs the user.	XL_CFI_TIME_TRANS_P OC_REF_INIT_WARN	11

7.16.6 Runtime Performances

The following runtime performances have been measured.

Table 65: Runtime performances of xl_time_transport_to_processing

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.05572	0.00753	0.00992	0.00139

7.17 xl_time_transport_to_transport

7.17.1 Overview

The **xl_time_transport_to_transport** CFI function transforms a time expressed in a given Transport format and reference (TAI, UTC, UT1 or GPS) into a time in a different Transport format and/or reference (TAI, UTC, UT1 or GPS).

7.17.2 Calling Interface

The calling interface of the **xl_time_transport_to_transport** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long trans_id_in, trans_id_out;
    long time_ref_in, time_ref_out;
    long transport_in[XL_TIME_TRANS_DIM_MAX];
    long transport_out[XL_TIME_TRANS_DIM_MAX];
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_TRANS_TRANS], status;

    status = xl_time_transport_to_transport(&time_id, &trans_id_in,
                                           &time_ref_in, transport_in, &trans_id_out,
                                           &time_ref_out, transport_out, ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_time_transport_to_transport_run(&run_id, &trans_id_in,
                                               &time_ref_in, transport_in, &trans_id_out,
                                               &time_ref_out, transport_out, ierr);
}
```

7.17.3 Input Parameters

The `xl_time_transport_to_transport` CFI function has the following input parameters:

Table 66: Input parameters of `xl_time_transport_to_transport` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>time_id</code>	<code>xl_time_id*</code>	-	Structure that contains the time correlations.	-	-
<code>trans_id_in</code>	<code>long *</code>	-	Transport format ID	-	Complete
<code>time_ref_in</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>
<code>transport_in[dim]</code>	<code>long</code>	See table 3	Time in Transport format	See table 3	See table 3
<code>trans_id_out</code>	<code>long *</code>	-	Transport format ID	-	Complete
<code>time_ref_out</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Transport format ID: `trans_id_in` and `trans_id_out`. Current document, section 6.2.
- Time reference ID: `time_ref_in` and `time_ref_out`. See [GEN_SUM].

Note that for the function to work correctly, the time references should be properly initialised before calling the function (see section 4.2 for details), unless `time_ref_in = time_ref_out`.

7.17.4 Output Parameters

The output parameters of the `xl_time_transport_to_transport` CFI function are:

Table 67: Output parameters of `xl_time_transport_to_transport`

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_time_transport_to_transport</code>	long	-	Status flag	-	-
<code>transport_out[dim]</code>	long	See table 3	Time in Transport format	See table 3	See table 3
<code>ierr</code>	long	-	Error vector	-	-

7.17.5 Warnings and Errors

Next table lists the possible error messages that can be returned by the `xl_time_transport_to_transport` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the error vector returned by the `xl_time_transport_to_transport` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 68: Error messages of `xl_time_transport_to_transport` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input transport format ID is not correct	No calculation performed	XL_CFI_TIME_TRANS_TR ANS_TRANS_IN_ERR	0
ERR	Input time reference ID is not correct	No calculation performed	XL_CFI_TIME_TRANS_TR ANS_TIME_IN_ERR	1
ERR	Satellite ID and input format ID are not compatible	No calculation performed	XL_CFI_TIME_TRANS_TR ANS_COMP_IN_ERR	2
ERR	Output transport format ID is not correct	No calculation performed	XL_CFI_TIME_TRANS_TR ANS_TRANS_OUT_ERR	3
ERR	Output time reference ID is not correct	No calculation performed	XL_CFI_TIME_TRANS_TR ANS_TIME_OUT_ERR	4
ERR	Satellite ID and output format ID are not compatible	No calculation performed	XL_CFI_TIME_TRANS_TR ANS_COMP_OUT_ERR	5
ERR	Number of days out of range	No calculation performed	XL_CFI_TIME_TRANS_TR ANS_DAY_ERR	6
ERR	Number of seconds out of range	No calculation performed	XL_CFI_TIME_TRANS_TR ANS_SEC_ERR	7

Table 68: Error messages of *xl_time_transport_to_transport* function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Number of milliseconds out of range	No calculation performed	XL_CFI_TIME_TRANS_TR ANS_MILLISEC_ERR	8
ERR	Number of microseconds out of range	No calculation performed	XL_CFI_TIME_TRANS_TR ANS_MICROSEC_ERR	9
ERR	Number of SIRAL extra counter ticks out of range	No calculation performed	XL_CFI_TIME_TRANS_TR ANS_TICK_ERR	10
ERR	Time reference not initialised	No calculation performed	XL_CFI_TIME_TRANS_TR ANS_REF_INIT_ERR	11
WARN	Time out of initialization range	Calculation performed. A message informs the user.	XL_CFI_TIME_TRANS_TR ANS_REF_INIT_WARN	12

7.17.6 Runtime Performances

The following runtime performances have been measured.

Table 69: Runtime performances of *xl_time_transport_to_transport*

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.05262	0.00687	0.01059	0.00449

7.18 xl_time_add

7.18.1 Overview

The **xl_time_add** CFI function adds a time duration to a TAI, UTC, UT1 or GPS times expressed in Processing format.

User should be aware that the use of UTC in Processing format is not encouraged, due to the discontinuity that is caused by the introduction of leap seconds. See [IERS] for further details.

7.18.2 Calling interface

The calling interface of the **xl_time_add** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long proc_id, time_ref;
    double processing_in, added_duration, processing_out;
    long ierr[XL_NUM_ERR_TIME_ADD], status;

    status = xl_time_add(&proc_id, &time_ref,
                        &processing_in, &added_duration,
                        &processing_out, ierr);
}
```

The XL_NUM_ERR_TIME_ADD constant is defined in the file *explorer_lib.h*.

7.18.3 Input parameters

The `xl_time_add` CFI function has the following input parameters:

Table 70: Input parameters of xl_time_add function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
proc_id	long *	-	Processing format ID	-	Complete
time_ref	long *	-	Time reference ID	-	Any except XL_TIME_UNDEF
processing_in	double*	-	Time in Processing Format	Decimal days, MJD2000 (Processing format)	[-18262.0,36524.0]
added_duration	double*	-	Duration to be added	Decimal days (Processing format)	-

It is important to point out that the duration is not a time, but a time interval expressed in decimal days to be added to the original time.

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Processing format ID: `proc_id`. Current document, section 6.2.
- Time reference ID: `time_ref`. See [GEN_SUM].

7.18.4 Output parameters

The output parameters of the `xl_time_add` CFI function are:

Table 71: Output parameters of xl_time_add function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_time_add	long	-	Status flag	-	-
processing_output	double*	-	Time in Processing Format	Decimal days (Processing format)	[-18262.0,36524.0]
ierr	long	-	Error vector	-	-

7.18.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_time_add` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained by translating the error vector returned by the `xl_time_add` function by calling the function of the EXPLORER_LIB software

library `xl_get_code` (see [GEN_SUM]).

Table 72: Error messages of `xl_time_add` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Processing format ID is not correct	No calculation performed	XL_CFI_TIME_ADD_PROC_ERR	0
ERR	Time reference ID is not correct	No calculation performed	XL_CFI_TIME_ADD_TIME_ERR	1
ERR	Input processing time is out of range	No calculation performed	XL_CFI_TIME_ADD_DAY_IN_ERR	2
ERR	Output processing time is out of range	No calculation performed	XL_CFI_TIME_ADD_DAY_OUT_ERR	3

7.18.6 Runtime performances

The following runtime performances have been measured.

Table 73: Runtime performances of `xl_time_add` function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.01335	0.00161	0.00200	0.00024

7.19 xl_time_diff

7.19.1 Overview

The **xl_time_diff** CFI function calculates the time difference between two TAI, UTC, UT1 or GPS times expressed in Processing format.

User should be aware that the use of UTC in Processing format is not encouraged, due to the discontinuity that is caused by the introduction of leap seconds. See [IERS] for further details.

7.19.2 Calling interface

The calling interface of the **xl_time_diff** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long proc_id, time_ref;
    double processing_in_1, processing_in_2, processing_out;
    long ierr[XL_NUM_ERR_TIME_DIFF], status;

    status = xl_time_diff(&proc_id, &time_ref,
                        &processing_in_1, &processing_in_2,
                        &processing_out, ierr);
}
```

Note that `processing_out` is a duration, not a time itself, so it should not be converted to another reference or format.

The `XL_NUM_ERR_TIME_DIFF` constant is defined in the file *explorer_lib.h*.

7.19.3 Input parameters

The `xl_time_diff` CFI function has the following input parameters:

Table 74: Input parameters of `xl_time_diff` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>proc_id</code>	long *	-	Processing format ID	-	Complete
<code>time_ref</code>	long *	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>
<code>processing_in_1</code>	double*	-	Time in Processing Format	Decimal days, MJD2000 (Processing format)	[-18262.0,36524.0]
<code>processing_in_2</code>	double*	-	Time in Processing Format	Decimal days, MJD2000 (Processing format)	[-18262.0,36524.0]

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Processing format ID: `proc_id`. Current document, section 6.2.
- Time reference ID: `time_ref`. See [GEN_SUM].

7.19.4 Output parameters

The output parameters of the `xl_time_diff` CFI function are:

Table 75: Output parameters of `xl_time_diff` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_time_diff</code>	long	-	Status flag	-	-
<code>processing_out</code>	double*	-	Time difference between <code>processing_in_1</code> and <code>processing_in_2</code> expressed in decimal days	Decimal days (Processing format)	-
<code>ierr</code>	long	-	Error vector	-	-

7.19.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_time_diff` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the `EXPLORER_LIB` software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (`WARN`) or an error (`ERR`), the

cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained by translating the error vector returned by the **xl_time_diff** function by calling the function of the EXPLORER_LIB software library **xl_get_code** (see [GEN_SUM]).

Table 76: Error messages of xl_time_diff function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Processing format ID is not correct	No calculation performed	XL_CFI_TIME_DIFF_PROC_ERR	0
ERR	Time reference ID is not correct	No calculation performed	XL_CFI_TIME_DIFF_TIME_ERR	1
ERR	Input processing time #1 is out of range	No calculation performed	XL_CFI_TIME_DIFF_DAY_I N_1_ERR	2
ERR	Input processing time #2 is out of range	No calculation performed	XL_CFI_TIME_DIFF_DAY_I N_2_ERR	3

7.19.6 Runtime performances

The following runtime performances have been measured.

Table 77: Runtime performances of xl_time_diff function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.01776	0.00234	0.00299	0.00036

7.20 xl_time_obt_to_time

7.20.1 Overview

The **xl_time_obt_to_time** CFI function transforms from On-board Time (OBT) count to UTC Processing time.

User should be aware that the use of UTC in Processing format is not encouraged, due to the discontinuity that is caused by the introduction of leap seconds. See [IERS] for further details.

See [MCD] for details on time formats and representations, in particular the definition of OBT.

Note that in the Envisat OBT case there is an ambiguity on the UTC to be computed, because a given OBT count corresponds to many possible times. This is due to the wrap-around of the OBT counter, which occurs about every 190 days.

To solve the ambiguity, the chosen time (given as output) is the time nearest to the reference (given as input) and corresponding to the specified OBT (also given as input).

The **xl_time_obt_to_time** CFI function applies to satellites where OBT time is a counter, which needs to be correlated to an actual time reference. Nevertheless, some other satellites, like Cryosat, use an actual time reference on-board. In this case, the on-board time conversions are handled by the **xl_time_processing_to_processing** function.

Due to the different OBT models used by the various spacecraft, specific data structures are used for each of them. The keep a single interface for the function, a void pointer is used to pass the specific structures to the generic function.

The following data structures are defined for ENVISAT:

```
/* Envisat OBT Structure */
typedef struct
{
    long          sat_id;
    double        time0;
    unsigned long obt0[2];
    unsigned long period0;
} xl_envisat_obt_param;

typedef struct
{
    long          sat_id;
    unsigned long obt[2];
} xl_envisat_obt_value;
```

for GOCE:

```
/* GOCE OBT Structure */
typedef struct
{
    long          sat_id;
    unsigned long utc0_c;
    unsigned int  utc0_f;
    unsigned long obt0_c;
```

```
unsigned int  obt0_f;  
double       gradient;  
double       offset;  
} xl_goce_obt_param;
```

```
typedef struct  
{  
    long       sat_id;  
    double     obt;  
} xl_goce_obt_value;
```

for SMOS

```
typedef struct  
{  
    long sat_id;  
    long delta_seconds; /* number of seconds to be applied to UTC to  
                        give UTC Proteus (just in case UTC Proteus  
                        reference is actually GPS Time)*/  
    unsigned long obet0_c; /* OBET Coarse Time (in seconds) */  
    unsigned long obet0_f; /* OBET Fine Time */  
    unsigned long utc0_week; /* UTC (Proteus format) week number */  
    unsigned long utc0_seconds; /* UTC (Proteus format) seconds of  
                                week */  
    unsigned long utc0_fraction; /* UTC (Proteus format) fraction of  
                                seconds */  
} xl_smos_obt_param;
```

```
typedef struct  
{  
    long sat_id;  
    unsigned long obet_c; /* OBET Coarse Time (in seconds) */  
    unsigned long obet_f; /* OBET Fine Time */  
} xl_smos_obt_value;
```

and for ADM

```
typedef struct  
{  
    long sat_id;  
    long delta_seconds; /* it refers to the number of seconds to be  
                        applied to UTC to give GPS (GPST - UTC) */  
} xl_adm_obt_param;
```

```
typedef struct
{
    long sat_id;
    unsigned long cuc_sec; /* CCSDS Unsegmented Time Code (secs) */
    unsigned long cuc_subsec; /* CCSDS Unsegmented Time Code
                               (subseconds) */
} xl_adm_obt_value;
```

The `sat_id` parameter within the structure has to be assigned equal to the `sat_id` passed to the function.

7.20.2 Calling interface

The calling interface of the `xl_time_obt_to_time` CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long sat_id, proc_id;
    xl_envisat_obt_param obt_param; /*example for ENVISAT */
    xl_envisat_obt_value obt_value_in; /*example for ENVISAT */
    double time_out;
    long ierr[XL_NUM_ERR_OBT_TIME], status;

    status = xl_time_obt_to_time (&sat_id,
                                &proc_id,
                                &obt_param,
                                &obt_value_in,
                                &time_out,
                                ierr);

    /* Or, using the run_id */
    long run_id;
    status = xl_time_obt_to_time_run (&run_id,
                                     &proc_id,
                                     &obt_param,
                                     &obt_value_in,
                                     &time_out,
                                     err);
}
```

The `XL_NUM_ERR_OBT_TIME` constant is defined in the file `explorer_lib.h`.

