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CIC DATA EXCHANGE PROTOCOL V2.0

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SUMMARY : This document presents the exchange protocol to allow the creation of a technical reference and the transfers between the various design, analysis and simulation tools during the working sessions in the Concurrent Engineering Center.

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GLOSSARY AND LIST OF TBC AND TBD ITEMS

AEM	Attitude Ephemeris Message
ASCII	American Standard Code for Information Interchange
CIC	Centre d'Ingénierie Concourante
CNES	French National Space Agency
KVN	Keyword Value Notation
LoS	Line of Sight
MEM	Mission Ephemeris Message
MJD	Modified Julian Date
MPM	Mission Parameter Message
OEM	Orbit Ephemeris Message
TAI	International Atomic Time
TDB	Barycentric Dynamical Time
TT	Terrestrial Time
UTC	Coordinated Universal Time

List of TBC items:

List of TBD items:

1. OVERVIEW

1.1. REFERENCE DOCUMENTS

[RD-1] Orbit data messages
CCSDS, 01/11/2009, Issue B, Rev. 2
CCSDS_502.0

[RD-2] Attitude data messages
CCSDS, 01/05/2008, Issue B, Rev. 1
CCSDS_504.0

1.2. APPLICABLE DOCUMENTS

2. INTRODUCTION

2.1. PURPOSE

The purpose of this document is to specify the exchange protocol, which will enable the constitution of a technical reference and the transmission of information between the different tools of conception, analysis and simulation used during the working sessions of the *Centre d'Ingénierie Concourante (CIC)*.

The data to be stored and exchanged can be either:

- "static values": time-independent data
    - Example: definition of the axis of rotation for a solar array in the satellite reference frame
- "dynamic values": time-dependent data
    - Example: definition of the satellite's position on its orbit

2.2. APPROACH

The CIC protocol defines a set of variables required to describe the various aspects of a satellite: geometry, orbit, AOCS, RF link…

In order to enable storage and exchange of the data described by the CIC protocol, several file types have been designed. These file types are inspired from the CCSDS reference format, so that they can benefit from the maturity of a recognised international standard.

The following entities are used:

- OEM (*Orbit Ephemeris Message*) files for the description of position ephemerides; and
- AEM (*Attitude Ephemeris Message*) files for the description of attitude ephemerides.

Files from the CIC protocol somewhat differ from the CCSDS format, by both restricting and expanding it. Parameters from the CCSDS standard are not all taken into account, and some additional formatting is allowed (MJD dates, tab characters…).

This affiliation to the European standard explains the presence of some ignored fields in the file types.

Furthermore, complementary file types have been designed in order to fit engineering requirements:

- MEM (*Mission Ephemeris Message*) files for the description of time-dependent data; and
- MPM (*Mission Parameter Message*) files for the description of time-independent data.

This structure enables the CIC protocol to fully satisfy the storage and exchange needs between the various tools used at the Concurrent Engineering Center.

2.3. DOCUMENT STRUCTURE

This document consists of the following chapters:

1. A general description of the file types and their formatting rules
   - Purpose and structure of each file type
   - Formatting rules of fields common to all file types
2. A detailed description of the content of each of these file types
   - Header fields
   - Metadata fields
   - Data formatting
   - Sample files
3. A description of the content of the CIC exchange protocol
   - Specification of the quantities described by the protocol

3. GENERAL DESCRIPTION

3.1. GENERAL DATA SET STRUCTURE

Data is stored and exchanged as a set of files, referred to as “data set”, and managed as a directory.

The files, no matter their types (OEM, AEM, MEM or MPM), are written as ASCII text files, and consist of three sections:

- the header
- the metadata (delineated by the `META_START` and `META_STOP` keywords in OEM, AEM and MEM files)
- the data

It is recommended (not mandatory) to name the files by the data type name, preceded by the “CIC” prefix: “`CIC_POSITION_VELOCITY.txt`”, “`CIC_ATTITUDE.txt`” or in a general manner “`CIC_USER_DEFINED_CONTENT.txt`” for MEM and MPM files.

3.2. FILE TYPES

3.2.1. OEM files

The OEM (*Orbit Ephemeris Message*) file type allows description of time-dependent orbit data.

An OEM file contains position and velocity ephemerides for a single celestial body (satellite, planet …) in a defined time range.

Moreover, it contains metadata allowing proper interpretation of the data.

Due to its tabular format, an OEM file requires its data to be interpolated if the user needs a position value that is not part of the ephemerides. This also holds for velocity values if provided.

Here is the general structure of an OEM file:

```
[Header fields]

META_START
[Metadata fields]
META_STOP

[Date 1] [Position at date 1]
[Date 2] [Position at date 2]
...
[Date N] [Position at date N]
```

3.2.2. AEM files

The AEM (*Attitude Ephemeris Message*) file type allows description of time-dependent attitude data.

An OEM file contains orientation ephemerides for a single celestial body (satellite, planet …) in a defined time range. These ephemerides may be provided under different forms (Euler angles, quaternion).

Moreover, it contains metadata allowing proper interpretation of the data.

In the same way as an OEM file, an AEM file requires its data to be interpolated if the user needs an orientation value that is not part of the ephemerides.

Here is the general structure of an AEM file:

```
[Header fields]

META_START
[Metadata fields]
META_STOP

[Date 1] [Attitude at date 1]
[Date 2] [Attitude at date 2]
...
[Date N] [Attitude at date N]
```

3.2.3. MEM files

The MEM (*Mission Ephemeris Message*) file type allows description of arbitrary time-dependent data.

A MEM file contains ephemerides for the quantity it describes in a defined time range. This quantity and its associated data formatting are defined either by the CIC protocol, or directly by the user (or another protocol that has been previously agreed upon).

When the quantity is defined by a protocol, its protocol name can be used and data formatting need not be supplied. Otherwise, the user must specify the number of value fields in an ephemeris line, as well as the type and unit of these values.

Moreover, a MEM file contains metadata allowing proper interpretation of the data.

The MEM file type hence allows storage and exchange of any time-varying quantity that can't be described in the specialised OEM or AEM file types.

In the same way as an OEM or AEM file, a MEM file requires its data to be interpolated if the user needs a value for the described quantity that is not part of the ephemerides. However, interpolating might not always be relevant or possible, depending on the quantity being described.

Here is the general structure of a MEM file:

```
[Header fields]

META_START
[Metadata fields]
[Data formatting definition]
META_STOP

[Date 1] [Data value at date 1]
[Date 2] [Data value at date 2]
...
[Date N] [Data value at date N]
```

3.2.4. MPM files

The MPM (*Mission Parameter Message*) file type allows description of arbitrary time-independent data.

A MPM file contains the value for the constant parameter it describes. As for the MEM file type, this parameter and its associated data formatting must either be defined in the CIC protocol or any other user-defined protocol, or be supplied directly by the user.

In the same way as for a MEM file, the parameter's data formatting is defined either by its protocol name or by a user-provided specification.

Moreover, a MPM file contains metadata allowing proper interpretation of the data.

The MPM file type hence allows storage and exchange of any fixed parameter.