7.20.3 Input parameters

The `xl_time_obt_to_time` CFI function has the following input parameters:

Table 78: Input parameters of `xl_time_obt_to_time` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long *	-	Satellite ID	-	Complete
proc_id	long *	-	Processing format ID	-	Complete
obt_param	void *	-	Pointer to <code>xl_<satellite>_obt_param</code>	-	-
obt_value_in	void *	-	Pointer to <code>xl_<satellite>_obt_value</code>	-	-

Table 79: Input parameters of `xl_envisat_obt_param` structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_ENVISAT
time0	double	-	Reference time	Decimal days (Processing format)	[-18262.0,36524.0]
obt0	unsigned long[2]	-	Array of counters containing the OBТ at the reference time (in the satellite dependant format)	TBD	TBD
period0	unsigned long	-	Actual on-board clock period	TBD	TBD

Table 80: Input parameters of `xl_envisat_obt_value` structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_ENVISAT
obt	unsigned long[2]	-	Array of counters containing the OBТ time (in the satellite dependant format)	TBD	TBD

Table 81: Input parameters of xl_goce_obt_param structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_GOCE
utc0_c	unsigned long	-	Coarse UTC0	seconds	>=0
utc0_f	unsigned int	-	Fine UTC0	2 ⁻¹⁶ seconds	>=0
obt0_c	unsigned long	-	Coarse OBT0	seconds	>=0
obt0_f	unsigned int	-	Fine OBT0	2 ⁻¹⁶ seconds	>=0
gradient	double	-	Gradient between the OBT and the UTC	-	-
offset	double	-	Offset between the OBT and the UTC	seconds	-

Table 82: Input parameters of xl_goce_obt_value structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_GOCE
obt	double	-	OBT time	seconds	-

Table 83: Input parameters of xl_smos_obt_param structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_SMOS
delta_seconds	long	-	Number of seconds to be applied to UTC to give UTC Proteus (in case UTC Proteus reference is actually GPS Time)	seconds	
obet0_c	unsigned long	-	OBET0 Coarse Time	seconds	>=0
obet0_f	unsigned long	-	OBET0 Fine Time	2 ⁻¹⁶ seconds	>=0
utc0_week	unsigned long	-	UTC0 (Proteus format) week number	weeks	>=0
utc0_second	unsigned long	-	UTC0 (Proteus format) seconds of week	seconds	>=0
utc0_fraction	unsigned long	-	UTC0 (Proteus format) fraction of seconds	2 ⁻¹⁶ seconds	>=0

Table 84: Input parameters of xl_smos_obt_value structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_SMOS
obet_c	unsigned long	-	OBET Coarse Time	seconds	>=0
obet_f	unsigned long	-	OBET Fine Time	2 ⁻¹⁶ seconds	>=0

Table 85: Input parameters of xl_adm_obt_param structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_ADM
delta_seconds	long	-	Number of seconds to be applied to UTC to give GPS (GPST - UTC)	seconds	

Table 86: Input parameters of xl_adm_obt_value structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_ADM
cuc_sec	unsigned long	-	CCSDS Unsegmented Time Code (seconds)	seconds	>=0
cuc_subsec	unsigned long	-	CCSDS Unsegmented Time Code (subseconds)	2 ⁻¹⁶ seconds	>=0

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Satellite ID: sat_id. See [GEN_SUM].
- Processing format ID: proc_id. Current document, section 6.2.

7.20.4 Output parameters

The output parameters of the xl_time_obt_to_time CFI function are:

Table 87: Output parameters of `xl_time_obt_to_time` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_time_obt_to_time</code>	long	-	Status flag	-	-
<code>time_out</code>	double*	-	UTC Time in Processing Format	Decimal days, MJD2000 (Processing format)	[-18262.0,36524.0]
<code>ierr</code>	long	-	Error vector	-	-

7.20.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_time_obt_to_time` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained by translating the error vector returned by the `xl_time_obt_to_time` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 88: Error messages of `xl_time_obt_to_time` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Satellite ID is not correct	No calculation performed	XL_CFI_TIME_OBT_TIME_SAT_ERR	0
ERR	Processing format ID is not correct	No calculation performed	XL_CFI_TIME_OBT_TIME_PROC_ERR	1
ERR	Structure inconsistent with Satellite ID	No calculation performed	XL_CFI_TIME_OBT_TIME_INCONSISTENT_STRUCTURE_ERR	2
ERR	Input reference time is out of range	No calculation performed	XL_CFI_TIME_OBT_TIME_DAY_REF_ERR	3
ERR	No OBT defined for this satellite ID	No calculation performed	XL_CFI_TIME_OBT_TIME_OBT_SAT_ERR	4
ERR	OBT at reference time is out of allowed range	No calculation performed	XL_CFI_TIME_OBT_TIME_OBT_ERR	5
ERR	Period of the On-Board clock is null	No calculation performed	XL_CFI_TIME_OBT_TIME_CLOCK_ERR	6
ERR	Output time is out of range	No calculation performed	XL_CFI_TIME_OBT_TIME_DAY_OUT_ERR	7

7.20.6 Runtime performances

The following runtime performances have been measured.

Table 89: Runtime performances of xl_time_obt_to_time function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.01899	0.00254	0.00319	0.00050

7.21 xl_time_time_to_obt

7.21.1 Overview

The **xl_time_time_to_obt** CFI function transforms a UTC Processing time to OBT count.

User should be aware that the use of UTC in Processing format is not encouraged, due to the discontinuity that is caused by the introduction of leap seconds. See [IERS] for further details.

See [MCD] for details on time formats and representations, in particular the definition OBT.

Note that no rounding to any number of significant bits is performed by **xl_time_time_to_obt**. The user application must perform this rounding if necessary. An example of rounding is provided in the example program within the EXPLORER_LIB library.

The **xl_time_time_to_obt** CFI function applies to satellites where OBT time is a counter, which needs to be correlated to an actual time reference. Nevertheless, some other satellites, like Cryosat, use an actual time reference on-board. In this case, the on-board time conversions are handled by the **xl_time_processing_to_processing** function.

Due to the different OBT models used by the various spacecraft, specific data structures are used for each of them. To keep a single interface for the function, a void pointer is used to pass the specific structures to the generic function.

The following data structures are defined for ENVISAT:

```
/* Envisat OBT Structure */
typedef struct
{
    long          sat_id;
    double        time0;
    unsigned long obt0[2];
    unsigned long period0;
} xl_envisat_obt_param;

typedef struct
{
    long          sat_id;
    unsigned long obt[2];
} xl_envisat_obt_value;
```

for GOCE:

```
/* GOCE OBT Structure */
typedef struct
{
    long          sat_id;
    unsigned long utc0_c;
    unsigned int  utc0_f;
    unsigned long obt0_c;
    unsigned int  obt0_f;
    double        gradient;
    double        offset;
} xl_goce_obt_param;
```

```
typedef struct
{
    long          sat_id;
    double        obt;
} xl_goce_obt_value;
```

for SMOS

```
typedef struct
{
    long sat_id;
    long delta_seconds; /* number of seconds to be applied to UTC to
                        give UTC Proteus (just in case UTC Proteus
                        reference is actually GPS Time)*/
    unsigned long obet0_c; /* OBET Coarse Time (in seconds) */
    unsigned long obet0_f; /* OBET Fine Time */
    unsigned long utc0_week; /* UTC (Proteus format) week number */
    unsigned long utc0_seconds; /* UTC (Proteus format) seconds of
                                week */
    unsigned long utc0_fraction; /* UTC (Proteus format) fraction of
                                seconds */
} xl_smos_obt_param;
```

```
typedef struct
{
    long sat_id;
    unsigned long obet_c; /* OBET Coarse Time (in seconds) */
    unsigned long obet_f; /* OBET Fine Time */
} xl_smos_obt_value;
```

and for ADM

```
typedef struct
{
    long sat_id;
    long delta_seconds; /* it refers to the number of seconds to be
                        applied to UTC to give GPS (GPST - UTC) */
} xl_adm_obt_param;
```

```
typedef struct
{
    long sat_id;
```

```

    unsigned long cuc_sec; /* CCSDS Unsegmented Time Code (secs) */
    unsigned long cuc_subsec; /* CCSDS Unsegmented Time Code
                               (subseconds) */

} xl_adm_obt_value;

```

The `sat_id` parameter within the structure has to be assigned equal to the `sat_id` passed to the function.

7.21.2 Calling interface

The calling interface of the `xl_time_time_to_obt` CFI function is the following (input parameters are underlined):

```

#include <explorer_lib.h>
{
    long sat_id, proc_id;
    double time_in;
    xl_envisat_obt_param obt_param; /*example for ENVISAT */
    xl_envisat_obt_value obt_value_out; /*example for ENVISAT */
    long ierr[XL_NUM_ERR_TIME_OBT], status;

    status = xl_time_time_to_obt (&sat_id,
                                  &proc_id,
                                  &obt_param,
                                  &time_in,
                                  &obt_value_out,
                                  ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_time_time_to_obt_run (&run_id,
                                       &proc_id,
                                       &obt_param,
                                       &time_in,
                                       &obt_value_out,
                                       ierr);
}

```

The `XL_NUM_ERR_TIME_OBT` constant is defined in the file `explorer_lib.h`.

7.21.3 Input parameters

The `xl_time_time_to_obt` CFI function has the following input parameters:
 wing input parameters:

Table 90: Input parameters of `xl_time_obt_to_time` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long *	-	Satellite ID	-	Complete
proc_id	long *	-	Processing format ID	-	Complete
obt_param	void *	-	Pointer to <code>xl_<satellite>_obt_param</code>	-	-
time_in	double*	-	UTC Time	Decimal days (Processing format)	[-18262.0,36524.0]

Table 91: Input parameters of `xl_envisat_obt_param` structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_ENVISAT
time0	double	-	Reference time	Decimal days (Processing format)	[-18262.0,36524.0]
obt0	unsigned long[2]	-	Array of counters containing the OBT at the reference time (in the satellite dependant format)	TBD	TBD
period0	unsigned long	-	Actual on-board clock period	TBD	TBD

Table 92: Input parameters of `xl_goce_obt_param` structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_GOCE
utc0_c	unsigned long	-	Coarse UTC0	seconds	>=0
utc0_f	unsigned int	-	Fine UTC0	2 ⁻¹⁶ seconds	>=0
obt0_c	unsigned long	-	Coarse OBT0	seconds	>=0
obt0_f	unsigned int	-	Fine OBT0	2 ⁻¹⁶ seconds	>=0
gradient	double	-	Gradient between the OBT and the UTC	-	-
offset	double	-	Offset between the OBT and the UTC	seconds	-

Table 93: Input parameters of xl_smos_obt_param structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_SMOS
delta_seconds	long	-	Number of seconds to be applied to UTC to give UTC Proteus (in case UTC Proteus reference is actually GPS Time)	seconds	
obet0_c	unsigned long	-	OBET0 Coarse Time	seconds	>=0
obet0_f	unsigned long	-	OBET 0Fine Time	2 ⁻¹⁶ seconds	>=0
utc0_week	unsigned long	-	UTC0 (Proteus format) week number	weeks	>=0
utc0_second	unsigned long	-	UTC0 (Proteus format) seconds of week	seconds	>=0
utc0_fraction	unsigned long	-	UTC0 (Proteus format) fraction of seconds	2 ⁻¹⁶ seconds	>=0

Table 94: Input parameters of xl_adm_obt_param structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_ADM
delta_seconds	long	-	Number of seconds to be applied to UTC to give GPS (GPST - UTC)	seconds	

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Satellite ID: sat_id. See [GEN_SUM].
- Time reference ID: time_ref. See [GEN_SUM].

7.21.4 Output parameters

The output parameters of the xl_time_time_to_obt CFI function are:

Table 95: Output parameters of xl_time_time_to_obt function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_time_time_t_o_obt	long	-	Status flag	-	-
obt_value_out	void *	-	Pointer to xl_<satellite>_obt_value	-	-
ierr	long	-	Error vector	-	-

Table 96: Output parameters of xl_envisat_obt_value structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_ENVISAT
obt	unsigned long[2]	-	Array of counters containing the OBT time (in the satellite dependant format)	TBD	TBD

Table 97: Output parameters of xl_goce_obt_value structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_GOCE
obt	double	-	OBT time	sconds	-

Table 98: Output parameters of xl_smos_obt_value structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_SMOS
obet_c	unsigned long	-	OBET Coarse Time	seconds	>=0
obet_f	unsigned long	-	OBET Fine Time	2 ⁻¹⁶ seconds	>=0

Table 99: Output parameters of xl_adm_obt_value structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long	-	Satellite ID	-	XL_SAT_ADM
cuc_sec	unsigned long	-	CCSDS Unsegmented Time Code (seconds)	seconds	>=0

Table 99: Output parameters of xl_adm_obt_value structure

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
cuc_subsec	unsigned long	-	CCSDS Unsegmented Time Code (subseconds)	2 ⁻¹⁶ seconds	>=0

7.21.5 Warnings and errors

Next table lists the possible error messages that can be returned by the **xl_time_time_to_obt** CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library **xl_get_msg** (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained by translating the error vector returned by the **xl_time_time_to_obt** function by calling the function of the EXPLORER_LIB software library **xl_get_code** (see [GEN_SUM]).

Table 100: Error messages of xl_time_time_to_obt function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Satellite ID is not correct	No calculation performed	XL_CFI_TIME_TIME_OBT_SAT_ERR	0
ERR	Processing format ID is not correct	No calculation performed	XL_CFI_TIME_TIME_OBT_PROC_ERR	1
ERR	Structure inconsistent with Satellite ID	No calculation performed	XL_CFI_TIME_TIME_OBT_INCONSISTENT_STRUCT_ERR	2
ERR	Input time is out of range	No calculation performed	XL_CFI_TIME_TIME_OBT_DAY_IN_ERR	3
ERR	Input reference time is out of range	No calculation performed	XL_CFI_TIME_TIME_OBT_DAY_REF_ERR	4
ERR	No OBT defined for this satellite ID	No calculation performed	XL_CFI_TIME_TIME_OBT_OBT_SAT_ERR	5
ERR	OBT at reference time is out of allowed range	No calculation performed	XL_CFI_TIME_TIME_OBT_OBT_ERR	6
ERR	Period of the On-Board clock is null	No calculation performed	XL_CFI_TIME_TIME_OBT_CLOCK_ERR	7

7.21.6 Runtime performances

The following runtime performances have been measured.

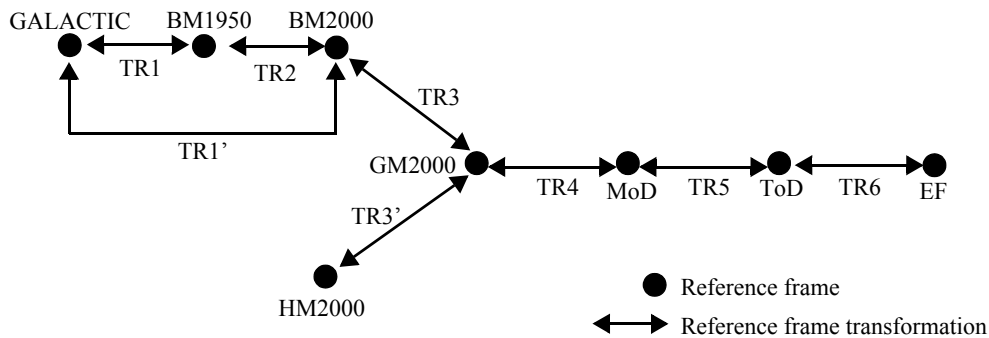
Table 101: Runtime performances of xl_time_time_to_obt function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.01904	0.00348	0.00429	0.00063

7.22 xl_change_cart_cs

7.22.1 Overview

The `xl_change_cart_cs` CFI function transforms a cartesian state vector between different reference frames. The transformation are done sequentially following the schema in figure 2. Note that the transformations between BM2000, HM2000 and GM2000 involve a translation of the input vectors (TR3 and TR3'). In case that the input vector is a direction and not a location, the transformation should only apply the rotations between frames, so the transformation should be done in several steps with `xl_change_cart_cs`, skipping the translations¹.