Here is the general structure of a MPM file:

```
[Header fields]

[Metadata fields]
[Data formatting definition]

DATA = [Data value]
```

3.3. GENERAL SPECIFICATIONS

3.3.1. Field separator

The CIC standard allows for the space and tab characters (single or multiple ones) to be used as field separators.

3.3.2. Header and metadata formatting

The header and metadata sections of each file consist of a sequence of items, one per line, in the following form:

```
KEYWORD = VALUE
```

This format is designated by the acronym KVN (*Keyword Value Notation*).

Here are a few examples of lines in the KVN format:

```
OBJECT_NAME = CubeSat
CREATION_DATE = 2018-03-21T12:34:56
```

Each of the metadata and header items is defined in the following way:

- the keyword to be used;
- a short description of the item;
- examples of allowed values; and
- the presence requirement concerning this item.

The presence requirement defines whether the item's presence in its section is obligatory ("*Required*"), optional ("*Optional*"), or if its appearance should be considered as an error ("*Error*"). When needed, it also provides additional information about how the item shall be treated: "*Info*" means that the item's value has an informative role but does not affect interpretation of the data, "*Ignored*" means that the item's value is ignored. There may be several cases of presence requirement for the same item, depending on the value of other items.

The only exceptions to the KVN format are the `COMMENT`, `META_START` and `META_STOP` keywords. `META_START` and `META_STOP` always appear as the only content on a line. For a description of the `COMMENT` keyword, see 3.3.5.

Header and metadata keywords are presented in the exact same order in which they are expected in CIC files.

3.3.3. Date formatting and time systems

3.3.3.1. Date formatting

In the CIC standard, date fields are used in the header, metadata and data sections.

Two date formats may be used:

- A calendar-based format, from the ISO 8601 standard:

```
YYYY-MM-DDThh:mm:ss[.d→d][Z]
```

- A Julian day-based format (see 3.3.3.3 for more information) :

```
DDDDDD sssss[.d→d]
```

In order to satisfy the accuracy needs from several specialties, format using fractional days – and their inaccuracies[1] – were dismissed. The retained format uses two separate fields, a first one for the undivided

[1] For example, using 1/1/1950 0:00 as the reference, the March 23rd 2010 at 16:00 would be written as 21996.666666

number of days since the reference, and a second for the number of seconds within that day.

This format has the added advantage of providing greater handling simplicity for software that needs to read or write dates.

For better understanding, those two formats will be referred to as the *"ISO format"* and the *"day seconds format"*.

In the data section of CIC files, the date format is not explicitly indicated: applications must decide on their own which format is being used. However, it is required for the date format to remain consistent throughout the whole data section of a single file.

Date converters may be found on the Internet[2].

3.3.3.2. Time systems

The time system defines the time standard[3] to which refers the time data in the data section of a CIC file. The CIC standard retains the following time systems:

- UTC
- TAI
- TT
- TDB[4].

Note that the time delta between UTC and TAI systems is always an integer. Leap seconds[5] affect the time delta between the two systems.

3.3.3.3. Reference date

In the day seconds format, a reference date has to be defined for which the date is zero, no matter the time system.

In order to make exchange the CIC standard simpler, a common reference date shall be used for all CIC files: the reference date used for MJDs[6]. Under this reference, date zero corresponds to:

```
UTC 00:00 November 17, 1858, Wednesday
```

3.3.3.4. Examples

The table below offers a few examples of dates expressed in all of the possible combinations in the CIC standard:

2 http://www.csgnetwork.com/julianmodifdateconv.html
3 Wikipedia: http://en.wikipedia.org/wiki/Time_standard
4 http://www.navipedia.net/index.php/Transformations_between_Time_Systems
5 Wikipedia: http://en.wikipedia.org/wiki/Leap_second
6 Wikipedia: http://en.wikipedia.org/wiki/Julian_day#Alternatives

Format	ISO		Day seconds	
Time system	UTC	TAI	UTC	TAI
Now	2012-07-19T12:34:56.0	2012-07-19T12:35:31.0	56127 45296.000	56127 45331.000
0:00 November 17th, 1858	1858-11-17T00:00:00	1858-11-17T00:00:10	0 0.000	0 10.000
0:00 January 1st, 2000	2000-01-01T00:00:00	2000-01-01T00:00:32	51544 0.000	51544 32.000

3.3.4. Unit formatting

MEM and MPM files allow the user to describe as a string of characters the unit in which the values in the data section are expressed. This character string must comply with the following formatting rules:

- the string describing the unit must start and end with square brackets: `[ ]`
- multiplication, division and exponentiation are respectively denoted by the following characters: `* / **`
- there are no restrictions on the allowed base units
- available unit prefixes are those of the International System of Units (SI)[7]

Dimensionless values are denoted using the `[n/a]` notation. The following table gives some examples of unit strings:

Quantity	Time	Length	Velocity	Angle	Angular rate	Torque	Flux	Current	Power ratio	Percentage
Unit	s	km	km.s^{-1}	deg	rad.s^{-1}	N.m	W.m^{-2}	A	dB	%
Notation	[s]	[km]	[km/s]	[deg]	[rad/s]	[N*m]	[W/m**2]	[A]	[db]	[%]

3.3.5. Comment formatting

The purpose of comments is to allow the author of a CIC file to provide additional information that cannot be described using the protocol's specified keywords.

A comment consists of a file line beginning with the `COMMENT` keyword, followed by a field separator. The text following the keyword, on the same line, is the body of the comment. This text need not follow any specific formatting rule.

A comment may be formed by several lines of text, each beginning with the `COMMENT` keyword. Here is an example of a multi-line comment:

```
COMMENT   This is a very long comment, containing an awful lot of
COMMENT   textual information, and hence spreading on several lines
COMMENT   for increased readability.
```

The different file types of the CIC standard define the exact locations where comments may appear.

7 Wikipedia: http://en.wikipedia.org/wiki/SI_prefix

4. SPECIFICATION OF THE CIC FILE TYPE

4.1. OEM FILES (POSITION/VELOCITY)

See 3.2.1 for a general description of the file type.

4.1.1. Header

The header section for OEM files of the CIC protocol consists of the following items:

Keyword	Description	Examples	Presence
CIC_OEM_VERS	CIC version field in the form of 'x.y', where 'y' is incremented for corrections and minor changes, and 'x' is incremented for major changes.	`1.0`	**Required**
COMMENT	Comments (allowed only immediately after the OEM version number). (See 3.3.5 for formatting rules.)	`This is a comment.`	Optional
CREATION_DATE	File creation date et time in UTC, using the ISO format. (See 3.3.3 for formatting rules.)	`2001-11-06T11:17:33`	Required *Info*
ORIGINATOR	Originator of the file (spatial agency, company, application …). The value for this field is unconstrained.	`CNES, SPACEBEL, VTS`	Required *Info*

4.1.2. Metadata

The metadata section must be delineated with the `META_START` and `META_STOP` keywords, each on a line by itself.

The metadata section for OEM files of the CIC protocol consists in the following items:

Keyword	Description	Examples	Presence
META_START	Delineates the start of the metadata section. Must appear on a line by itself.	n/a	**Required**
COMMENT	Comments (allowed only immediately after the `META_START` keyword). (See3.3.5 for formatting rules.)	`This is a comment.`	Optional

OBJECT_NAME	Name of the object for which the ephemerides are provided. The value for this field is unconstrained.	`EUTELSAT W1`
		`MARS PATHFINDER`
		`STS 106`
		`NEAR`
			Required
			Info

OBJECT_ID	ID of the object for which the ephemerides are provided. The value for this field is unconstrained.	`2000-052A` `1996-068A`	Required *Info*

CENTER_NAME	Origin of the reference frame in which the ephemerides are expressed. The value for this field is unconstrained.	`EARTH`
		`EARTH BARYCENTER`
		`MOON`
		`SOLAR SYSTEM BARYCENTER`
		`JUPITER BARYCENTER`
		`STS 106`
		`EROS`
			Required
			Info

REF_FRAME	Name of the reference frame in which the ephemerides are expressed. The value EME2000 is obligatory for this field.	`EME2000` (Earth Mean Equator and Equinox of J2000)	Required *Info*

TIME_SYSTEM	Time system for the file's dates. (See3.3.3.2 for available systems).	`UTC`
		`TAI`
		`TT`
		`TDB`
			Required

META_STOP	Delineates the end of the metadata section. Must appear on a line by itself.	n/a	**Required**

The following parameters are defined in the CCSDS standard but are not required by the CIC file format: REF_FRAME_EPOCH, START_TIME, USEABLE_START_TIME, USEABLE_STOP_TIME, STOP_TIME, INTERPOLATION, INTERPOLATION_DEGREE. When present, they are ignored silently.

4.1.3. Data

Ephemeris lines in an OEM file must be formatted in the following way:

Epoch X Y Z `X_DOT Y_DOT Z_DOT`

Epoch and position are mandatory. Velocity is optional.

Ephemeris lines must be ordered by increasing epoch, and epoch tags must not be repeated. The time delta between two consecutive epochs may vary.

Units for ephemeris lines are km and $km.s^{-1}$ respectively for position and velocity.

Here are a few sample data lines, with different date formats and fields:

```
2018-06-21T12:34:56.789   4264.0859 -832.2544 5618.2084
58290 45296.789   4264.0859 -832.2544 5618.2084   7.3370 -3.4958 -1.0419
58290 45296.789   4264.0859 -832.2544 5618.2084   7.3370 -3.4958 -1.0419
```

4.1.4. Example

The following file is an example of an OEM file of the CIC protocol, without velocity fields:

```
CIC_OEM_VERS    = 1.0
COMMENT           Sample position file for CubeSat
CREATION_DATE   = 2009-12-08T09:00:00
ORIGINATOR      = CNES

META_START

OBJECT_NAME = CubeSat
OBJECT_ID   = CubeSat
CENTER_NAME = EARTH
REF_FRAME   = EME2000
TIME_SYSTEM = UTC

META_STOP

55276   0.000 4264.085921  -832.254441 5618.208465
55276  30.000 4421.338968  -916.904119 5481.941484
55276  60.000 4574.176227 -1000.637990 5340.185449
55276  90.000 4722.444369 -1083.372281 5193.081475
55276 120.000 4865.994574 -1165.024190 5040.776067
```

4.2. AEM FILES (ATTITUDE)

See 3.2.2 for a general description of the file type.

4.2.1. Header

The header section for AEM files of the CIC protocol consists of the following items:

Keyword	Description	Examples	Presence
CIC_AEM_VERS	CIC version field in the form of 'x.y', where 'y' is incremented for corrections and minor changes, and 'x' is incremented for major changes.	`1.0`	**Required**
COMMENT	Comments (allowed only immediately after the AEM version number). (See 3.3.5 for formatting rules.)	`This is a comment.`	Optional
CREATION_DATE	File creation date et time in UTC, using the ISO format. (See 3.3.3.1 for formatting rules.)	`2001-11-06T11:17:33`	Required *Info*
ORIGINATOR	Originator of the file (spatial agency, company, application …). The value for this field is unconstrained.	`CNES, SPACEBEL, VTS`	Required *Info*

4.2.2. Metadata

The metadata section must be delineated with the `META_START` and `META_STOP` keywords, each on a line by itself.

The metadata section for AEM files of the CIC protocol consists in the following items:

Keyword	Description	Examples	Presence
META_START	Delineates the start of the metadata section. Must appear on a line by itself.	n/a	**Required**
COMMENT	Comments (allowed only immediately after the `META_START` keyword). (See 3.3.5 for formatting rules.)	`This is a comment.`	Optional

OBJECT_NAME	Name of the object for which the ephemerides are provided. The value for this field is unconstrained.	`EUTELSAT W1`
		`MARS PATHFINDER`
		`STS106`
		`NEAR`
			Required *Info*

OBJECT_ID	ID of the object for which the ephemerides are provided. The value for this field is unconstrained.	`2000-052A` `1996-068A`	Required *Info*

CENTER_NAME	Origin of the reference frame in which the ephemerides are expressed. The value for this field is unconstrained.	EARTH SOLAR SYSTEM BARYCENTER JUPITER BARYCENTER STS 106 EROS	Optional *Ignored*
REF_FRAME_A	Name of the first reference frame involved in the transformation described by the file's ephemerides. The key ATTITUDE_DIR indicates whether it is the source or destination reference frame for the transformation. The value EME2000 is obligatory for this field.	EME2000	Required *Info*
REF_FRAME_B	Name of the second reference frame involved in the transformation described by the file's ephemerides. The key ATTITUDE_DIR indicates whether it is the source or destination reference frame for the transformation. The value for this field is unconstrained.	SC_BODY_1	Required *Info*
ATTITUDE_DIR	Direction of the rotation described by the file's ephemerides: A2B indicates a rotation from REF_FRAME_A to REF_FRAME_B. The value A2B is obligatory for this field.	A2B	Required *Info*
TIME_SYSTEM	Time system for the file's dates. (See 3.3.3.2 for available systems).	UTC TAI TT TDB	**Required**
ATTITUDE_TYPE	Type of the ephemerides. Directs formatting rules for the data section. Available formats are described in 4.2.3	QUATERNION EULER_ANGLE	**Required**
QUATERNION_ TYPE	Placement of the scalar portion of a quaternion in the ephemerides, if ATTITUDE_TYPE is set to QUATERNION. Possible values are described in 4.2.3.1. Default value is FIRST.	FIRST LAST	QUATERNION: Optional EULER_ANGLE: Error
EULER_ROT_SEQ	Rotation sequence of the Euler angles in the ephemerides, if ATTITUDE_TYPE is set to EULER_ANGLE. Possible values are described in 4.2.3.2. Default value is 313.	131 231 321	EULER_ANGLE: Optional QUATERNION: Error
META_STOP	Delineates the end of the metadata section. Must appear on a line by itself.	n/a	**Required**

The following parameters are defined in the CCSDS standard but are not required by the CIC file format: START_TIME, USEABLE_START_TIME, USEABLE_STOP_TIME, STOP_TIME, RATE_FRAME, INTERPOLATION_METHOD, INTERPOLATION_DEGREE. When present, they are ignored silently.