Reference frames:

GALACTIC = Galactic CS
 BM1950 = Barycentric Mean of 1950.0
 BM2000 = Barycentric Mean of 2000.0
 HM2000 = Heliocentric Mean of 2000.0
 GM2000 = Geocentric Mean of 2000.0
 MoD = Mean of Date
 ToD = True of Date
 EF = Earth Fixed

Figure 2: Change cartesian coordinates

1. For this purpose it is also possible to use the CFI function `xp_change_frame` in the `explorer_pointing` library

7.22.2 Calling interface

The calling interface of the `xl_change_cart_cs` CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long mode, cs_in, cs_out, time_ref;
    double time;
    double pos[3], vel[3], acc[3];
    double pos_out[3], vel_out[3], acc_out[3];
    xl_time_id time_id = {NULL};
    long status;

    status = xl_change_cart_cs (&time_id, &mode, &cs_in, &cs_out,
                               &time_ref, &time, pos, vel, acc,
                               pos_out, vel_out, acc_out);

    /* Or, using the run_id */
    long run_id;

    status = xl_change_cart_cs_run (&run_id, &mode, &cs_in, &cs_out,
                                   &time_ref, &time, pos, vel, acc,
                                   pos_out, vel_out, acc_out);
}
```

7.22.3 Input parameters

The `xl_change_cart_cs` CFI function has the following input parameters:

Table 102: Input parameters of `xl_xhange_cart_cs` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>time_id</code>	<code>xl_time_id*</code>	-	Structure that contains the time correlations.	-	-
<code>mode</code>	<code>long*</code>	-	Calculation mode selection	-	Complete
<code>cs_in</code>	<code>long *</code>	-	Initial reference frame ID	-	Complete
<code>cs_out</code>	<code>long *</code>	-	Final reference frame ID	-	Complete
<code>time_ref</code>	<code>long *</code>	-	Time reference ID	-	Any except <code>XL_TIME_UNDEF</code>
<code>time</code>	<code>double*</code>	-	Reference time	Decimal days (Processing format)	[-18262.0,36524.0]
<code>pos[3]</code>	<code>double</code>	all	Input position vector (Initial reference frame)	m	-
<code>vel[3]</code>	<code>double</code>	all	Input velocity vector (Initial reference frame) This value is dummy if <code>mode</code> is <code>XL_CALC_POS</code> except for the transformations between BM1950 and BM2000	m/s	-
<code>acc[3]</code>	<code>double</code>	all	Input acceleration vector (Initial reference frame) Dummy if <code>mode</code> is either: · <code>XL_CALC_POS</code> · <code>XL_CALC_POS_VEL</code>	m/s ²	-

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Calculation mode selection: `mode`. See current document, section 6.2.
- Time reference ID: `time_ref`. See [GEN_SUM].
- Reference frame: `cs_in`, `cs_out`. See current document, section 6.2.

Notes:

- the function could not work correctly if the time references are not properly initialised before calling the function (see section 4.2 for details).
- For objects located closer to 1 AU, the transformation from and to BM1950 may produce incorrect results

7.22.4 Output parameters

The output parameters of the `xl_change_cart_cs` CFI function are:

Table 103: Output parameters of `xl_change_cart_cs` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_change_cart_cs</code>	long	-	Extended status flag	-	-
<code>pos_out[3]</code>	double	all	Output position vector (Final reference frame)	m	-
<code>vel_out[3]</code>	double	all	Output velocity vector (Final reference frame) Returned only if <i>mode</i> is either: · <code>XL_CALC_POS_VEL</code> · <code>XL_CALC_POS_VEL_ACC</code>	m/s	-
<code>acc_out[3]</code>	double	all	Output acceleration vector (Final reference frame) Returned only if <i>mode</i> is: · <code>XL_CALC_POS_VEL_ACC</code>	m/s ²	-

7.22.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_change_cart_cs` CFI function after translating the returned extended status flag into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the extended status flag returned by the `xl_change_cart_cs` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 104: Error messages of `xl_change_cart_cs` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input time reference ID is not correct	No calculation performed	<code>XL_CFI_CHANGE_CART_CS_REF_ERR</code>	0
ERR	Input date is out of range	No calculation performed	<code>XL_CFI_CHANGE_CART_CS_DAY_ERR</code>	1
ERR	Calculation mode ID is not correct	No calculation performed	<code>XL_CFI_CHANGE_CART_CS_MODE_ERR</code>	2
ERR	Input reference frame is not correct	No calculation performed	<code>XL_CFI_CHANGE_CART_CS_INPUT_CS_ERR</code>	3
ERR	Output reference frame is not correct	No calculation performed	<code>XL_CFI_CHANGE_CART_CS_OUTPUT_CS_ERR</code>	4

Table 104: Error messages of xl_change_cart_cs function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Time Reference not initialised	No calculation performed	XL_CFI_CHANGE_CART_CS_REF_INIT_ERR	5

7.22.6 Runtime performances

The following runtime performances have been measured.

Two runtime figures are provided, one with fixed inputs, i.e. the function has been called several times with the same time, but modifying the other input parameters; and a second one with random inputs, i.e all the inputs have been modified from call to call and the average time has been taken.

Table 105: Runtime performances of xl_change_cart_cs function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.163	0.028	0.036	0.0065

7.23 xl_geod_to_cart

7.23.1 Overview

The `xl_geod_to_cart` CFI function transforms from geodetic to cartesian coordinates.

7.23.2 Calling interface

The calling interface of the `xl_geod_to_cart` CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long mode;
    double lon, lat, h, lon_rate, lat_rate, h_rate;
    double pos[3], vel[3];
    long status;

    status = xl_geod_to_cart (&mode, &lon, &lat, &h,
                             &lon_rate, &lat_rate, &h_rate,
                             pos, vel);
}
```

7.23.3 Input parameters

The `xl_geod_to_cart` CFI function has the following input parameters:

Table 106: Input parameters of `xl_geod_to_cart` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
mode	long*	-	Calculation mode selection	-	Select either: · XL_CALC_POS · XL_CALC_POS_VEL
lon	double *	-	Geocentric longitude (Earth fixed CS)	deg	[0,360)
lat	double *	-	Geodetic latitude (Earth fixed CS)	deg	[-90,90]
h	double *	-	Geodetic altitude (Earth fixed CS)	m	$h \geq -b_{\text{ellipsoid}}$ (sat_id dependent)
lon_rate	double *	-	Geocentric longitude rate (Earth fixed CS) Dummy if <i>mode</i> is: · XL_CALC_POS	deg/s	-
lat_rate	double *	-	Geodetic latitude rate (Earth fixed CS) Dummy if <i>mode</i> is: · XL_CALC_POS	deg/s	-
h_rate	double *	-	Geodetic altitude rate (Earth fixed CS) Dummy if <i>mode</i> is: · XL_CALC_POS	m/s	-

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Calculation mode selection: mode. See current document, section 6.2.

7.23.4 Output parameters

The output parameters of the `xl_geod_to_cart` CFI function are:

Table 107: Output parameters of `xl_geod_to_cart` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_geod_to_cart	long	-	Extended status flag	-	-
pos[3]	double	all	Cartesian position vector (Earth fixed CS)	m	-

Table 107: Output parameters of `xl_geod_to_cart` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
vel[3]	double	all	Cartesian velocity vector (Earth fixed CS) Returned only if <i>mode</i> is: · XL_CALC_POS_VEL	m/s	-

7.23.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_geod_to_cart` CFI function after translating the returned extended status flag into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the extended status flag returned by the `xl_geod_to_cart` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 108: Error messages of `xl_geod_to_cart` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Wrong geodetic latitude on input (out of range)	No calculation performed	XL_CFI_GEOD_CART_EL_GT_90_ERR	0
WARN	Calculation mode ID is not correct	Calculation performed. A message informs the user.	XL_CFI_GEOD_CART_MODE_WARN	1

The altitude of the geodetic state vector is not checked, so in case it does not satisfy its allowed range it may result in raising an internal error (see section 9).

7.23.6 Runtime performances

The following runtime performances have been measured.

Table 109: Runtime performances of `xl_geod_to_cart` function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.01321	0.00248	0.00310	0.00051

7.24 xl_cart_to_geod

7.24.1 Overview

The **xl_cart_to_geod** CFI function transforms from cartesian to geodetic coordinates.

7.24.2 Calling interface

The calling interface of the **xl_cart_to_geod** function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long mode;
    double pos[3], vel[3];
    double lon, lat, h, lon_rate, lat_rate, h_rate;
    long status;

    status = xl_cart_to_geod (&mode, pos, vel, &lon, &lat,
                             &h, &lon_rate, &lat_rate, &h_rate);
}
```

7.24.3 Input parameters

The `xl_cart_to_geod` CFI function has the following input parameters:

Table 110: Input parameters of `xl_cart_to_geod` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
mode	long*	-	Calculation mode selection	-	Select either: · XL_CALC_POS · XL_CALC_POS_VEL
pos[3]	double	all	Cartesian position vector (Earth fixed CS)	m	$r > a_{\text{ellipsoid}} - b_{\text{ellipsoid}}$
vel[3]	double	all	Cartesian velocity vector (Earth fixed CS) Dummy if <i>mode</i> is: · XL_CALC_POS	m/s	-

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Calculation mode selection: mode. See current document, section 6.2.

7.24.4 Output parameters

The output parameters of the `xl_cart_to_geod` CFI function are:

Table 111: Output parameters of `xl_cart_to_geod` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_cart_to_geod	long	-	Extended status flag	-	-
lon	double *	-	Geocentric longitude (Earth fixed CS)	deg	≥ 0 $< +360$
lat	double *	-	Geodetic latitude (Earth fixed CS)	deg	≥ -90 $\leq +90$
h	double *	-	Geodetic altitude (Earth fixed CS)	m	-
lon_rate	double *	-	Geocentric longitude rate (Earth fixed CS) Returned only if <i>mode</i> is: · XL_CALC_POS_VEL	deg/s	-
lat_rate	double *	-	Geodetic latitude rate (Earth fixed CS) Returned only if <i>mode</i> is: · XL_CALC_POS_VEL	deg/s	-

Table 111: Output parameters of `xl_cart_to_geod` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>h_rate</code>	double *	-	Geodetic altitude rate (Earth fixed CS) Returned only if <i>mode</i> is: · <code>XL_CALC_POS_VEL</code>	m/s	-

7.24.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_cart_to_geod` CFI function after translating the returned extended status flag into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the extended status flag returned by the `xl_cart_to_geod` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 112: Error messages of `xl_cart_to_geod` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Internal computation error # 1	No calculation performed	<code>XL_CFI_CART_GEOD_FR AME_ERR</code>	0
ERR	Input vector out of valid range	No calculation performed	<code>XL_CFI_CART_GEOD_VE CTOR_ERR</code>	1
WARN	Calculation mode ID is not correct	Calculation performed. A message informs the user.	<code>XL_CFI_CART_GEOD_MO DE_WARN</code>	2
WARN	Geocentric longitude set to 0 deg (ambiguous case)	Calculation performed. A message informs the user.	<code>XL_CFI_CART_GEOD_AM BIGUITY_WARN</code>	3
WARN	Internal computation warning # 1	Calculation performed. A message informs the user.	<code>XL_CFI_CART_GEOD_AC CURACY_WARN</code>	4
WARN	Internal computation warning # 2	Calculation performed. A message informs the user.	<code>XL_CFI_CART_GEOD_ITE RATIONS_WARN</code>	5
WARN	Internal computation warning # 3	Calculation performed. A message informs the user.	<code>XL_CFI_CART_GEOD_DE FVAL_WARN</code>	6

7.24.6 Runtime performances

The following runtime performances have been measured.

Table 113: Runtime performances of xl_cart_to_geod function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.08676	0.01778	0.02500	0.00395

7.25 xl_kepl_to_cart

7.25.1 Overview

The `xl_kepl_to_cart` CFI function transforms from keplerian to cartesian coordinates.

7.25.2 Calling interface

The calling interface of the `xl_kepl_to_cart` CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long kepl_mode;
    double kepl_in[6];
    double pos_out[3], vel_out[3];
    long ierr[XL_NUM_ERR_KEPL_CART], status;

    status = xl_kepl_to_cart (&kepl_mode, kepl_in, pos_out,
                             vel_out, ierr);
}
```

7.25.3 Input parameters

The `xl_kepl_to_cart` CFI function has the following input parameters:

Table 114: Input parameters of `xl_kepl_to_cart` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>kepl_mode</code>	long*	-	Flag for selecting: · Mean elements = <code>XL_KEPLER_MEAN</code> · Osculating elements = <code>XL_KEPLER_OSC</code>	-	Complete
<code>kepl_in[6]</code>	double	[0]	Semi-major axis (True of Date CS)	m	≥ 0
		[1]	Eccentricity (True of Date CS)	-	[0,1)
		[2]	Inclination (True of Date CS)	deg	[0,180]
		[3]	Right ascension of the ascending node (True of Date CS)	deg	[0,360)
		[4]	Argument of perigee (True of Date CS)	deg	[0,360)
		[5]	Mean anomaly (True of Date CS)	deg	[0,360)

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Kepler state vector model: `kepl_mode`. See section 6.2.

7.25.4 Output parameters

The output parameters of the `xl_kepl_to_cart` CFI function are:

Table 115: Output parameters of `xl_kepl_to_cart` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_kepl_to_cart</code>	long	-	Status flag	-	-
<code>pos_out[3]</code>	double	all	Cartesian position vector (True of Date CS)	m	-
<code>vel_out[3]</code>	double	all	Cartesian velocity vector (True of Date CS)	m/s	-
<code>ierr</code>	long	-	Error vector	-	-

7.25.5 Warnings and errors

Next table lists the possible error messages that can be returned by the **xl_kepl_to_cart** CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library **xl_get_msg** (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the error vector returned by the **xl_kepl_to_cart** function by calling the function of the EXPLORER_LIB software library **xl_get_code** (see [GEN_SUM])

Table 116: Error messages of xl_kepl_to_cart function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input semi-major axis <= 0	No calculation performed	XL_CFI_K2C_A_ZERO_ERR	0
ERR	Input eccentricity < 0	No calculation performed	XL_CFI_K2C_E_ZERO_ERR	1
ERR	Input eccentricity > 1	No calculation performed	XL_CFI_K2C_E_ONE_ERR	2
ERR	Internal Error: Error in calling XL_Mean_to_osc	No calculation performed	XL_CFI_K2C_INTERNAL_M2O_ERR	3
ERR	Internal computation error #1	No calculation performed	XL_CFI_K2C_COMPUTATION_ERR	4
WARN	Internal Warning: Warning in calling XL_Mean_to_osc	Calculation performed. A message informs the user.	XL_CFI_K2C_INTERNAL_M2O_WARN	5
WARN	Kepler's equations not converged	Calculation performed. A message informs the user.	XL_CFI_K2C_NO_CONVERGED_WARN	6

7.25.6 Runtime performances

The following runtime performances have been measured.

Table 117: Runtime performances of xl_kepl_to_cart function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.022	0.0056	0.0058	0.0012

7.26 xl_cart_to_kepl

7.26.1 Overview

The `xl_cart_to_kepl` CFI function transforms from cartesian to keplerian coordinates.