4.2.3. Data

Ephemeris lines in an AEM file must be formatted in either of the following ways:

Format	Value for `ATTITUDE_TYPE`	Ephemeris line format
Quaternion	`QUATERNION`	**`Epoch Q1 Q2 Q3 Q4`**
Euler angles	`EULER_ANGLE`	**`Epoch E1 E2 E3`**

4.2.3.1. Attitude by quaternion

The `QUATERNION_TYPE` keyword in the metadata section of the AEM file allows to specify the placement for the scalar portion of a quaternion in the file's ephemerides.

Possible values are described in the table below, with `QW` being the quaternion's scalar portion.

Value for `QUATERNION_TYPE`	Quaternion format
`FIRST`	**`QW QX QY QZ`**
`LAST`	**`QX QY QZ QW`**

Here are a few sample data lines using quaternions:

```
2018-06-21T12:34:56.789    0.003498 0.924460 -0.202258 -0.323192
58290 45296.789           -0.085656 0.703617  0.186078 -0.680412
```

4.2.3.2. Attitude by Euler angles

The `EULER_ROT_SEQ` keyword in the metadata section of the AEM file specifies the rotation sequence used to compose the Euler angles. This sequence identifies the rotation axes of the three composed rotations, in the mobile reference frame. Hence sequence `313` corresponds to the composition of three rotations with axes Z, X', and Z''.

There are 12 possible combinations for this field, all presented in the following table:

Sequence	131	132	121	123	212	213	232	231	323	321	313	312
Axes	X Z' X''	X Z' Y''	X Y' X''	X Y' Z''	Y X' X''	Y X' Z''	Y Z' Y''	Y Z' X''	Z Y' Z''	Z Y' X''	Z X' Z''	Z X' Y''

The angles for the three rotations must be in degrees.

Here are a few sample data lines using Euler angles:

```
2018-06-21T12:34:56.789   -20.18  48.63   11.91
58290 45296.789             78.14   2.57 -89.43
```

4.2.4. Examples

The following file is an example of an AEM file of the CIC protocol, using quaternions:

```
CIC_AEM_VERS    = 1.0
COMMENT           Sample attitude file for CubeSat
CREATION_DATE   = 2009-12-08T09:00:00
ORIGINATOR      = CNES

META_START

COMMENT   Attitude is expressed using quaternions

OBJECT_NAME    = CubeSat
OBJECT_ID      = CubeSat

REF_FRAME_A    = EME2000
REF_FRAME_B    = SC_BODY_1
ATTITUDE_DIR   = A2B

TIME_SYSTEM    = UTC

ATTITUDE_TYPE = QUATERNION

META_STOP

55276  30.0  0.003321 0.924460 -0.202258 -0.323192
55276  60.0  0.000134 0.919235 -0.202341 -0.337735
55276  90.0 -0.003230 0.913780 -0.202373 -0.352194
55276 120.0 -0.006593 0.908096 -0.202354 -0.366565
```

The following file is an example of an AEM file of the CIC protocol, using Euler angles:

```
CIC_AEM_VERS    = 1.0
COMMENT           Sample attitude file for CubeSat
CREATION_DATE   = 2009-12-08T09:00:00
ORIGINATOR      = CNES

META_START

COMMENT   Attitude is expressed using Euler angles

OBJECT_NAME    = CubeSat
OBJECT_ID      = CubeSat

REF_FRAME_A    = EME2000
REF_FRAME_B    = SC_BODY_1
ATTITUDE_DIR   = A2B

TIME_SYSTEM    = UTC

ATTITUDE_TYPE = EULER_ANGLE
EULER_ROT_SEQ = 313

META_STOP

55276   30.0    0   0   0
55276   60.0    0   0   0
55276   90.0   45   0   0
55276  120.0   45   0   0
55276  150.0   45  45   0
55276  180.0   45  45   0
55276  210.0   45  45  45
```

4.3. MEM FILES (ADDITIONAL DYNAMIC DATA)

See 3.2.3 for a general description of the file type.

4.3.1. Header

The header section for MEM files of the CIC standard consists of the following items:

Keyword	Description	Examples	Presence
CIC_MEM_VERS	CIC version field in the form of 'x.y', where 'y' is incremented for corrections and minor changes, and 'x' is incremented for major changes.	`1.0`	**Required**
COMMENT	Comments (allowed only immediately after the OEM version number). (See 3.3.5 for formatting rules.)	`This is a comment.`	Optional
CREATION_DATE	File creation date et time in UTC, using the ISO format. (See 3.3.1 for formatting rules.)	`2001-11-06T11:17:33`	Required *Info*
ORIGINATOR	Originator of the file (spatial agency, company, application …). The value for this field is unconstrained.	`CNES, SPACEBEL, VTS`	Required *Info*

4.3.2. Metadata

The metadata section must be delineated with the `META_START` and `META_STOP` keywords, each on a line by itself.

The metadata section for MEM files of the CIC protocol consists in the following items:

Keyword	Description	Examples	Presence
META_START	Delineates the start of the metadata section. Must appear on a line by itself.	n/a	**Required**
COMMENT	Comments (allowed only immediately after the `META_START` keyword). (See 3.3.5 for formatting rules.)	`This is a comment.`	Optional

OBJECT_NAME	Name of the object for which the ephemerides are provided. The value for this field is unconstrained.	`EUTELSAT W1`
		`MARS PATHFINDER`
		`STS 106`
		`NEAR`
			Required
			Info

OBJECT_ID	ID of the object for which the ephemerides are provided. The value for this field is unconstrained.	`2000-052A` `1996-068A`	Required *Info*

USER_DEFINED_ PROTOCOL	Name of the protocol used in the ephemerides. Available values are CIC and NONE by default, but other protocols may be used if defined by the user. (See chapter 5 for a description of the CIC protocol.)	CIC NONE	**Required**
USER_DEFINED_ CONTENT	Variable described by the ephemerides. Interpretation depends on the value for USER_DEFINED_PROTOCOL: ▪ For a known protocol, USER_DEFINED_CONTENT must reference a protocol-defined variable. ▪ Pour NONE, USER_DEFINED_CONTENT only provides the name of the variable.	GS_ANGLE ANTENNA_ANGLE	CIC/*other*: **Required** NONE: Required *Info*
USER_DEFINED_ SIZE	Number of value fields in an ephemeris line, if the variable described by the MEM file isn't part of a protocol.	2 5	CIC/other: Error NONE: **Required**
USER_DEFINED_ TYPE	Data type of the ephemerides, if the variable described by the MEM file isn't part of a protocol. Available values are: ▪ INTEGER ▪ REAL ▪ STRING	INTEGER	CIC/other: Error NONE: **Required**
USER_DEFINED_ UNIT	Unit for the ephemerides, if the variable described by the MEM file isn't part of a protocol. (See 3.3.4 for formatting rules.)	[kg*m**2] [rad/s**2]	CIC/other: Error NONE: **Required**
TIME_SYSTEM	Time system for the file's dates. (3.3.3.2 for available systems).	UTC TAI TT TDB	**Required**
META_STOP	Delineates the end of the metadata section. Must appear on a line by itself.	n/a	**Required**

4.3.3. Data

Ephemeris lines in a MEM file must be formatted in the following way:

```
Epoch   Data
```

The format for the Data field must either correspond to the format defined by the specified protocol for the described variable, or to the format defined by the USER_DEFINED_SIZE and USER_DEFINED_TYPE keywords if the protocol is set to NONE. The unit in which the data is expressed is defined either by the protocol or by the USER_DEFINED_UNIT keyword.

The following table presents a few sample data lines for a MEM file:

Quantity	Dim.	Type	Unit	Ephemeris line
Antenna rotation angle around an axis	1	REAL	[deg]	`2018-06-21T12:34:56.789    -158.12`
Angular velocity of an antenna around an axis	3	REAL	[rad/s]	`58290 45296.789  -0.0012 0.2451 0.0000`

4.3.4. Examples

The following file is an example of a MEM file, referencing a quantity from the CIC protocol:

```
CIC_MEM_VERS    = 1.0
COMMENT           Sample dynamic data file for CubeSat
CREATION_DATE   = 2009-12-08T09:00:00
ORIGINATOR      = CNES

META_START

COMMENT   Quantity from the CIC protocol: rotation angle for solar array 1

OBJECT_NAME = CubeSat
OBJECT_ID   = CubeSat

USER_DEFINED_PROTOCOL = CIC
USER_DEFINED_CONTENT  = ROTATION_ANGLE_SA1

TIME_SYSTEM = UTC

META_STOP

55276  60.0 93.45
55276 120.0 95.27
55276 180.0 97.08
55276 240.0 98.89
55276 300.0 100.70
55276 360.0 102.52
55276 420.0 104.33
```

The following file is an example of a MEM file, not referencing a quantity from the CIC protocol:

```
CIC_MEM_VERS    = 1.0
COMMENT           Sample dynamic data file for CubeSat
CREATION_DATE   = 2009-12-08T09:00:00
ORIGINATOR      = SPACEBEL

META_START

COMMENT   Quantity not defined by any protocol: hydrazine volume

OBJECT_NAME = CubeSat
OBJECT_ID   = CubeSat

USER_DEFINED_PROTOCOL = NONE
USER_DEFINED_CONTENT  = HYDRAZINE
USER_DEFINED_SIZE     = 1
USER_DEFINED_TYPE     = REAL
USER_DEFINED_UNIT     = [l]

TIME_SYSTEM = UTC

META_STOP

55276  60.0 5.623
55276 120.0 5.623
55276 180.0 5.487
55276 240.0 5.485
55276 300.0 5.484
55276 360.0 5.483
```

4.4. MPM FILES (ADDITIONAL STATIC DATA)

See 3.2.4 for a general description of the file type.

4.4.1. Header

The header section for MPM files of the CIC standard consists of the following items:

Keyword	Description	Examples	Presence
CIC_MPM_VERS	CIC version field in the form of 'x.y', where 'y' is incremented for corrections and minor changes, and 'x' is incremented for major changes.	`1.0`	**Required**
COMMENT	Comments (allowed only immediately after the OEM version number). (See 3.3.5 for formatting rules.)	`This is a comment.`	Optional
CREATION_DATE	File creation date et time in UTC, using the ISO format. (See 5 for formatting rules.)	`2001-11-06T11:17:33`	Required *Info*
ORIGINATOR	Originator of the file (spatial agency, company, application …). The value for this field is unconstrained.	`CNES, SPACEBEL, VTS`	Required *Info*

4.4.2. Metadata

The metadata section must be delineated with the `META_START` and `META_STOP` keywords, each on a line by itself.

The metadata section for MPM files of the CIC protocol consists in the following items:

Keyword	Description	Examples	Presence
COMMENT	Comments (allowed only immediately after the `META_START` keyword). (3.3.5 for formatting rules.)	`This is a comment.`	Optional

OBJECT_NAME	Name of the object for which the ephemerides are provided. The value for this field is unconstrained.	`EUTELSAT W1`
		`MARS PATHFINDER`
		`STS 106`
			Required *Info*

OBJECT_ID	ID of the object for which the ephemerides are provided. The value for this field is unconstrained.	`2000-052A` `1996-068A`	Required *Info*
USER_DEFINED_ PROTOCOL	Name of the protocol used for the data. Available values are `CIC` and `NONE` by default, but other protocols may be used if defined by the user. (See chapter 5 for a description of the CIC protocol.)	`CIC` `NONE`	**Required**

USER_DEFINED_ CONTENT	Variable described by the data. Interpretation depends on the value for `USER_DEFINED_PROTOCOL`: ▪ For a known protocol, `USER_DEFINED_CONTENT` must reference a protocol-defined variable. ▪ Pour `NONE`, `USER_DEFINED_CONTENT` only provides the name of the variable.	`GS_ANGLE` `ANTENNA_ANGLE`	`CIC/`*`other`*: **Required** `NONE`: Required *Info*
USER_DEFINED_ SIZE	Number of value fields in the data, if the variable described by the MPM file isn't part of a protocol.	`2` `5`	`CIC/other`: Error `NONE`: **Required**
USER_DEFINED_ TYPE	Data type for the data, if the variable described by the MPM file isn't part of a protocol. Available values are: ▪ `INTEGER` ▪ `REAL` ▪ `STRING`	`INTEGER`	`CIC/other`: Error `NONE`: **Required**
USER_DEFINED_ UNIT	Unit for the data, if the variable described by the MPM file isn't part of a protocol. (See 3.3.4 for formatting rules.)	`[kg*m**2]` `[rad/s**2]`	`CIC/other`: Error `NONE`: **Required**

4.4.3. Data

Data in MPM files is always prefixed by the `DATA` keyword:

```
DATA = Data
```

The format for the `Data` field must either correspond to the format defined by the specified protocol for the described variable, or to the format defined by the `USER_DEFINED_SIZE` and `USER_DEFINED_TYPE` keywords if the protocol is set to `NONE`. The unit in which the data is expressed is defined either by the protocol or by the `USER_DEFINED_UNIT` keyword.

The following table presents a few sample data lines for a MPM file:

Quantity	Dim.	Type	Unit	Data line
Satellite reference frame	3	`STRING`	`[n/a]`	`DATA = -w q -s`
Centre of gravity of the satellite in its reference frame	3	`REAL`	`[m]`	`DATA = -1.003 0.2451 4.8056`

4.4.4. Example

The following file is an example of a MPM file:

```
CIC_AEM_VERS    = 1.0
COMMENT           Sample static data file for CubeSat
CREATION_DATE   = 2009-12-08T09:00:00
ORIGINATOR      = CNES

COMMENT   Direction of the sensitive face of the SA when ANGSA = 0

OBJECT_NAME = CubeSat
OBJECT_ID   = CubeSat

USER_DEFINED_PROTOCOL = NONE
USER_DEFINED_CONTENT  = DIR_GS
USER_DEFINED_SIZE     = 3
USER_DEFINED_TYPE     = REAL
USER_DEFINED_UNIT     = [n/a]

DATA = 0 0.707 -0.707
```

5. SPECIFICATION OF THE CIC EXCHANGE PROTOCOL

This chapter presents the list of quantities defined by the CIC protocol.