7.26.2 Calling interface

The calling interface of the `xl_cart_to_kepl` CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long kepl_mode;
    double pos_in[3], vel_in[3];
    double kepl_out[6];
    long ierr[XL_NUM_ERR_CART_KEPL], status;

    status = xl_cart_to_kepl (pos_in, vel_in, &kepl_mode,
                             kepl_out, ierr);
}
```


7.26.3 Input parameters

The `xl_cart_to_kepl` CFI function has the following input parameters:

Table 118: Input parameters of `xl_cart_to_kepl` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>pos_in[3]</code>	double	all	Cartesian position vector (True of Date CS)	m	-
<code>vel_in[3]</code>	double	all	Cartesian velocity vector (True of Date CS)	m/s	-
<code>kepl_mode</code>	long*	-	Flag for selecting: · Mean elements = <code>XL_KEPLER_MEAN</code> · Osculating elements = <code>XL_KEPLER_OSC</code>	-	Complete

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Kepler state vector model: `kepl_mode`. See section 6.2.

7.26.4 Output parameters

The output parameters of the `xl_cart_to_kepl` CFI function are:

Table 119: Output parameters of `xl_cart_to_kepl` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_cart_to_kepl</code>	long	-	Status flag	-	-
<code>kepl_out[6]</code>	double	[0]	Semi-major axis (True of Date CS)	m	≥ 0
		[1]	Eccentricity (True of Date CS)	-	[0,1)
		[2]	Inclination (True of Date CS)	deg	[0,180]
		[3]	Right ascension of the ascending node (True of Date CS)	deg	[0,360)
		[4]	Argument of perigee (True of Date CS)	deg	[0,360)
		[5]	Mean anomaly (True of Date CS)	deg	[0,360)
<code>ierr</code>	long	-	Error vector	-	-

7.26.5 Warnings and errors

Next table lists the possible error messages that can be returned by the **xl_cart_to_kepl** CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library **xl_get_msg** (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the error vector returned by the **xl_cart_to_kepl** function by calling the function of the EXPLORER_LIB software library **xl_get_code** (see [GEN_SUM]).

Table 120: Error messages of xl_cart_to_kepl function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Earth's Mu < 0	No calculation performed	XL_CFI_C2K_MU_ZERO_ERR	0
ERR	Input orbit radius = 0	No calculation performed	XL_CFI_C2K_OR_ZERO_ERR	1
ERR	Input orbit velocity = 0	No calculation performed	XL_CFI_C2K_OV_ZERO_ERR	2
ERR	Semi-major axis undefined	No calculation performed	XL_CFI_C2K_OA_UNDEFINED_ERR	3
ERR	Semi-major axis < 0	No calculation performed	XL_CFI_C2K_OA_ZERO_ERR	4
ERR	Internal computation error #1	No calculation performed	XL_CFI_C2K_COMPUTATION_ERR	5
ERR	Internal Error: Error in calling XL_Osc_to_mean	No calculation performed	XL_CFI_C2K_INTERNAL_O2M_ERR	6
WARN	Inclination = 0 or 180 deg	Calculation performed. A message informs the user.	XL_CFI_C2K_OI_ZERO_WARN	7
WARN	Eccentricity = 0	Calculation performed. A message informs the user.	XL_CFI_C2K_OE_ZERO_WARN	8
WARN	Internal Warning: Warning in calling XL_Osc_to_mean	Calculation performed. A message informs the user.	XL_CFI_C2K_INTERNAL_O2M_WARN	9

7.26.6 Runtime performances

The following runtime performances have been measured.

Table 121: Runtime performances of xl_cart_to_kepl function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.01274	0.00345	0.00499	0.00099

7.27 xl_cart_to_radec

7.27.1 Overview

The **xl_cart_to_radec** CFI function transforms cartesian coordinates to spherical coordinates:

- From equatorial cartesian coordinates to right ascension and declination.
or
- From galactic cartesian coordinates to galactic longitude and latitude.

7.27.2 Calling interface

The calling interface of the **xl_cart_to_radec** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long mode, cs_in;
    double pos[3], vel[3];
    double ra, dec, mu_ra, mu_dec, rad_vel, par;
    long ierr[XL_NUM_ERR_CART_RADEC], status;

    status = xl_cart_to_radec (&mode, &cs_in, pos, vel,
                             &ra, &dec, &mu_ra, &mu_dec,
                             &rad_vel, &par, ierr);
}
```

7.27.3 Input parameters

The `xl_cart_to_radec` CFI function has the following input parameters:

Table 122: Input parameters of `xl_cart_to_radec` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
mode	long*	-	Flag to select transformation, position or position and velocity: <ul style="list-style-type: none"> • XL_CALC_POS • XL_CALC_POS_VEL For galactic coordinates only position can be transformed.	-	Complete
cs_in	long*	-	Coordinate reference frame for the input vector.	-	All except XL_EF
pos[3]	double	all	Cartesian position vector	m	-
vel[3]	double	all	Cartesian velocity vector	m/s	-

It is possible to use enumeration values rather than integer values for some of the input arguments:

Calculation mode: mode. See section 6.2

Reference frame: cs_in. See section 6.2

7.27.4 Output parameters

The output parameters of the `xl_cart_to_radec` CFI function are:

Table 123: Output parameters of `xl_cart_to_radec` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_cart_to_radec	long	-	Status flag	-	-
ra	double	-	Right ascension (or galactic longitude)	rad	$[0, 2\pi)$
dec	double	-	Declination (or galactic latitude)	rad	$[-\pi/2, \pi/2]$
mu_ra	double	-	Proper motion in the right ascension	rad/century	-
mu_dec	double	-	Proper motion in the declination	rad/century	-
rad_vel	double	-	Radial velocity	AU/century	-
par	double	-	Parallax	rad	$[0, 2\pi)$
ierr	long	-	Error vector	-	-

7.27.5 Warnings and errors

Next table lists the possible error messages that can be returned by the **xl_cart_to_radec** CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library **xl_get_msg** (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the error vector returned by the **xl_cart_to_radec** function by calling the function of the EXPLORER_LIB software library **xl_get_code** (see [GEN_SUM]).

Table 124: Error messages of xl_cart_to_radec function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Not possible to calculate velocity vector in galactic frame.	No calculation performed	XL_CFI_CART_TO_RADEC_WRONG_INPUT_ERR	0
ERR	Mode input is not an allowed value.	No calculation performed	XL_CFI_CART_TO_RADEC_WRONG_MODE_ERR	1
ERR	cs_in input is not an allowed value.	No calculation performed	XL_CFI_CART_TO_RADEC_WRONG_CS_IN_ERR	2
ERR	The frame's center is not an allowed position input	No calculation performed	XL_CFI_CART_TO_RADEC_WRONG_POSITION_ERR	3

7.27.6 Runtime performances

The following runtime performances have been measured.

Table 125: Runtime performances of xl_cart_to_radec function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.01220	0.00340	0.00371	0.00112

7.28 xl_radec_to_cart

7.28.1 Overview

The **xl_radec_to_cart** CFI function transforms spherical coordinates to cartesian coordinates:

- From right ascension and declination to equatorial cartesian coordinates.
or
- From galactic longitude and latitude to galactic cartesian coordinates.

7.28.2 Calling interface

The calling interface of the **xl_radec_to_cart** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long mode, cs_in;
    double pos[3], vel[3];
    double ra, dec, mu_ra, mu_dec, rad_vel, par;
    long ierr[XL_NUM_ERR_RADEC_CART], status;

    status = xl_radec_to_cart (&mode, &cs_in, &ra, &dec,
                             &mu_ra, &mu_dec,
                             &rad_vel, &par,
                             pos, vel, ierr);
}
```

7.28.3 Input parameters

The `xl_radec_to_cart` CFI function has the following input parameters:

Table 126: Input parameters of `xl_radec_to_cart` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
mode	long*	-	Flag to select transformation, position or position and velocity: <ul style="list-style-type: none"> • XL_CALC_POS • XL_CALC_POS_VEL For galactic coordinates only position can be transformed.	-	Complete
cs_in	long*	-	Coordinate reference frame for the input vector.	-	All except XL_EF
ra	double	-	Right ascension (or galactic longitude)	rad	$[0, 2\pi)$
dec	double	-	Declination (or galactic latitude)	rad	$[-\pi/2, \pi/2]$
mu_ra	double	-	Proper motion in the right ascension	rad/century	-
mu_dec	double	-	Proper motion in the declination	rad/century	-
rad_vel	double	-	Radial velocity	AU/century	-
par	double	-	Parallax	rad	$[0, 2\pi)$

7.28.4 Output parameters

The output parameters of the `xl_radec_to_cart` CFI function are:

Table 127: Output parameters of `xl_radec_to_cart` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_radec_to_cart	long	-	Status flag	-	-
pos[3]	double	all	Cartesian position vector	m	-
vel[3]	double	all	Cartesian velocity vector	m/s	-
ierr	long	-	Error vector	-	-

7.28.5 Warnings and errors

Next table lists the possible error messages that can be returned by the **xl_radec_to_cart** CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library **xl_get_msg** (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the error vector returned by the **xl_radec_to_cart** function by calling the function of the EXPLORER_LIB software library **xl_get_code** (see [GEN_SUM]).

Table 128: Error messages of xl_radec_to_cart function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Not possible to calculate velocity vector in galactic frame.	No calculation performed	XL_CFI_RADEC_TO_CART_WRONG_INPUT_ERR	0
ERR	Mode input is not an allowed value.	No calculation performed	XL_CFI_RADEC_TO_CART_WRONG_MODE_ERR	1
ERR	cs_in input is not an allowed value."	No calculation performed	XL_CFI_RADEC_TO_CART_WRONG_CS_IN_ERR	2
ERR	parallax can't be equal to zero.	No calculation performed	XL_CFI_RADEC_TO_CART_PAR_ERR	3

7.28.6 Runtime performances

The following runtime performances have been measured.

Table 129: Runtime performances of xl_radec_to_cart function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.013	0.00365	0.00396	0.00095

7.29 xl_topocentric_to_ef

7.29.1 Overview

The `xl_topocentric_to_ef` CFI function transforms topocentric azimuth and elevation to the Earth Fixed Reference frame.

7.29.2 Calling interface

The calling interface of `xl_topocentric_to_ef` the CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long    mode, deriv;
    double  pos[3], vel[3];
    double  azim, elev, range,
            azim_d, elev_d, range_d,
            ef_dir[3], ef_dir_d[3];
    long    ierr[XL_NUM_ERR_TOP_TO_EF], status;

    status = xl_topocentric_to_ef(&mode, &deriv, pos, vel,
                                &azim, &elev, &range,
                                &azim_d, &elev_d, &range_d,
                                ef_dir, ef_dir_d,
                                ierr);
}
```

7.29.3 Input parameters

The `xl_topocentric_to_ef` CFI function has the following input parameters:

Table 130: Input parameters of `xl_topocentric_to_ef` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
mode	long	-	Flag to indicate if the input coordinates is location or a direction	-	<ul style="list-style-type: none"> • XL_MODE_FLAG_LOCATION • XL_MODE_FLAG_DIRECTION
deriv	long	-	Flag to indicate if the 1st. derivative has to be computed.	-	<ul style="list-style-type: none"> • XL_NO_DER • XL_DER_1ST
pos	double	all	Position of the topocentric CS in the EF CS	m	-
vel	double	all	Velocity of the topocentric CS in the EF CS	m/s	-
azim	double	-	Azimuth	deg	[0, 360)
elev	double	-	Elevation	deg	[-90, +90]
range	double	-	Distance	m	-
azim_d	double	-	Azimuth rate	deg/s	[0, 360)
elev_d	double	-	Elevation rate	deg/s	[-90, +90]
range_d	double	-	Range rate	m/s	-

7.29.4 Output parameters

The output parameters of the `xl_topocentric_to_ef` CFI function are:

Table 131: Output parameters of `xl_topocentric_to_ef` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_topocentric_to_ef</code>	long	-	Status flag	-	-
<code>ef_dir</code>	double	all	Cartesian position vector in EF	m	-
<code>ef_dir_d</code>	double	all	Cartesian velocity vector in EF	m/s	-
<code>ierr</code>	long	-	Error vector	-	-

7.29.5 Warnings and errors

Next table lists the possible error messages that can be returned by the **xl_topocentric_to_ef** CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library **xl_get_msg** (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the error vector returned by the **xl_topocentric_to_ef** function by calling the function of the EXPLORER_LIB software library **xl_get_code** (see [GEN_SUM]).

Table 132: Error messages of xl_topocentric_to_ef function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Wrong for the parameter Location/Direction	No calculation performed	XL_CFI_TOP_TO_EF_WRONG_MODE_FLAG_ERR	0
ERR	Wrong parameter for the derivative	No calculation performed	XL_CFI_TOP_TO_EF_WRONG_DERIV_FLAG_ERR	1
ERR	Could not convert input vector for the topocentric center to geodetic coordinates	No calculation performed	XL_CFI_TOP_TO_EF_CART_TO_GEOD_ERR	2
ERR	Could not get the pointing direction from the input Azimuth and elevation	No calculation performed	XL_CFI_TOP_TO_EF_POINTING_DIR_ERR	3

7.29.6 Runtime performances

The following runtime performances have been measured.

Table 133: Runtime performances of xl_topocentric_to_ef function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.0965	0.0248	0.0366	0.0064

7.30 xl_ef_to_topocentric

7.30.1 Overview

The `xl_ef_to_topocentric` CFI function transforms Earth Fixed coordinates to topocentric coordinates for a given ground position.

7.30.2 Calling interface

The calling interface of `xl_ef_to_topocentric` the CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long    mode, deriv;
    double pos[3], vel[3];
    double azimuth, elev, range,
           azimuth_d, elev_d, range_d,
           ef_dir[3], ef_dir_d[3];
    long ierr[XL_NUM_ERR_TOP_TO_EF], status;

    status = xl_ef_to_topocentric(&mode, &deriv, pos, vel,
                                ef_dir, ef_dir_d,
                                &azimuth, &elev, &range,
                                &azimuth_d, &elev_d, &range_d,
                                ierr);
}
```

7.30.3 Input parameters

The `xl_ef_to_topocentric` CFI function has the following input parameters:

Table 134: Input parameters of `xl_ef_to_topocentric` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
mode	long	-	Flag to indicate if the input coordinates is location or a direction	-	<ul style="list-style-type: none"> • XL_MODE_FLAG_LOCATION • XL_MODE_FLAG_DIRECTION
deriv	long	-	Flag to indicate if the 1st. derivative has to be computed.	-	<ul style="list-style-type: none"> • XL_NO_DER • XL_DER_1ST
pos	double	all	Position of the topocentric CS in the EF CS	m	-
vel	double	all	Velocity of the topocentric CS in the EF CS	m/s	-
ef_dir	double	all	Cartesian position vector in EF	m	-
ef_dir_d	double	all	Cartesian velocity vector in EF	m/s	-

7.30.4 Output parameters

The output parameters of the `xl_ef_to_topocentric` CFI function are:

Table 135: Output parameters of `xl_ef_to_topocentric` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_topocentric_to_ef	long	-	Status flag	-	-
azim	double	-	Azimuth	deg	[0, 360]
elev	double	-	Elevation	deg	[-90, +90]
range	double	-	Distance	m	-
azim_d	double	-	Azimuth rate	deg/s	[0, 360]
elev_d	double	-	Elevation rate	deg/s	[-90, +90]
range_d	double	-	Range rate	m/s	-
ierr	long	-	Error vector	-	-

7.30.5 Warnings and errors

Next table lists the possible error messages that can be returned by the **xl_ef_to_topocentric** CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library **xl_get_msg** (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the error vector returned by the **xl_ef_to_topocentric** function by calling the function of the EXPLORER_LIB software library **xl_get_code** (see [GEN_SUM]).

Table 136: Error messages of xl_ef_to_topocentric function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Wrong for the parameter Location/Direction	No calculation performed	XL_CFI_EF_TO_TOP_WRONG_MODE_FLAG_ERR	0
ERR	Could not convert input vector for the topocentric center to geodetic coordinates	No calculation performed	XL_CFI_EF_TO_TOP_CART_TO_GEOD_ERR	1
ERR	Wrong parameter for the derivative	No calculation performed	XL_CFI_EF_TO_TOP_WRONG_DERIV_FLAG_ERR	2
ERR	Error when computing Azimuth and Elevation	No calculation performed	XL_CFI_EF_TO_TOP_DIRECTION_POINTING_ERR	3

7.30.6 Runtime performances

The following runtime performances have been measured.

Table 137: Runtime performances of xl_ef_to_topocentric function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.1012	0.0245	0.0364	0.0067

7.31 xl_sun

7.31.1 Overview

The **xl_sun** CFI function calculates the position and velocity vector of the Sun in the Earth Fixed coordinate system.

7.31.2 Calling interface

The calling interface of the **xl_sun** function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long time_ref;
    double time, sun_pos[3], sun_vel[3];
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_SUN], status;

    status = xl_sun(&time_id, &time_ref, &time, sun_pos, sun_vel,
                  ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_sun_run(&run_id, &time_ref, &time, sun_pos, sun_vel,
                      ierr);
}
```

7.31.3 Input parameters

The `xl_sun` CFI function has the following input parameters:

Table 138: Input parameters of `xl_sun` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
time_id	xl_time_id*	-	Structure that contains the time correlations.	-	-
time_ref	long *	-	Initial time reference ID	-	Any except XL_TIME_UNDEF
time	double*	-	Input time	Decimal days (Processing format)	[-18262.0,36524.0]

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Time reference ID: `time_ref`. See [GEN_SUM].

Note that for the function to work correctly, the time references should be properly initialised before calling the function (see section 4.2 for details).

7.31.4 Output parameters

The output parameters of the `xl_sun` CFI function are:

Table 139: Output parameters of `xl_sun` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_sun	long	-	Status flag	-	-
sun_pos[3]	double	all	Position vector of the Sun in the Earth Fixed CS	m	-
sun_vel[3]	double	all	Velocity vector of the Sun in the Earth Fixed CS	m/s	-
ierr	long	-	Error vector	-	-

7.31.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_sun` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the error vector returned by the `xl_sun` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 140: Error messages of xl_sun function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input time reference ID is not correct	No calculation performed	XL_CFI_SUN_REF_ERR	0
ERR	Input date is out of range	No calculation performed	XL_CFI_SUN_DAY_ERR	1
ERR	Time Reference not initialised	No calculation performed	XL_CFI_SUN_REF_INIT_ERR	2
ERR	Error in calling XL_Sun_PosVel	No calculation performed	XL_CFI_SUN_SUN_ERR	3

7.31.6 Runtime performances

The following runtime performances have been measured.

Two runtime figures are provided, one with fixed inputs, i.e. the function has been called several times with the same time, but modifying the other input parameters; and a second one with random inputs, i.e all the inputs have been modified from call to call and the average time has been taken.

Table 141: Runtime performances of xl_sun function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.28	0.083	0.086	0.023

7.32 xl_moon

7.32.1 Overview

The **xl_moon** CFI function calculates the position and velocity vector of the Moon in the Earth Fixed coordinate system.

7.32.2 Calling interface

The calling interface of the **xl_moon** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long time_ref;
    double time, moon_pos[3], moon_vel[3];
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_MOON], status;

    status = xl_moon(&time_id, &time_ref, &time, moon_pos, moon_vel,
                    ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_moon_run(&run_id, &time_ref, &time,
                        moon_pos, moon_vel,
                        ierr);
}
```

7.32.3 Input parameters

The `xl_moon` CFI function has the following input parameters:

Table 142: Input parameters of `xl_moon` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
time_id	xl_time_id*	-	Structure that contains the time correlations.	-	-
time_ref	long *	-	Initial time reference ID	-	Any except XL_TIME_UNDEF
time	double*	-	Input time	Decimal days (Processing format)	[-18262.0,36524.0]

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Time reference ID: `time_ref`. See [GEN_SUM].

Note that for the function to work correctly, the time references should be properly initialised before calling the function (see section 4.2 for details).

7.32.4 Output parameters

The output parameters of the `xl_moon` CFI function are:

Table 143: Output parameters of `xl_moon` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_moon	long	-	Status flag	-	-
moon_pos[3]	double	all	Position vector of the Moon in the Earth Fixed CS	m	-
moon_vel[3]	double	all	Velocity vector of the Moon in the Earth Fixed CS	m/s	-
ierr	long	-	Error vector	-	-

7.32.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_moon` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the error vector returned by the `xl_moon` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 144: Error messages of xl_moon function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input time reference ID is not correct	No calculation performed	XL_CFI_MOON_REF_ERR	0
ERR	Input date is out of range	No calculation performed	XL_CFI_MOON_DAY_ERR	1
ERR	Time Reference not initialised	No calculation performed	XL_CFI_MOON_REF_INIT_ERR	2
ERR	Error in calling XL_Moon_PosVel	No calculation performed	XL_CFI_MOON_MOON_ER R	3

7.32.6 Runtime performances

The following runtime performances have been measured.

Two runtime figures are provided, one with fixed inputs, i.e. the function has been called several times with the same time, but modifying the other input parameters; and a second one with random inputs, i.e all the inputs have been modified from call to call and the average time has been taken.

Table 145: Runtime performances of xl_moon function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.333	0.112	0.095	0.035

7.33 xl_planet

7.33.1 Overview

The **xl_planet** CFI function calculates the position and velocity vector of a planet in the Earth Fixed coordinate system.

7.33.2 Calling interface

The calling interface of the **xl_planet** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long sat_id, planet, time_ref;
    double time, planet_pos[3], planet_vel[3];
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_PLANET], status;

    status = xl_planet(&time_id, &planet, &time_ref, &time,
                     planet_pos, planet_vel, ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_planet_run(&run_id, &planet, &time_ref, &time,
                          planet_pos, planet_vel, ierr);
}
```

7.33.3 Input parameters

The **xl_planet** CFI function has the following input parameters:

Table 146: Input parameters of xl_planet function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
time_id	xl_time_id*	-	Structure that contains the time correlations.	-	-
planet	long *	-	Planet ID	-	Complete
time_ref	long *	-	Initial time reference ID	-	Any except XL_TIME_UNDEF
time	double*	-	Input time	Decimal days (Processing format)	[-18262.0,36524.0]

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Time reference ID: time_ref. See [GEN_SUM].
- Planet ID: planet. Current document, section 6.2.

Note that for the function to work correctly, the time references should be properly initialised before calling the function (see section 4.2 for details).

7.33.4 Output parameters

The output parameters of the **xl_planet** CFI function are:

Table 147: Output parameters of xl_planet function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
xl_planet	long	-	Status flag	-	-
planet_pos[3]	double	all	Position vector of the Planet in the Earth Fixed coordinate system	m	-
planet_vel[3]	double	all	Velocity vector of the Planet in the Earth Fixed coordinate system	m/s	-
ierr	long	-	Error vector	-	-

7.33.5 Warnings and errors

Next table lists the possible error messages that can be returned by the **xl_planet** CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library **xl_get_msg** (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the error vector returned by the `xl_planet` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 148: Error messages of `xl_planet` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input time reference ID is not correct	No calculation performed	XL_CFI_PLANET_REF_ERR	0
ERR	Input date is out of range	No calculation performed	XL_CFI_PLANET_DAY_ERR	1
ERR	Time Reference not initialised	No calculation performed	XL_CFI_PLANET_REF_INIT_ERR	2
ERR	Planet code is not correct	No calculation performed	XL_CFI_PLANET_PLANET_ERR	3
WARN	Internal Warning: XL_Planets solution didn't converge	Calculation performed. A message informs the user.	XL_CFI_PLANET_CONV_WARN	4

7.33.6 Runtime performances

The following runtime performances have been measured.

Two runtime figures are provided, one with fixed inputs, i.e. the functions has been called several times with the same time (reference and value); and a second one with random inputs (random time).

Table 149: Runtime performances of `xl_planet` function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.331	0.095	0.097	0.027

7.34 xl_star_radec

7.34.1 Overview

The **xl_star_radec** CFI function calculates the right ascension and declination of a star in the True of Date coordinate system.

7.34.2 Calling interface

The calling interface of the **xl_star_radec** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long time_ref;
    double time, ra0, dec0, mu_ra, mu_dec;
    double rad_vel, par, ra, dec;
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_STAR], status;

    status = xl_star_radec(&time_id, &time_ref, &time, &ra0, &dec0,
                          &mu_ra, &mu_dec, &rad_vel, &par,
                          &ra, &dec, ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_star_radec_run(&run_id, &time_ref, &time, &ra0, &dec0,
                              &mu_ra, &mu_dec, &rad_vel, &par,
                              &ra, &dec, ierr);
}
```


7.34.3 Input parameters

The `xl_star_radec` CFI function has the following input parameters:

Table 150: Input parameters of `xl_star_radec` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
time_id	xl_time_id*	-	Structure that contains the time correlations.	-	-
time_ref	long *	-	Initial time reference ID	-	Any except XL_TIME_UNDEF
time	double*	-	Input time	Decimal days (Processing format)	[-18262.0,36524.0]
ra0	double *	-	Right ascension of the star at J2000.0 (Barycentric Mean of 2000.0 CS)	rad	[0,2 π)
dec0	double *	-	Declination of the star at J2000.0 (Barycentric Mean of 2000.0 CS)	rad	$[-\pi/2, \pi/2]$
mu_ra	double *	-	Proper motion in the right ascension at J2000.0 (Barycentric Mean of 2000.0 CS)	rad/century	-
mu_dec	double *	-	Proper motion in the declination at J2000.0 (Barycentric Mean of 2000.0 CS)	rad/century	-
rad_vel	double *	-	Radial velocity of the star at J2000.0 (Barycentric Mean of 2000.0 CS)	AU/century	-
par	double *	-	Parallax of the star at J2000.0 (Barycentric Mean of 2000.0 CS)	rad	-

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Time reference ID: `time_ref`. See [GEN_SUM].

Note that for the function to work correctly, the time references should be properly initialised before calling the function (see section 4.2 for details).

7.34.4 Output parameters

The output parameters of the `xl_star_radec` CFI function are:

Table 151: Output parameters of `xl_star_radec` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_star_radec</code>	long	-	Status flag	-	-
<code>ra</code>	double *	-	Right ascension of the star at specified time (True of Date CS)	rad	$[0, 2\pi)$
<code>dec</code>	double *	-	Declination of the star at specified time (True of Date CS)	rad	$[-\pi/2, \pi/2]$
<code>ierr</code>	long	-	Error vector	-	-

7.34.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_star_radec` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the error vector returned by the `xl_star_radec` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 152: Error messages of `xl_star_radec` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input time reference ID is not correct	No calculation performed	XL_CFI_STAR_RADEC_REF_ERR	0
ERR	Input date is out of range	No calculation performed	XL_CFI_STAR_RADEC_DATE_ERR	1
ERR	Time Reference not initialised	No calculation performed	XL_CFI_STAR_RADEC_REF_INIT_ERR	2
ERR	Error in calling <code>XL_Star</code>	No calculation performed	XL_CFI_STAR_RADEC_STAR_ERR	3
ERR	Error in calling <code>XL_Dir_Pointing</code>	No calculation performed	XL_CFI_STAR_RADEC_DIRPOINT_ERR	4
WARN	Warning in calling <code>XL_Dir_Pointing</code>	Calculation performed. A message informs the user.	XL_CFI_STAR_RADEC_DIRPOINT_WARN	5

The declination is not checked, so in case it does not satisfy its allowed range it may result in raising an internal error (see section 9).

7.34.6 Runtime performances

The following runtime performances have been measured.

Two runtime figures are provided, one with fixed inputs, i.e. the functions has been called several times with the same time (reference and value), but modifying the other input parameters; and a second one with random inputs, i.e all the inputs have been modified from call to call and the average time has been taken.

Table 153: Runtime performances of xl_star_radec function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.287	0.084	0.093	0.022

7.35 xl_star_catalog

7.35.1 Overview

The **xl_star_catalog** CFI function calculates the right ascension and declination of a star in a selected star catalogue.

7.35.2 Calling interface

The calling interface of the **xl_star_catalog** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long time_ref, catalog_in, cs_out, mode;
    double time, ra0, dec0, mu_ra0, mu_dec0;
    double rad_vel0, par0, ra, dec;
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_STAR_CATALOG], status;

    status = xl_star_catalog(&time_id, &time_ref, &time, &mode,
                            &catalog_in, &catalog_out, &ra0, &dec0,
                            &mu_ra0, &mu_dec0, &rad_vel0, &par0,
                            &ra, &dec, ierr);

    /* Or, using the run_id */
    long run_id;
    status = xl_star_catalog_run(&run_id, &time_ref, &time, &mode,
                                &catalog_in, &catalog_out, &ra0, &dec0,
                                &mu_ra0, &mu_dec0, &rad_vel0, &par0,
                                &ra, &dec, ierr);
}
```

7.35.3 Input parameters

The `xl_star_catalog` CFI function has the following input parameters:

Table 154: Input parameters of `xl_star_catalog` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
time_id	xl_time_id*	-	Structure that contains the time correlations.	-	-
time_ref	long *	-	Initial time reference ID	-	Any except XL_TIME_UNDEF
time	double*	-	Input time	Decimal days (Processing format)	[-18262.0,36524.0]
mode	long*	-			
catalog_in	long*	-	Input star catalog	-	All
catalog_out	long*	-	Output coordinate frame	-	All
ra0	double *	-	Right ascension of the star in the input catalog	rad	[0,2 π)
dec0	double *	-	Declination of the star in the input catalog	rad	[- $\pi/2$, $\pi/2$]
mu_ra0	double *	-	Proper motion in the right ascension in the input catalog	rad/century	-
mu_dec0	double *	-	Proper motion in the declination in the input catalog	rad/century	-
rad_vel0	double *	-	Radial velocity of the star in the input catalog	AU/century	-
par0	double *	-	Parallax of the star in the input catalog	rad	-

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Time reference ID: `time_ref`. See [GEN_SUM].
- Star catalog ID: `catalog_in`. See section 6.2
- Reference frame: `cs_out`. See section 6.2

Note that for the function to work correctly, the time references should be properly initialised before calling the function (see section 4.2 for details).