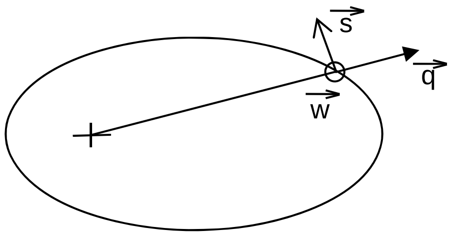
5.1. SATELLITE DATA

5.1.1. Local orbital coordinate system

The (G_{SAT}, q,s,w) reference frame is used, which refers to the geocentric axis (q // OG_{SAT}):

O, G_{SAT} respectively designate the Earth's centre and the satellite's centre of mass.

- q is directed along the ascending geocentric axis
- w is parallel to, and in the same direction as the orbital momentum
- s is normal to the (q,w) plane



5.1.2. Satellite coordinate system

USER_DEFINED_CONTENT (MPM file) SATELLITE_COORDINATE_SYSTEM	
Type	STRING
Dimension	3
Unit	[n/a]
Description	Satellite coordinate system X, Y, Z relating to the local orbital coordinate system: X = q or −q or s or −s or w or −w Y = q or −q or s or −s or w or −w Z = q or −q or s or −s or w or −w **Example :** DATA = s w q

5.1.3. Satellite centre of gravity

USER_DEFINED_CONTENT (MPM file) **CENTER_OF_GRAVITY**	
Type	REAL
Dimension	3
Unit	[m]
Description	Centre of gravity of the satellite in the satellite coordinate system: X_G, Y_G, Z_G

5.1.4. Centre of rotation for solar array 1

USER_DEFINED_CONTENT (MPM file) **CENTER_OF_ROTATION_SA_1**	
Type	REAL
Dimension	3
Unit	[m]
Description	Centre of rotation for solar array 1

5.1.5. Centre of rotation for solar array 2, 3, 4…

Parameters **CENTER_OF_ROTATION_SA_2**, **CENTER_OF_ROTATION_SA_3** and **CENTER_OF_ROTATION_SA_4** have the same properties as **CENTER_OF_ROTATION_SA_1**.

5.1.6. Axis of rotation for solar array 1

USER_DEFINED_CONTENT (MPM file) **AXIS_OF_ROTATION_SA_1**	
Type	REAL
Dimension	3
Unit	[n/a]
Description	Axis of rotation for solar array 1

5.1.7. Axis of rotation for solar array 2, 3, 4…

Parameters **AXIS_OF_ROTATION_SA_2**, **AXIS_OF_ROTATION _SA_3** and **AXIS_OF_ROTATION_SA_4** have the same properties as **AXIS_OF_ROTATION_SA_1**.

5.1.8. Reference position for solar array 1

USER_DEFINED_CONTENT (MPM file) **REFERENCE_POSITION_SA_1**	
Type	REAL
Dimension	3
Unit	[n/a]
Description	Reference position of the rotation axis for solar array 1 in the satellite coordinate system.

5.1.9. Reference position for solar array 2, 3, 4…

Parameters **REFERENCE_POSITION_SA_2**, **REFERENCE_POSITION_SA_3** and **REFERENCE_POSITION_SA_4** have the same properties as **REFERENCE_POSITION_SA_1**.

5.2. MISSION DATA

5.2.1. Simulation time

USER_DEFINED_CONTENT SIMULATION_TIME	
Type	REAL
Dimension	1
Unit	[s]
Description	Time of simulation

5.2.2. Satellite modes

USER_DEFINED_CONTENT SATELLITE_MODES	
Type	STRING
Dimension	1
Unit	[n/a]
Description	Modes of the satellite

5.3. GEOMETRICAL DATA

5.3.1. Satellite position and velocity

OEM DATA **POSITION_VELOCITY**	
Type	REAL
Dimension	6
Unit	[km] [km/s]
Description	Satellite position and velocity: X, Y, Z, X_DOT, Y_DOT, Z_DOT

5.3.2. Satellite geographical coordinates

USER_DEFINED_CONTENT **GEOGRAPHICAL_COORDINATES**	
Type	REAL
Dimension	2
Unit	[deg]
Description	Satellite longitude and latitude

5.3.3. Satellite geodetic altitude

USER_DEFINED_CONTENT **SATELLITE_ALTITUDE**	
Type	REAL
Dimension	1
Unit	[km]
Description	Geodetic altitude of the satellite

5.3.4. Beta angle

USER_DEFINED_CONTENT **BETA_ANGLE**	
Type	REAL
Dimension	1
Unit	[deg]
Description	Angle between the Sun and the orbital plane

5.3.5. Sun direction in the satellite reference frame

USER_DEFINED_CONTENT **SUN_DIRECTION-SATELLITE_FRAME**	
Type	REAL
Dimension	3
Unit	[n/a]
Description	Sun direction (cosine director) in the satellite reference frame

5.3.6. Sun direction in the local orbital reference frame

USER_DEFINED_CONTENT SUN_DIRECTION-ORBITAL_FRAME	
Type	REAL
Dimension	3
Unit	[n/a]
Description	Sun direction (cosine director) in the local orbital reference frame

5.3.7. Moon direction in the satellite reference frame

USER_DEFINED_CONTENT MOON_DIRECTION-SATELLITE_FRAME	
Type	REAL
Dimension	3
Unit	[n/a]
Description	Moon direction (cosine director) in the satellite reference frame

5.3.8. Earth direction in the satellite reference frame

USER_DEFINED_CONTENT EARTH_DIRECTION-SATELLITE_FRAME	
Type	REAL
Dimension	3
Unit	[n/a]
Description	Earth direction (cosine director) in the satellite reference frame

5.3.9. Satellite eclipse

USER_DEFINED_CONTENT SATELLITE_ECLIPSE	
Type	REAL
Dimension	1
Unit	[%]
Description	Eclipse ratio of the satellite (0.0 : 0% eclipsed, 1.0: 100% eclipsed (umbra), 0.7 : 70% eclipsed (penumbra))

5.3.10. Sun visibility

USER_DEFINED_CONTENT SUN_VISIBILITY	
Type	REAL
Dimension	1
Unit	[%]
Description	Visibility of the Sun

5.3.11. Satellite local time

USER_DEFINED_CONTENT SATELLITE_LOCAL_TIME	
Type	REAL
Dimension	1
Unit	[h]
Description	Satellite local time

5.3.12. Mean argument of latitude

USER_DEFINED_CONTENT MEAN_ARGUMENT_OF_LATITUDE	
Type	REAL
Dimension	1
Unit	[deg]
Description	Sum of the argument of the perigee and of the mean anomaly

5.3.13. Sun angle for solar array 1

USER_DEFINED_CONTENT SUN_ANGLE_SA_1	
Type	REAL
Dimension	1
Unit	[deg]
Description	Angle between the Sun and the axis rotation for solar array 1

5.3.14. Sun angle for solar array 2, 3, 4 …

Parameters **SUN_ANGLE_SA_2**, **SUN_ANGLE_SA_3** and **SUN_ANGLE_SA_4** have the same properties as **SUN_ANGLE_SA_1.**

5.3.15. Earth angle for solar array 1

USER_DEFINED_CONTENT EARTH_ANGLE_SA_1	
Type	REAL
Dimension	1
Unit	[deg]
Description	Angle between the Earth and the axis of rotation for solar array 1

5.3.16. Earth angle for solar array 2, 3, 4 …

Parameters **EARTH_ANGLE_SA_2**, **EARTH_ANGLE_SA_3** and **EARTH_ANGLE_SA_4** have the same properties as **EARTH_ANGLE_SA_1**.