7.35.4 Output parameters

The output parameters of the `xl_star_catalog` CFI function are:

Table 155: Output parameters of `xl_star_catalog` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_star_catalog</code>	long	-	Status flag	-	-
<code>ra</code>	double *	-	Right ascension of the star at specified time in the <code>out_cs</code> reference frame.	rad	$[0, 2\pi)$
<code>dec</code>	double *	-	Declination of the star at specified time in the <code>out_cs</code> reference frame.	rad	$[-\pi/2, \pi/2]$
<code>ierr</code>	long	-	Error vector	-	-

7.35.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_star_catalog` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the error vector returned by the `xl_star_catalog` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 156: Error messages of `xl_star_catalog` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Wrong input catalog	No calculation performed	<code>XL_CFI_STAR_CATALOG_WRONG_INPUT_CATALOG_ERR</code>	0
ERR	Wrong output catalog	No calculation performed	<code>XL_CFI_STAR_CATALOG_WRONG_OUTPUT_CATALOG_ERR</code>	1
ERR	Error in <code>xl_star_radec</code>	No calculation performed	<code>XL_CFI_STAR_CATALOG_STAR_RADEC_ERR</code>	2
ERR	Error when converting from FK4 to FK5	No calculation performed	<code>XL_CFI_STAR_CATALOG_FK4_TO_FK5_ERR</code>	3
ERR	Error in <code>xl_radec_to_cart</code>	No calculation performed	<code>XL_CFI_STAR_CATALOG_RADEC_TO_CART_ERR</code>	4
ERR	Error in <code>xl_change_coordinate_cs</code>	No calculation performed	<code>XL_CFI_STAR_CATALOG_CHANGE_CART_CS_ERR</code>	5
ERR	Error in <code>xl_cart_to_radec</code>	No calculation performed	<code>XL_CFI_STAR_CATALOG_CART_TO_RADEC_ERR</code>	6

7.35.6 Runtime performances

The following runtime performances have been measured.

Two runtime figures are provided, one with fixed inputs, i.e. the functions has been called several times with the same time (reference and value), but modifying the other input parameters; and a second one with random inputs, i.e all the inputs have been modified from call to call and the average time has been taken.

Table 157: Runtime performances of xl_star_catalog function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.5924	0.1826	0.2093	0.0527

7.36 xl_geod_distance

7.36.1 Overview

The **xl_geod_distance** CFI function calculates the geodesic distance between two points that lay on the same ellipsoid, and the azimuth of the related geodesic line at both points. See diagram below.

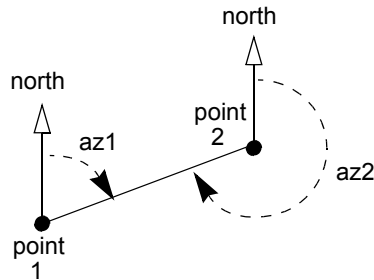


Figure 3: Azimuth figures returned by xl_geod_distance function

7.36.2 Calling interface

The calling interface of the **xl_geod_distance** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    double lon1, lat1, lon2, lat2, h;
    double distance, az_1_to_2, az_2_to_1;
    long status;
    status = xl_geod_distance (&lon1, &lat1, &lon2, &lat2,
                               &h, &distance, &az_1_to_2,
                               &az_2_to_1);
}
```


7.36.3 Input parameters

The `xl_geod_distance` CFI function has the following input parameters:

Table 158: Input parameters of `xl_geod_distance` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
lon1	double *	-	Geocentric longitude of the first input point (Earth fixed CS)	deg	[0,360)
lat1	double *	-	Geodetic latitude of the first input point (Earth fixed CS)	deg	[-90,90]
lon2	double *	-	Geocentric longitude of the second input point (Earth fixed CS)	deg	[0,360)
lat2	double *	-	Geodetic latitude of the second input point (Earth fixed CS)	deg	[-90,90]
h	double *	-	Geodetic altitude of both input points (Earth fixed CS)	m	$h \geq -b_{WGS}$ (satellite ID dependent)

7.36.4 Output parameters

The output parameters of the `xl_geod_distance` CFI function are:

Table 159: Output parameters of `xl_geod_distance` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_geod_distance</code>	long	-	Extended status flag	-	-
distance	double *	-	Geodesic distance between the two input points (Earth fixed CS)	m	≥ 0
az_1_to_2	double *	-	Azimuth of the geodesic line from point 1 to point 2 (Topocentric CS)	deg	[0,360)
az_2_to_1	double *	-	Azimuth of the geodesic line from point 2 to point 1 (Topocentric CS) Note that $az_2 = az_1 + 180$ approximately	deg	≥ 0 < 360

7.36.5 Warnings and errors

Next table lists the possible error messages that can be returned by the **xl_geod_distance** CFI function after translating the returned extended status flag into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library **xl_get_msg** (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the extended status flag returned by the **xl_geod_distance** function by calling the function of the EXPLORER_LIB software library **xl_get_code** (see [GEN_SUM]).

Table 160: Error messages of xl_geod_distance function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Different altitudes in the two points	No calculation performed	XL_CFI_GEOD_DIST_ALTITUDE_ERR	0
ERR	Calculation not performed in XL_Geo_Car	No calculation performed	XL_CFI_GEOD_DIST_GEO_CAR_ERR	1
ERR	Calculation not performed in XL_Pt_Dir_Range	No calculation performed	XL_CFI_GEOD_DIST_DIR_RANGE_ERR	2
ERR	No solution returned by XL_Dir_Pointing	No calculation performed	XL_CFI_GEOD_DIST_DIR_POINTING_ERR	3
WARN	Antipodal points. Two possible azimuth values (0 or 180). Selected value is 0.0 deg	Calculation performed. A message informs the user.	XL_CFI_GEOD_DIST_ANTIPODAL_POINTS_WARN	4
WARN	Default values returned by XL_Dir_Pointing	Calculation performed. A message informs the user.	XL_CFI_GEOD_DIST_DIR_POINTING_WARN	5

The altitude of the two points is not checked, so in case it does not satisfy its allowed range it may result in raising an internal error (see section 9).

For antipodal points, a little variation of the input coordinates may lead to incoherent values for the output distance, depending on the point location on the ellipsoid.

7.36.6 Runtime performances

The following runtime performances have been measured.

Table 161: Runtime performances of xl_geod_distance function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.1730	0.0450	0.0600	0.0120

7.37 xl_time_get_leap_second_info

7.37.1 Overview

The `xl_time_get_leap_second_info` CFI function retrieves the leap second location (if any) in the initialised time range.

In order to avoid ambiguities the instant of Leap Second insertion is given both as the instant just before insertion (i.e. when the LS start) and the instant just after insertion (i.e. when the LS ends).

As an example, in the case of the (positive) LS inserted on January 1st, 1999, the function would return (if `ascii_id_out = XL_ASCII_STD_REF_MICROSEC`):

```

    leap_flag = 1
    ascii_utc_time_before_leap = UTC=1998-12-31_23:59:60.000000
    ascii_utc_time_after_leap = UTC=1999-01-01_00:00:00.000000
  
```

In the case of a negative LS, inserted as an example on January 1st, 2009, the function would return (if `ascii_id_out = XL_ASCII_STD_REF_MICROSEC`):

```

    leap_flag = -1
    ascii_utc_time_before_leap = UTC=2008-12-31_23:59:58.000000
    ascii_utc_time_after_leap = UTC=2009-01-01_00:00:00.000000
  
```

Note that, if the time correlations were initialised with an Orbit Scenario File, LS could be wrongly calculated (see section 7.1).

7.37.2 Calling interface

The calling interface of the `xl_time_get_leap_second_info` CFI function is the following (input parameters are underlined):

```

#include <explorer_lib.h>
{
    long ascii_id_out, leap_flag;
    char ascii_utc_time_before_leap[XL_TIME_ASCII_DIM_MAX];
    char ascii_utc_time_after_leap[XL_TIME_ASCII_DIM_MAX];
    xl_time_id time_id = {NULL};
    long ierr[XL_NUM_ERR_LEAP_INFO], status;

    status = xl_time_get_leap_second_info(&time_id, &ascii_id_out,
                                         &leap_flag, ascii_utc_time_before_leap,
                                         ascii_utc_time_after_leap, ierr);

    /* Or, using the run_id */
    long run_id;
    status = xl_time_get_leap_second_info_run(&run_id, &ascii_id_out,
                                             &leap_flag, ascii_utc_time_before_leap,
                                             ascii_utc_time_after_leap, ierr);
  }
  
```

}

The `XL_TIME_ASCII_DIM_MAX` and `XL_NUM_ERR_LEAP_INFO` constants are defined in the file `explorer_lib.h`.

7.37.3 Input parameters

The `xl_time_get_leap_second_info` CFI function has the following input parameters:

Table 162: Input parameters of `xl_time_get_leap_second_info` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>time_id</code>	<code>xl_time_id*</code>	-	Structure that contains the time correlations.	-	-
<code>ascii_id_out</code>	<code>long *</code>	-	ASCII format ID for output	-	Complete

It is possible to use enumeration values rather than integer values for the input argument:

- ASCII format ID: `ascii_id_out`. Current document, section 6.2.

7.37.4 Output parameters

The output parameters of the `xl_time_get_leap_second_info` CFI function are:

Table 163: Output parameters of `xl_time_get_leap_second_info` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_time_get_leap_second_info</code>	<code>long</code>	-	Status flag	-	-
<code>leap_flag</code>	<code>long *</code>	-	Flag for leap second presence within time initialization data	-	-1 = Negative Leap Second (a LS has been removed) (very rare case) 0 = No leap second within initialization data +1 = Positive Leap Second (a LS has been added) (usual case)
<code>ascii_utc_time_before_leap</code>	<code>char</code>	See table 4 and table 5	UTC time just before leap second insertion (dummy if <code>leap_flag=0</code>)	See table 4 and table 5	See table 4 and table 5
<code>ascii_utc_time_after_leap</code>	<code>char</code>	See table 4 and table 5	UTC time just after leap second insertion (dummy if <code>leap_flag=0</code>)	See table 4 and table 5	See table 4 and table 5
<code>ierr</code>	<code>long</code>	-	Error vector	-	-

Note that if more than one leap second is contained within the time initialization data for the selected satellite, only the last (most recent) one is returned.

No more than one leap second is likely to be found in the data, unless the range of time initialization span more than one year (a total of 23 leap seconds have been inserted until 2002, since the system was introduced in 1972).

7.37.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_time_get_leap_second_info` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained by translating the error vector returned by the `xl_time_get_leap_second_info` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 164: Error messages of `xl_time_get_leap_second_info` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Output ascii format ID is not correct	No calculation performed	XL_CFI_TIME_LEAP_SEC OND_ASCII_OUT_ERR	0
ERR	Satellite ID and output format ID are not compatible	No calculation performed	XL_CFI_TIME_LEAP_SEC OND_COMP_OUT_ERR	1
ERR	Error in adding times in Processing format	No calculation performed	XL_CFI_TIME_LEAP_SEC OND_ADD_ERR	2
ERR	Error in converting from Processing to ASCII format	No calculation performed	XL_CFI_TIME_LEAP_SEC OND_P2A_ERR	3
WARN	Time Reference not initialised	No calculation performed A message informs the user.	XL_CFI_TIME_LEAP_SEC OND_TIME_REF_INIT_WA RN	4

7.37.6 Runtime performances

The following runtime performances have been measured.

Table 165: Runtime performances of `xl_time_get_leap_second_info` function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.13	0.023	0.044	0.0072

7.38 xl_euler_to_matrix

7.38.1 Overview

The `xl_euler_to_matrix` CFI function computes the rotation matrix equivalent to apply the three consecutive rotation through the given Euler angles. In other words, the result of multiplying the matrix to a vector is the same that applying the Euler rotations to the vector.

The rotation of a vector through the Euler angles is defined as three rotations of the reference frame:

1. Rotation around $-Y_s$ over a roll angle η
2. Rotation around $-X^1_s$ (i.e the rotated X_s) over a pitch angle ξ
3. Rotation around $+Z^2_s$ (i.e the rotated Z^1_s) over a yaw angle ζ .

Next drawing depicts the three rotations:

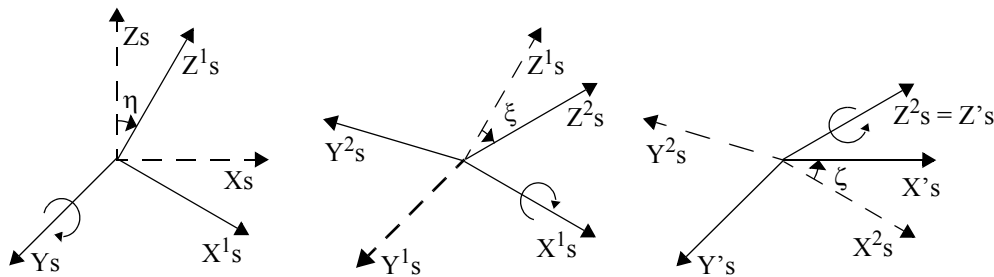


Figure 4: Euler Angles

Note on matrix notation:

if XYZ are the axes of the original reference frame, and X'Y'Z' are the axes of the rotated frame, the rows of the rotation matrix are respectively X, Y and Z axes expressed in X'Y'Z' system.

In the C representation, $M[0][\]$, $M[1][\]$, $M[2][\]$ are respectively 1st, 2nd and 3rd row of a rotation matrix M. The rotation matrix M satisfies the following equivalence:

$$\mathbf{V} = \mathbf{M} * \mathbf{V}'$$

where \mathbf{V}' is a vector expressed in the X'Y'Z' reference system and \mathbf{V} is expressed in the XYZ reference system.

7.38.2 Calling interface

The calling interface of the `xl_euler_to_matrix` CFI function is the following (input parameters are underlined>):

```
#include <explorer_lib.h>
{
    double angles[3];
    double matrix[3][3];
    long ierr[XL_NUM_ERR_EULER_TO_MATRIX], status;

    status = xl_euler_to_matrix(angles, matrix, ierr);
}
```

The `XL_NUM_ERR_EULER_TO_MATRIX` constant is defined in the file `explorer_lib.h`.

7.38.3 Input parameters

The `xl_euler_to_matrix` CFI function has the following input parameters:

Table 166: Input parameters of `xl_euler_to_matrix` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
angles	double[3]	[0]	Pitch angle	degrees	-
		[1]	Roll angle		
		[2]	Yaw angle		

7.38.4 Output parameters

The output parameters of the `xl_euler_to_matrix` CFI function are:

Table 167: Output parameters of `xl_euler_to_matrix` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_euler_to_matrix</code>	long	-	Status flag	-	-
matrix	double [3][3]	All	Rotation matrix equivalent to the Euler angles	-	-
ierr	long	-	Error vector	-	-

7.38.5 Warnings and errors

No errors have been envisaged for this function.

7.38.6 Runtime performances

The following runtime performances have been measured.

Table 168: Runtime performances of `xl_euler_to_matrix` function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.00926	0.00203	0.00277	0.00124

7.39 xl_matrix_to_euler

7.39.1 Overview

The **xl_matrix_to_euler** CFI function computes the Euler angles (see section 7.38.1) equivalent to the input rotation matrix. This function is the inverse of **xl_euler_to_matrix**.

The transformation from a rotation matrix to Euler angles is not unique, there are two sets of angles that lead to the same rotation matrix. More precisely, the rotation given by (*pitch*, *roll*, *yaw*) is equivalent to (*180-pitch*, *180+roll*, *180+yaw*). Of the two possible solutions, this function chooses the one in which the *pitch* angle is between -90° and $+90^\circ$ (or $\cos(\textit{pitch}) > 0$)

Another indetermination happens when the pitch angle is ± 90 . In this case, the values for roll and yaw depends on each other. In this case the function returns a warning (section 7.39.5) and a solution is returned for which the yaw angle is set to 0.

Note on matrix notation:

if XYZ are the axes of the original reference frame, and X'Y'Z' are the axes of the rotated frame, the rows of the rotation matrix are respectively X, Y and Z axes expressed in X'Y'Z' system.

In the C representation, M[0][], M[1][], M[2][] are respectively 1st, 2nd and 3rd row of a rotation matrix M. The rotation matrix M satisfies the following equivalence:

$$\mathbf{V} = \mathbf{M} * \mathbf{V}'$$

where \mathbf{V}' is a vector expressed in the X'Y'Z' reference system and \mathbf{V} is expressed in the XYZ reference system.

7.39.2 Calling interface

The calling interface of the **xl_matrix_to_euler** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    double angles[3];
    double matrix[3][3];
    long ierr[XL_NUM_ERR_MATRIX_TO_EULER], status;

    status = xl_matrix_to_euler(matrix, angles, ierr);
}
```

The XL_NUM_ERR_MATRIX_TO_EULER constant is defined in the file *explorer_lib.h*.