5.3.17. Angle of rotation for solar array 1

USER_DEFINED_CONTENT **ROTATION_ANGLE_SA_1**	
Type	REAL
Dimension	1
Unit	[deg]
Description	Angle of rotation for solar array 1 (relative to the reference position)

5.3.18. Angle of rotation for solar array 2, 3, 4 …

Parameters **ROTATION_ANGLE_SA_2**, **ROTATION_ANGLE_SA_3** and **ROTATION_ANGLE_SA_4** have the same properties as **ROTATION_ANGLE_SA_1**.

5.3.19. Orbit number

USER_DEFINED_CONTENT **ORBIT_NUMBER**	
Type	INTEGER
Dimension	1
Unit	[n/a]
Description	Orbit number

5.3.20. Geometrical visibility for ground station 1

USER_DEFINED_CONTENT **GEOMETRICAL_VISIBILITY_GROUND_STATION_1**	
Type	`INTEGER`
Dimension	`1`
Unit	`[n/a]`
Description	Geometrical visibility status for ground station 1 (0: no, 1: yes)

5.3.21. Geometrical visibility for ground station 2, 3, 4 …

Parameters **GEOMETRICAL_VISIBILITY_GROUND_STATION_2**, **GEOMETRICAL_VISIBILITY_GROUND_STATION_3** and **GEOMETRICAL_VISIBILITY_GROUND_STATION_4** have the same properties as **GEOMETRICAL_VISIBILITY_GROUND_STATION_1**.

5.3.22. Type of over-flown mesh

USER_DEFINED_CONTENT **MESH_TYPE**	
Type	`INTEGER`
Dimension	`1`
Unit	`[n/a]`
Description	Type of over-flown mesh (1: sea, 2: land, 3: coast)

5.3.23. Hot spot

USER_DEFINED_CONTENT **HOT_SPOT**	
Type	`REAL`
Dimension	`2`
Unit	`[deg]`
Description	Longitude and latitude of the hot spot point (999: no hot spot)

5.3.24. Sun glint

USER_DEFINED_CONTENT **SUN_GLINT**	
Type	REAL
Dimension	2
Unit	[deg]
Description	Longitude and latitude of the sun glint point (999: no sun glint)

5.4. AOCS DATA

5.4.1. Satellite attitude

AEM DATA **ATTITUDE**	
Type	`REAL`
Dimension	`4 – 3`
Unit	Applicable units are determined by the value set for the `ATTITUDE_TYPE` keyword: • `QUATERNION` : `[n/a]` • `EULER_ANGLE` : `[deg]`
Description	Attitude of the satellite. Formatting is determined by the value set for the `ATTITUDE_TYPE` keyword: • `QUATERNION` : `QW`, `QX`, `QY`, `QZ` • `EULER_ANGLE` : `X_ANGLE`, `Y_ANGLE`, `Z_ANGLE`

5.4.2. Satellite attitude mode

USER_DEFINED_CONTENT **SATELLITE_ATTITUDE_MODE**	
Type	`INTEGER`
Dimension	`1`
Unit	`[n/a]`
Description	Attitude mode for the satellite (1: quaternion, 2: geocentric, 3: Sun pointing)

5.4.3. Attitude law

USER_DEFINED_CONTENT **ATTITUDE_LAW**	
Type	`INTEGER`
Dimension	`1`
Unit	`[n/a]`
Description	Attitude law (1: nadir pointing, 2: site pointing)

5.4.4. Satellite angular velocity

USER_DEFINED_CONTENT **SATELLITE_ANGULAR_VELOCITY**	
Type	`REAL`
Dimension	`3`
Unit	`[rad/s]`
Description	Angular velocity of the satellite

5.4.5. Satellite angular acceleration

USER_DEFINED_CONTENT **SATELLITE_ANGULAR_ACCELERATION**	
Type	`REAL`
Dimension	`3`
Unit	`[rad/s**2]`
Description	Angular acceleration of the satellite

5.4.6. Satellite wheels torques

USER_DEFINED_CONTENT **WHEELS_TORQUES**	
Type	`REAL`
Dimension	`3`
Unit	`[N*m]`
Description	Torques produced by the satellite’s wheels

5.5. THERMAL DATA

5.5.1. Solar flux

USER_DEFINED_CONTENT SOLAR_FLUX	
Type	REAL
Dimension	6
Unit	[W/m**2]
Description	Solar flux on a cube (ordering of cube faces: +x +y +z -x -y -z)

5.5.2. Albedo flux

USER_DEFINED_CONTENT ALBEDO_FLUX	
Type	REAL
Dimension	6
Unit	[W/m**2]
Description	Albedo of a cube (ordering of cube faces: +x +y +z -x -y -z)

5.5.3. Earth flux

USER_DEFINED_CONTENT EARTH_FLUX	
Type	REAL
Dimension	6
Unit	[W/m**2]
Description	Earth flux on a cube (ordering of cube faces: +x +y +z -x -y -z)

5.6. ELECTRICAL DATA

5.6.1. Satellite power consumption

USER_DEFINED_CONTENT **SATELLITE_CONSUMED_POWER**	
Type	REAL
Dimension	1
Unit	[W]
Description	Power consumed by the satellite

5.6.2. Battery voltage

USER_DEFINED_CONTENT **BATTERY_VOLTAGE**	
Type	REAL
Dimension	1
Unit	[V]
Description	Voltage of the satellite’s battery

5.6.3. Battery current

USER_DEFINED_CONTENT **BATTERY_CURRENT**	
Type	REAL
Dimension	1
Unit	[A]
Description	Electrical current in the satellite’s battery

5.6.4. Solar array current

USER_DEFINED_CONTENT SOLAR_ARRAY_CURRENT	
Type	REAL
Dimension	1
Unit	[A]
Description	Electrical current in a solar array

5.6.5. Battery depth of discharge

USER_DEFINED_CONTENT BATTERY_DOD	
Type	REAL
Dimension	1
Unit	[n/a]
Description	Depth of discharge for the battery

5.7. RADIO DATA

5.7.1. RF link to ground station 1

USER_DEFINED_CONTENT RF_LINK_GROUND_STATION_1	
Type	`INTEGER`
Dimension	`1`
Unit	`[n/a]`
Description	Status of RF link with ground station 1 (0: down, 1: established)

5.7.2. RF link to ground station 2, 3, 4…

Parameters **RF_LINK_GROUND_STATION_2**, **RF_LINK_GROUND_STATION_3** and **RF_LINK_GROUND_STATION_4** have the same properties as **RF_LINK_GROUND_STATION_1**.