7.39.3 Input parameters

The `xl_matrix_to_euler` CFI function has the following input parameters:

Table 169: Input parameters of `xl_matrix_to_euler` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
matrix	double [3][3]	All	Rotation matrix	-	-

7.39.4 Output parameters

The output parameters of the `xl_matrix_to_euler` CFI function are:

Table 170: Output parameters of `xl_matrix_to_euler` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xl_matrix_to_euler</code>	long	-	Status flag	-	-
angles	double[3]	[0]	Pitch angle	degrees	[-180, 180]
		[1]	Roll angle		
		[2]	Yaw angle		
ierr	long	-	Error vector	-	-

7.39.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_matrix_to_euler` CFI function after translating the returned error vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained by translating the error vector returned by the `xl_matrix_to_euler` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 171: Error messages of `xl_matrix_to_euler` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	The matrix does not define a rotation	No calculation performed	XL_CFI_MATRIX_TO_EULER_WRONG_MATRIX_ERROR	0

Table 171: Error messages of xl_matrix_to_euler function

Error type	Error message	Cause and impact	Error code	Error No
WARN	Ambiguity in angles determination	Calculation performed. The roll and yaw angles are indetermined, so the yaw is set to zero and the roll is computed as if the yaw were 0. In whatever case the three angles are equivalent to the rotation matrix. This situation happens when the pitch angle is 90° or -90°.	XL_CFI_MATRIX_TO_EULER_ANGLES_UNDEFINED_WARN	1

7.39.6 Runtime performances

The following runtime performances have been measured.

Table 172: Runtime performances of xl_matrix_to_euler function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.01195	0.00258	0.00345	0.00157

7.40 xl_position_on_orbit

7.40.1 Overview

The **xl_position_on_orbit** CFI function calculates a value describing the position of the satellite within the orbit, using as input a Cartesian orbit state vector.

7.40.2 Calling interface

The calling interface of the **xl_position_on_orbit** CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long angle_type, time_ref, deriv;
    double time, pos[3], vel[3], acc[3],
    double angle, angle_rate, angle_rate_rate;
    xl_time_id time_id = {NULL};
    long status, ierr[XL_NUM_ERR_POSITION_ON_ORBIT];

    status = xl_position_on_orbit(&time_id,
                                &angle_type,
                                &time_ref, &time,
                                &pos, &vel, &acc, &deriv,
                                &angle, &angle_rate,
                                &angle_rate_rate,
                                ierr);

    /* Or, using the run_id */
    long run_id;

    status = xl_position_on_orbit_run(&run_id,
                                     &angle_type,
                                     &time_ref, &time,
                                     &pos, &vel, &acc, &deriv,
                                     &angle, &angle_rate,
                                     &angle_rate_rate,
                                     ierr);
}
```

7.40.3 Input parameters

The `xl_position_on_orbit` CFI function has the following input parameters:

Table 173: Input parameters of `xl_position_on_orbit` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
time_id	xl_time_id*	-	Structure that contains the time correlations.	-	-
angle_type	long*	-	Type of angle	-	XL_ANGLE_TYPE _TRUE_LAT_TOD XL_ANGLE_TYPE _MEAN_LAT_TOD
time_ref	long*	-	Time reference ID	-	Complete
time	double*	-	Reference time	Decimal days (Processing format)	[-18262.0,36524.0]
pos	double[3]	all	Satellite position vector (Earth Fixed CS)	m	-
vel	double[3]	all	Satellite velocity vector (Earth Fixed CS)	m/s	-
acc	double[3]	all	Satellite acceleration vector (Earth Fixed CS)	m/s ²	-
deriv	long *	-	Derivative ID	-	Allowed values: (0) XL_NO_DER (1) XL_DER_1ST (2) XL_DER_2ND

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Time reference ID: `time_ref`.

7.40.4 Output parameters

The output parameters of the `xl_position_on_orbit` CFI function are:

Table 174: Output parameters of `xl_position_on_orbit` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>angle</code>	double*	-	Angle describing the position in the orbit	deg	-
<code>angle_rate</code>	double*	-	Angle describing the position in the orbit-rate	deg/s	-
<code>angle_rate_rate</code>	double*	-	Angle describing the position in the orbit-rate-rate	deg/s ²	-
<code>ier[XL_NUM_ERR_POSITION_ON_ORBIT]</code>	long	all	Status vector	-	-

7.40.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_position_on_orbit` CFI function after translating the returned status vector into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation, mainly on the results vector.

The table is completed by the error code and value. These error codes can be obtained translating the status vector returned by the `xl_position_on_orbit` CFI function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 175: Error messages of `xl_position_on_orbit` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Angle type is not valid	No calculation performed	<code>XL_CFI_POSITION_ON_ORBIT_ANGLE_TYPE_ERR</code>	0
ERR	Error occurred during call to <code>xl_change_cart_cs</code>	No calculation performed	<code>XL_CFI_POSITION_ON_ORBIT_CHANGE_CART_CS_ERR</code>	1
ERR	Error occurred during call to <code>XL_True_Lat</code>	No calculation performed	<code>XL_CFI_POSITION_ON_ORBIT_TRUE_LAT_ERR</code>	2

7.40.6 Runtime performances

The following runtime performance has been measured.

Table 176: Runtime performances of xl_position_on_orbit function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.14065	0.02846	0.03919	0.00711

7.41 xl_get_rotation_angles

7.41.1 Overview

The `xl_get_rotation_angles` CFI function calculates the rotation angles between two sets of orthonormal right-handed unit vectors expressed wrt an identical coordinate frame.

7.41.2 Calling interface

The calling interface of the `xl_get_rotation_angles` CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    double xs_initial[3], ys_initial[3], zs_initial[3];
    double xs_final[3], ys_final[3], zs_final[3];
    double ang[3];
    long ierr[XL_NUM_ERR_GET_ROTATION_ANGLES], status;
    status = xl_get_rotation_angles (xs_initial, ys_initial,
                                    zs_initial, xs_final, ys_final, zs_final,
                                    ang, ierr);
}
```

The `XL_NUM_ERR_GET_ROTATION_ANGLES` constant is defined in the file `explorer_lib.h`.

7.41.3 Input parameters

The `xl_get_rotation_angles` CFI function has the following input parameters:

Table 177: Input parameters of `xl_get_rotation_angles` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xs_initial[3]</code>	double	all	Unitary direction vector along the X-axes of the initial attitude frame (Coordinate System)	-	-
<code>ys_initial[3]</code>	double	all	Unitary direction vector along the Y-axes of the initial attitude frame (Coordinate System)	-	-
<code>zs_initial[3]</code>	double	all	Unitary direction vector along the Z-axes of the initial attitude frame (Coordinate System)	-	-
<code>xs_final[3]</code>	double	all	Unitary direction vector along the X-axes of the final attitude frame (Coordinate System)	-	-
<code>ys_final[3]</code>	double	all	Unitary direction vector along the Y-axes of the final attitude frame (Coordinate System)	-	-
<code>zs_final[3]</code>	double	all	Unitary direction vector along the Z-axes of the final attitude frame (Coordinate System)	-	-

7.41.4 Output parameters

The output parameters of the `xl_get_rotation_angles` CFI function are:

Table 178: Output parameters of `xl_get_rotation_angles` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>ang[3]</code>	double	[0]	Pitch angle between initial and final Attitude Frames	deg	[-180,180)
		[1]	Roll angle between initial and final Attitude Frames	deg	[-180,180)
		[2]	Yaw angle between initial and final Attitude Frames	deg	[-180,180)

Table 178: Output parameters of `xl_get_rotation_angles` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
ierr	long	-	Error vector	-	-

7.41.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_get_rotation_angles` CFI function after translating the returned extended status flag into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the extended status flag returned by the `xl_get_rotation_angles` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 179: Error messages of `xl_get_rotation_angles` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input vectors are not orthogonal	No calculation performed.	XL_CFI_GET_ROTATION_ANGLES_NO_ORTHOGONAL_ERR	0
ERR	Error occurred during call to function XL_CS_Rotation	No calculation performed	XL_CFI_GET_ROTATION_ANGLES_CS_ROTATION_ERR	1

7.41.6 Runtime performances

The following runtime performances have been measured.

Two runtime figures are provided, one with fixed inputs, i.e. the function has been called several times with the same position, velocity and acceleration vectors, but modifying the other input parameters; and a second one with random inputs, i.e. all the inputs have been modified from call to call and the average time has been taken.

Table 180: Runtime performances of `xl_get_rotation_angles` function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.02582	0.00435	0.00057	0.00090

7.42 xl_get_rotated_vectors

7.42.1 Overview

The `xl_get_rotated_vectors` CFI function calculates the rotated unit vectors given a set of unit vectors and the rotation angles expressed wrt an identical coordinate frame.

7.42.2 Calling interface

The calling interface of the `xl_get_rotated_vectors` CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    double xs_initial[3], ys_initial[3], zs_initial[3];
    double xs_final[3], ys_final[3], zs_final[3];
    double ang[3];
    long ierr[XL_NUM_ERR_GET_ROTATED_VECTORS], status;
    status = xl_get_rotated_vectors (xs_initial, ys_initial,
                                    zs_initial, ang, xs_final, ys_final,
                                    zs_final, ierr);
}
```

The `XL_NUM_ERR_GET_ROTATED_VECTORS` constant is defined in the file `explorer_lib.h`.

7.42.3 Input parameters

The `xl_get_rotated_vectors` CFI function has the following input parameters:

Table 181: Input parameters of `xl_get_rotated_vectors` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xs_initial[3]</code>	double	all	Unitary direction vector along the X-axes of the initial attitude frame (Coordinate System)	-	-
<code>ys_initial[3]</code>	double	all	Unitary direction vector along the Y-axes of the initial attitude frame (Coordinate System)	-	-
<code>zs_initial[3]</code>	double	all	Unitary direction vector along the Z-axes of the initial attitude frame (Coordinate System)	-	-
<code>ang[3]</code>	double	[0]	Pitch angle between initial and final Attitude Frames	deg	[-180,180)
		[1]	Roll angle between initial and final Attitude Frames	deg	[-180,180)
		[2]	Yaw angle between initial and final Attitude Frames	deg	[-180,180)

7.42.4 Output parameters

The output parameters of the `xl_get_rotated_vectors` CFI function are:

Table 182: Output parameters of `xl_get_rotated_vectors` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>xs_final[3]</code>	double	all	Unitary direction vector along the X-axes of the rotated attitude frame (Coordinate System)	-	-
<code>ys_final[3]</code>	double	all	Unitary direction vector along the Y-axes of the rotated attitude frame (Coordinate System)	-	-
<code>zs_final[3]</code>	double	all	Unitary direction vector along the Z-axes of the rotated attitude frame (Coordinate System)	-	-

Table 182: Output parameters of `xl_get_rotated_vectors` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>ierr</code>	long	-	Error vector	-	-

7.42.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_get_rotated_vectorsCFI` function after translating the returned extended status flag into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the extended status flag returned by the `xl_get_rotated_vectors` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 183: Error messages of `xl_get_rotated_vectors` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Input vectors are not orthogonal	No calculation performed.	<code>XL_CFI_GET_ROTATED_VECTORS_NO_ORTHOGONAL_ERR</code>	1
ERR	Error occurred during call to function <code>XL_Rotate_CS</code>	No calculation performed	<code>XL_CFI_GET_ROTATED_VECTORS_ROTATE_CS_ERR</code>	2

7.42.6 Runtime performances

The following runtime performances have been measured.

Two runtime figures are provided, one with fixed inputs, i.e. the function has been called several times with the same position, velocity and acceleration vectors, but modifying the other input parameters; and a second one with random inputs, i.e. all the inputs have been modified from call to call and the average time has been taken.

Table 184: Runtime performances of `xl_get_rotated_vectors` function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]

7.43 xl_quaternions_to_vectors

7.43.1 Overview

The `xl_quaternions_to_vectors` CFI function calculates the orthonormal unit vectors from a given set of quaternions.

7.43.2 Calling interface

The calling interface of the `xl_quaternions_to_vectors` CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{

    double quaternions[4];
    double ux_vec[3], uy_vec[3], uz_vec[3];
    long ierr[XL_NUM_ERR_QUATERNIONS_TO_VEC], status;

    status = xl_quaternions_to_vectors (quaternions,
                                       ux_vec, uy_vec, uz_vec, ierr);
}
```

The `XL_NUM_ERR_QUATERNIONS_TO_VECTORS` constant is defined in the file *explorer_lib.h*.

7.43.3 Input parameters

The `xl_quaternions_to_vectors` CFI function has the following input parameters:

Table 185: Input parameters of `xl_quaternions_to_vectors` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
quaternions	double[4]	-	Quaternions	-	-

7.43.4 Output parameters

The output parameters of the `xl_quaternions_to_vectors` CFI function are:

Table 186: Output parameters of `xl_quaternions_to_vectors` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
ux_vec[3]	double	all	Unitary direction vector along the X-axes of the coordinate or attitude frame	-	-
uy_vec[3]	double	all	Unitary direction vector along the Y-axes of the coordinate or attitude frame	-	-
uz_vec[3]	double	all	Unitary direction vector along the Z-axes of the coordinate or attitude frame	-	-
ierr	long	-	Error vector	-	-

7.43.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_quaternions_to_vectors` CFI function after translating the returned extended status flag into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the extended status flag returned by the `xl_quaternions_to_vectors` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 187: Error messages of `xl_quaternions_to_vectors` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Wrong input quaternion. The module is different from 1	No calculation performed	XL_CFI_QUATERNIONS_TO_VEC_WRONG_INPUT_ERROR	0

7.43.6 Runtime performances

The following runtime performances have been measured. Two runtime figures are provided, one with fixed inputs, i.e. the function has been called several times with the same position, velocity and acceleration vectors, but modifying the other input parameters; and a second one with random inputs, i.e. all the inputs have been modified from call to call and the average time has been taken.

Table 188: Runtime performances of `xl_quaternions_to_vectors` function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.005	0.0008	0.0012	0.0001

7.44 xl_vectors_to_quaternions

7.44.1 Overview

The xl_vectors_to_quaternions CFI function calculates the set of quaternions that correspond to a set of orthonormal unit vectors.