5.7.3. Line of sight to ground station 1 in the satellite reference frame

USER_DEFINED_CONTENT LINE_OF_SIGHT_GROUND_STATION_1-SATELLITE_FRAME	
Type	`REAL`
Dimension	`2`
Unit	`[deg]`
Description	Ground station azimuth and elevation in the on-board antenna reference frame

5.7.4. LoS to ground station 2, 3, 4… in the satellite reference frame

Parameters **LINE_OF_SIGHT_GROUND_STATION_2-SATELLITE_FRAME**, **LINE_OF_SIGHT_GROUND_STATION_3-SATELLITE_FRAME** and **LINE_OF_SIGHT_GROUND_STATION_4-SATELLITE_FRAME** have the same properties as **LINE_OF_SIGHT_GROUND_STATION_1-SATELLITE_FRAME**.

5.7.5. LoS from ground station 1 in the station reference frame

USER_DEFINED_CONTENT LINE_OF_SIGHT_GROUND_STATION_1-STATION_FRAME	
Type	REAL
Dimension	2
Unit	[deg]
Description	Satellite azimuth and elevation in the ground station antenna reference frame

5.7.6. LoS from ground station 2, 3, 4… in the station reference frame

Parameters **LINE_OF_SIGHT_GROUND_STATION_2-STATION_FRAME**, **LINE_OF_SIGHT_GROUND_STATION_3-STATION_FRAME** and **LINE_OF_SIGHT_GROUND_STATION_4-STATION_FRAME** have the same properties as **LINE_OF_SIGHT_GROUND_STATION_1-STATION_FRAME.**

5.7.7. Distance to ground station 1

USER_DEFINED_CONTENT DISTANCE_GROUND_STATION_1	
Type	REAL
Dimension	1
Unit	[km]
Description	Distance between the satellite and ground station 1

5.7.8. Distance to ground station 2, 3, 4…

Parameters **DISTANCE_GROUND_STATION_2**, **DISTANCE_GROUND_STATION_3** and **DISTANCE_GROUND_STATION_4** have the same properties as **DISTANCE_GROUND_STATION_1**.

5.7.9. RF TM budget link margins for ground station 1

USER_DEFINED_CONTENT TM_RF_MARGIN_GROUND_STATION_1	
Type	`REAL`
Dimension	`4`
Unit	`[db]`
Description	RF TM budget link for: • "Design" margin case (obtained from RF TM Budget Link on design values) • "CCSDS" margin case (obtained from RF Budget Link Mean & Variance values of margin) • "Worst RSS" margin case (obtained from RF TM Budget Link Design & Worst cases values of margin) • "Worst" margin case (obtained from RF TM Budget Link Worst case margin)

5.7.10. RF TM budget link margins for ground station 2, 3, 4…

Parameters **TM_RF_MARGIN_GROUND_STATION_2**, **TM_RF_MARGIN_GROUND_STATION_3** and **M_RF_MARGIN_GROUND_STATION_4** have the same properties as **TM_RF_MARGIN_GROUND_STATION_1**.

5.8. SYNTHESIS

Category	Quantity	File	Type	Dim.	Unit
Satellite data	SATELLITE_COORDINATE_SYSTEM	MPM	STRING	3	[n/a]
	CENTER_OF_GRAVITY	MPM	REAL	3	[m]
	CENTER_OF_ROTATION_SA_1	MPM	REAL	3	[m]
	AXIS_OF_ROTATION_SA_1	MPM	REAL	3	[n/a]
	REFERENCE_POSITION_SA_1	MPM	REAL	3	[n/a]
Mission data	SIMULATION_TIME	MEM	REAL	1	[s]
	SATELLITE_MODES	MEM	STRING	1	[n/a]
Geometrical data	POSITION_VELOCITY	OEM	REAL	6	[km] [km/s]
	GEOGRAPHICAL_COORDINATES	MEM	REAL	2	[deg]
	SATELLITE_ALTITUDE	MEM	REAL	1	[km]
	BETA_ANGLE	MEM	REAL	1	[deg]
	SUN_DIRECTION-SATELLITE_FRAME	MEM	REAL	3	[n/a]
	SUN_DIRECTION-ORBITAL_FRAME	MEM	REAL	3	[n/a]
	MOON_DIRECTION-SATELLITE_FRAME	MEM	REAL	3	[n/a]
	EARTH_DIRECTION-SATELLITE_FRAME	MEM	REAL	3	[n/a]
	SATELLITE_ECLIPSE	MEM	REAL	1	[%]
	SUN_VISIBILITY	MEM	REAL	1	[%]
	SATELLITE_LOCAL_TIME	MEM	REAL	1	[h]
	MEAN_ARGUMENT_OF_LATITUDE	MEM	REAL	1	[deg]
	SUN_ANGLE_SA_1	MEM	REAL	1	[deg]
	EARTH_ANGLE_SA_1	MEM	REAL	1	[deg]
	ROTATION_ANGLE_SA_1	MEM	REAL	1	[deg]

	ORBIT_NUMBER		MEM	INTEGER	1	[n/a]
	GEOMETRICAL_VISIBILITY_GROUND_STATION_1		MEM	INTEGER	1	[n/a]
	MESH_TYPE		MEM	INTEGER	1	[n/a]
	HOT_SPOT		MEM	REAL	2	[deg]
	SUN_GLINT		MEM	REAL	2	[deg]
AOCS data	QUATERNION	QC, Q1, Q2, Q3	AEM	REAL	4	[n/a]
	EULER_ANGLE	X_ANGLE, Y_ANGLE, Z_ANGLE	AEM	REAL	3	[deg]
	SATELLITE_ATTITUDE_MODE		MEM	INTEGER	1	[n/a]
	ATTITUDE_LAW		MEM	INTEGER	1	[n/a]
	SATELLITE_ANGULAR_VELOCITY		MEM	REAL	3	[rad/s]
	SATELLITE_ANGULAR_ACCELERATION		MEM	REAL	3	[rad/s**2]
	WHEELS_TORQUES		MEM	REAL	3	[N*m]
Thermal data	SOLAR_FLUX		MEM	REAL	6	[W/m**2]
	ALBEDO_FLUX		MEM	REAL	6	[W/m**2]
	EARTH_FLUX		MEM	REAL	6	[W/m**2]
Electrical data	SATELLITE_CONSUMED_POWER		MEM	REAL	1	[W]
	BATTERY_VOLTAGE		MEM	REAL	1	[V]
	BATTERY_CURRENT		MEM	REAL	1	[A]
	SOLAR_ARRAY_CURRENT		MEM	REAL	1	[A]
	BATTERY_DOD		MEM	REAL	1	[n/a]
Radio data	RF_LINK_GROUND_STATION_1		MEM	INTEGER	1	[n/a]
	LINE_OF_SIGHT_GROUND_STATION_1-SATELLITE_FRAME		MEM	REAL	2	[deg]
	LINE_OF_SIGHT_GROUND_STATION_1-STATION_FRAME		MEM	REAL	2	[deg]
	DISTANCE_GROUND_STATION_1		MEM	REAL	1	[km]
	TM_RF_MARGIN_GROUND_STATION_1		MEM	REAL	4	[db]