7.44.2 Calling interface

The calling interface of the xl_vectors_to_quaternions CFI function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    double quaternions[4];
    double ux_vec[3], uy_vec[3], uz_vec[3];
    long ierr[XL_NUM_ERR_VEC_TO_QUATERNIONS], status;

    status = xl_vectors_to_quaternions (ux_vec, uy_vec, uz_vec,
                                       quaternions, ierr);
}
```

The XL_NUM_ERR_VECTORS_TO_QUATERNIONS constant is defined in the file *explorer_lib.h*.

7.44.3 Input parameters

The `xl_vectors_to_quaternions` CFI function has the following input parameters:

Table 189: Input parameters of `xl_vectors_to_quaternions` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>ux_vec[3]</code>	double	all	Unitary direction vector along the X-axes of the coordinate or attitude frame	-	-
<code>uy_vec[3]</code>	double	all	Unitary direction vector along the Y-axes of the coordinate or attitude frame	-	-
<code>uz_vec[3]</code>	double	all	Unitary direction vector along the Z-axes of the coordinate or attitude frame	-	-

7.44.4 Output parameters

The output parameters of the `xl_vectors_to_quaternions` CFI function are:

Table 190: Output parameters of `xl_vectors_to_quaternions` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>quaternions</code>	double[4]	-	Quaternions	-	-
<code>ierr</code>	long	-	Error vector	-	-

7.44.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_vectors_to_quaternions` CFI function after translating the returned extended status flag into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (WARN) or an error (ERR), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the extended status flag returned by the `xl_vectors_to_quaternions` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 191: Error messages of `xl_vectors_to_quaternions` function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Wrong input vectors.	No calculation performed	XL_CFI_VEC_TO_QUATERNIONS_WRONG_INPUT_ERROR	0

7.44.6 Runtime performances

The following runtime performances have been measured. Two runtime figures are provided, one with fixed inputs, i.e. the function has been called several times with the same position, velocity and acceleration vectors, but modifying the other input parameters; and a second one with random inputs, i.e. all the inputs have been modified from call to call and the average time has been taken.

Table 192: Runtime performances of *xl_vectors_to_quaternions* function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.0059	0.0010	0.0014	0.0003

7.45 xl_default_sat_init

7.45.1 Overview

The `xl_default_sat_init` CFI function initializes a default satellite from a satellite configuration file (see [D_H_SUM]). This operation is needed whenever a default satellite is to be used for the first time, otherwise the satellite will not be recognised.

When the satellite is initialized, the function returns the satellite identifier (the `sat_id`). The `sat_id` cannot be chosen by the user, as the program will give the first available satellite if there is any. In order that a `sat_id` number can be used again for another initialization, it has to be freed by calling to the CFI function `xl_default_sat_close`.

Important note: Some parameters in the configuration file should be within the following ranges:

- nominal semimajor axis (a): >0
- nominal inclination (i): $0 \text{ deg} < i < 180 \text{ deg}$
- nominal eccentricity (e): $10^{-6} \text{ deg} < e < 1$

7.45.2 Calling interface

The calling interface `xl_default_sat_init` function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long sat_id;
    char *conf_file;
    long ierr[XL_NUM_ERR_DEFAULT_SAT_INIT];
    long status;

    status = xl_default_sat_init(&sat_id, conf_file, ierr);
}
```

7.45.3 Input parameters

The `xl_default_sat_init` function has the following input parameters:

Table 193: Input parameters of `xl_default_sat_init` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>conf_file</code>	<code>char*</code>	-	Path and name for the Satellite Configuration File (see [D_H_SUM] for further details about the configuration file).	-	-

7.45.4 Output parameters

The output parameters of the `xl_default_sat_init` function are:

Table 194: Output parameters of `xl_default_sat_init` function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
<code>sat_id</code>	<code>long*</code>	-	Satellite ID The value is assigned automatically if there is an available satellite.	-	From <code>XL_SAT_DEFAULT</code> to <code>XL_SAT_DEFAULT9</code>
<code>ierr</code>	<code>long*</code>	all	Error status flags	-	

It is possible to use enumeration values rather than integer values for some of the input arguments:

- Satellite ID: `sat_id`. See [GEN_SUM].

7.45.5 Warnings and errors

Next table lists the possible error messages that can be returned by the `xl_default_sat_init` CFI function after translating the returned extended status flag into the equivalent list of error messages by calling the function of the EXPLORER_LIB software library `xl_get_msg` (see [GEN_SUM]).

This table also indicates the type of message returned, i.e. either a warning (`WARN`) or an error (`ERR`), the cause of such a message and the impact on the performed calculation.

The table is completed by the error code and value. These error codes can be obtained translating the extended status flag returned by the `xl_default_sat_init` function by calling the function of the EXPLORER_LIB software library `xl_get_code` (see [GEN_SUM]).

Table 195: Error messages of xl_default_sat_init function

Error type	Error message	Cause and impact	Error code	Error No
ERR	Default satellite ID is not correct	The satellite identification number does not belong to a default satellite. No computation performed	XL_CFI_DEFAULT_SAT_INIT_SAT_ERR	0
ERR	Error while reading satellite configuration file	Wrong configuration file. No computation performed	XL_CFI_DEFAULT_SAT_INIT_READ_FILE_ERR	1

7.45.6 Runtime performances

The following runtime performances have been measured.

Table 196: Runtime performances of xl_default_sat_init function

Solaris 32-bit. [ms]	Solaris 64 bit. [ms]	Linux 32-bit. [ms]	Linux 64-bit. [ms]
0.0073	0.0016	0.0023	0.0003

7.46 xl_default_sat_close

7.46.1 Overview

The `xl_default_sat_close` CFI function frees a default satellite id. that was initialized with `xl_default_sat_init`, so that it can be used again.

7.46.2 Calling interface

The calling interface `xl_default_sat_close` function is the following (input parameters are underlined>):

```
#include <explorer_lib.h>
{
    long sat_id;
    xl_default_sat_close(&sat_id);
}
```

7.46.3 Input parameters

The `xl_default_sat_close` function has the following input parameters:

Table 197: Input parameters of xl_default_sat_close function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long*	-	Satellite ID to free.	-	From XL_SAT_DEFAULT to XL_SAT_DEFAULT9

7.46.4 Output parameters

This function does not return any value nor parameters.

7.46.5 Warnings and errors

No warning nor errors are returned

7.47 xl_set_tle_sat_data

7.47.1 Overview

The **xl_set_tle_sat_data** CFI function changes the NORAD data that has been pre-established for every pre-defined satellite. These data are used for the reading/writing of the TLE files. The NORAD data that are defined for every satellite are:

- NORAD Satellite number
- Norad Satellite name
- NORAD International designator

This data can be found in: <http://celestrak.com/satcat/search.asp>

This function should not be needed if the NORAD data were already stabilised for every Earth Explorer satellite, however the data are not set until the satellite launch. So, in order to be able to handle TLE files it could be necessary to call this function so set the correct data for the satellite.

The table 199 shows the list of predefined satellites in the Earth Explorer CFI. Those satellites for which the NORAD data are not known has a NORAD Satellite number equal to "00000".

For the default satellites, that NORAD data cannot be set with this function as the data are set in the satellite configuration file.

WARNING: This function is not thread safe. However, this function could be used safely in the following way:

- The function should be called only if the real NORAD data are not correctly defined in the table 199.
- The function should be called only if TLE files are going to be handled to generate TLE files or for orbit initialization
- The function should be called only once and at the beginning of a program before launching any thread.

Table 198: NORAD Identifiers for satellites

Satellite ID	NORAD Satellite Number	NORAD Satellite Name	NORAD International Designator
XD_SAT_ERS1	21574	ERS1	"91050A "
XD_SAT_ERS2	23560	ERS2	"95021A "
XD_SAT_ENVISAT	27386	ENVISAT	"02009A "
XD_SAT_METOP1	29499	METOP-A	"06044A "
XD_SAT_METOP2	00000	METOP-B	"00000 "
XD_SAT_METOP3	00000	METOP-C	"00000 "
XD_SAT_CRYOSAT	36508	CRYOSAT 2	"10013A "
XD_SAT_ADM	00000	AEOLUS	"00000 "
XD_SAT_GOCE	34602	GOCE	"09013A "

Table 198: NORAD Identifiers for satellites

Satellite ID	NORAD Satellite Number	NORAD Satellite Name	NORAD International Designator
XD_SAT_SMOS	36036	SMOS	"09059A "
XD_SAT_TERRASAR	00000	TERRASAR	"00000 "
XD_SAT_EARTHCARE	00000	EARTHCARE	"00000 "
XD_SAT_SWARM_A	00000	SWARM-A	"00000 "
XD_SAT_SWARM_B	00000	SWARM-B	"00000 "
XD_SAT_SWARM_C	00000	SWARM-C	"00000 "
XD_SAT_SENTINEL_1A	00000	SENTINELA	"00000 "
XD_SAT_SENTINEL_1B	00000	SENTINELB	"00000 "
XD_SAT_SENTINEL_2	00000	SENTINEL2	"00000 "
XD_SAT_SENTINEL_3	00000	SENTINEL3	"00000 "
XD_SAT_SEOSAT	00000	SEOSAT	"00000 "
XD_SAT_GENERIC	00000	GENERIC	"00000 "

7.47.2 Calling interface

The calling interface `xl_set_tle_sat_data` function is the following (input parameters are underlined):

```
#include <explorer_lib.h>
{
    long sat_id, status;
    long norad_sat_number;
    char norad_satcat[25];
    char int_des[9];
    status = xl_set_tle_sat_data (&sat_id,
                                &norad_sat_number,
                                norad_satcat,
                                int_des);
}
```

7.47.3 Input parameters

The `xl_set_tle_sat_data` function has the following input parameters:

Table 199: Input parameters of xl_set_tle_sat_data function

C name	C type	Array Element	Description (Reference)	Unit (Format)	Allowed Range
sat_id	long*	-	Satellite ID	-	Any predefined satellite shown in table 198

7.47.4 Output parameters

This function returns the status of the execution:

- 0 if the execution was correct
- -1 if an error occurred. This only could happen if the input sat_id was incorrect.

7.47.5 Warnings and errors

No warning nor errors are returned

8 CFI EXECUTABLE PROGRAMS

The following sections describe executable programs based on the CFI functions.

8.1 time_conv

This program makes time conversions between different formats and time references. It is called in the following way:

```
time_conv [-ref_in] input_time_ref
          [-ref_out] output_time_ref
          -fmt_in input_format
          -fmt_out output_format
          {-day j200_date (days)|
          (-t1 transport_1 [-t2 transport_2] [-t3 transport_3] [-t4 transport_4]) |
          -date string_date (date)}
          [ -v ]
          [ -xd_v ]
          [ -xl_v ]
          [ -help ]
          [ -show ]
          [{ (-tai TAI_time -gps GPS_time -utc UTC_time -ut1 UT1_time) |
          (-tmod time_model -tfile time_file -trid time_reference
          {(-tm0 time0 -tm1 time1) | (-orb0 orbit0 -orb1 orbit1) } ) } ] }
```

Note that:

- Order of parameters does not matter.
- Bracketed parameters are not mandatory.
- Options between curly brackets and separated by a vertical bar are mutually exclusive.
- [-xd_v] option for EXPLORER_DATA_HANDLING Verbose mode.
- [-xl_v] option for EXPLORER_LIB Verbose mode.
- [-v] option for Verbose mode for all libraries (default is Silent).
- [-show] displays the inputs of the function and the results.
- Possible values for *time_model*: USER, NONE, IERS_B_PREDICTED, IERS_B_RESTITUTED, FOS_PREDICTED, FOS_RESTITUTED, DORIS_PRELIMINARY, DORIS_PRECISE, DORIS_NAVIGATOR.
- Possible values for *time_ref* and *time_reference*: TAI, UTC, UT1, GPS.
- Possible values for input_format and output_format:
 - Julian days: PROC
 - Transport format: TRANS_STD, TRANS_ENVI_GS, TRANS_CRYO_GS, TRANS_CRYO_TM, TRANS_CRYO_TM_SIRAL, SMOS_TM
 - date string: ASCII_STD, ASCII_STD_REF, ASCII_STD_MICROSEC, ASCII_STD_REF_MICROSEC, ASCII_COMPACT, ASCII_COMPACT_REF, ASCII_COMPACT_MICROSEC, ASCII_COMPACT_REF_MICROSEC, ASCII_ENVI, ASCII_ENVI_REF, ASCII_ENVI_MICROSEC,

ASCII_ENVI_REF_MICROSEC, ASCII_CCSDSA, ASCII_CCSDSA_REF, ASCII_CCSDSA_MICROSEC,
 ASCII_CCSDSA_REF_MICROSEC, ASCII_CCSDSA_COMPACT, ASCII_CCSDSA_COMPACT_REF,
 ASCII_CCSDSA_COMPACT_MICROSEC, ASCII_CCSDSA_COMPACT_REF_MICROSEC

- The last three lines of parameters are used for initialising the time correlations . Note that only one set of parameters should be introduced
 - TAI, GPS, UTC and UT1 input times (as in xl_time_ref_init)
 - A file with time reference data, the time mode, the time reference name and a time range (as in xl_time_ref_init_file)
- In a time conversion, if the time reference is not to be changed, the values for "-ref_in", "-ref_out" and the parameters for the time initialization are not needed. Note that the time reference will be always requested if the input/output format contains the reference in the date.

Examples:

```
time_conv -t1 1550 -t2 44266 -t3 176000 -t4 0 -fmt_in TRANS_STD
          -fmt_out PROC -ref_in TAI -ref_out TAI -v
          -tai 245.1000000000000 -gps 245.099780092
          -utc 245.099594907407 -ut1 245.099587962
```

```
time_conv -date 2004-03-30T12:17:46.176000
          -fmt_in ASCII_CCSDSA_MICROSEC
          -fmt_out ASCII_STD -ref_in TAI -ref_out GPS -v
          -tai 245.1000000000000 -gps 245.099780092
          -utc 245.099594907407 -ut1 245.099587962
```

9 LIBRARY PRECAUTIONS

The following precaution shall be taking into account when using EXPLORER_LIB library:

- When a message like

EXPLORER_LIB >>> ERROR in *xl_function*: Internal computation error # *n*

or

EXPLORER_LIB >>> WARNING in *xl_function*: Internal computation warning # *n*

appears, run the program in **verbose** mode for a complete description of warnings and errors and call for maintenance if necessary.

10 KNOWN PROBLEMS

The following precautions shall be taken into account when using the CFI software libraries:

Table 200: Known problems

CFI library	Problem	Work around solution
xl_time_obt_to_time	Cannot be called from ForTran- (no ForTran equivalence to unsigned long)	-
xl_time_obt_to_time	Since OBT is presently defined only for Envisat and GOCE, this function only works if: sat_id=XL_SAT_ENVISAT, sat_id=XL_SAT_GOCE, sat_id=XL_SAT_ADM or sat_id=XL_SAT_SMOS	-
xl_time_time_to_obt	Cannot be called from ForTran- (no ForTran equivalence to unsigned long)	-
xl_time_time_to_obt	Since OBT is presently defined only for Envisat and GOCE, this function only works if: sat_id=XL_SAT_ENVISAT, sat_id=XL_SAT_GOCE, sat_id=XL_SAT_ADM or sat_id=XL_SAT_SMOS	-
xl_euler_to_matrix	Functionality is not currently available	-
xl_matrix_to_euler	Functionality is not currently available	-
xl_time_ref_init_file	XL_SEL_FILE is not supported for time inputs selection (i.e. it is required to specify a time or an orbit range).	-
xl_change_cart_es	Changes from/to B1950 or GALACTIC coordinates are not currently available.	-
xl_cart_radec	Functionality is not currently available	-
xl_radec_to_cart	Functionality is not currently available	-
xl_star_catalog	Functionality is not currently available.	-
xl_topocentric_to_ef	Functionality is not currently available	-
xl_ef_to_topocentric	Functionality is not currently available	-
All	The error message "Satellite ID is not correct" that appears in some error tables in section 7 is obsolete. It is highly recommended using the enumeration values for the error (error codes) instead of the integer value (error number) to identify the error messages as these error codes will be removed in the next delivery.	-



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