Multi-Mission Administrative Message User Guide

Doc.No. : EUM/OPS/TEN/07/1573
Issue : v6B
Date : 7 October 2013

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Document Change Record

Issue / Revision	Date	DCN. No	Changed Pages / Paragraphs
v1	18 June 2008		First draft for consideration by OPS STG WG
v2A	24 June 2010		Additional events included: HRPT-on/off, day-night, obt-utc-wrap. Also, BZIP2 defined as compression algorithm for MMAM.
v3A	11 Aug. 2010		HRPT and day/night events structure re-worked. Second OBTUTC correlation dataset introduced for usage just after wrap-around.
v3B	6 April 2011		Section 3.26 OBTUTC correlation formula and its application simplified. Section 5.1.1.1 ephemeris interpolation in presence of manoeuvres re-worked. Section 3.19, “day-night-transitions” renamed to “subsatellite-daytimes”. Section 3.21, “HRPT-on-off” renamed to “HRPT-on-times”. Section 3.27, XML structure for instrument attitude bias modified. Section 3 and 8, minor changes to XML element and attribute names and multiplicity to improve consistency.
v3C	9 June 2011		Datatypes for elements and attributes based on W3C XML Schema Definition Language introduced, see section 3.1 and section 3 in general. Attribute format-version removed in element message in section 3.4. Redefined the permitted values for the attribute subject of an announcement and added an attribute impact to announcement, see in section 3.6. Introduced a last-updated-on attribute in the message/status element, see section 3.7 MMAM forward compatibility requirements added in section 4. List of permitted Metop subsystem and components names included in section 7.1 and referenced in sections 3.6, 3.8 and 3.9. This v ersion of the document is the Release Candidate 1 of the MMAM format version 1.0. Once internally reviewed and published, it will be distribution to the Station Manufacturers and key Users for review. Any corrections based on the comments from Station Manufacturers and key Users will be reflected in the final release of MMAM format version 1.0.
V3D	13 July 2011		In 5.2 indication added about when users must start using a TLE extracted from MMAM.

Issue / Revision	***Date***	***DCN. No***	***Changed Pages / Paragraphs***
V3E	14 Dec. 2011		In 5.2 TLE usage across manoeuvres added for issuing and non-issuing Metop flight models
V3F	29 June 2012		Following EUM/EPS/AR/14164: ANX OSV block: added, including OSV epoch. OSV is in EF frame, Cartesian format, 6 decimal digits for position, 6 decimal digits for velocity). ANX immediately preceding the MMAM validity start time.is included in the ANX OSV block.
V3G - I	05 July 2012		ANX OSV block: added, including OSV epoch. OSV is in TOD frame, Keplerian format, 6 decimal digits for position, 6 decimal digits for velocity). OSV at ANX have epoch with numerical resolution set to integer seconds (milliseconds set to zero) The numerical example of state vectors at ANX for Metop-A is limited to 2 out of 18 vectors. In the next version of the document.the example shall be expanded to all ANX vectors and to Metop-B element name "raan" changed in "right-ascension" for clarity
V3J - L	22 Aug. 2012		EUM/EPS/AR/14164: Orbital state vector for issuing satellite is now additionally published at each ANX within validity range plus the ANX preceding the validity start Changes in section 3.10, 3.12 Specific statement on numerical round-up of ephemeris values Examples inserted of MMAM for Metop-A without and with manoeuvre with new structure (OSV at ANX). Example for Metop-B removed. Change in signature table acc. to OPS DMP and reinsertion of distribution list.
4	29 Nov 2012		Chapter 5 re-worked to include clarifications requested by external users (software developers). The most important changes are in Equation 4: Satellite Frame (definition the N vector), Equation 5 argument of latitude Determination (inclination formula).
5	03 Dec 2012		Problem with DM Tool. Version regenerated, no change from version 4.
5.1	11 Dec 2012		Interpolation values now result from classical formulation. Results for geolocation are however very close to previous results All tables of numerical examples changed accordingly.
6	11 Dec 2012		Version 6 unintentionally generated (user error) in the new DM Tool
6A	01 Oct 2013		Document signature table updated to reflect changes

Issue / Revision	***Date***	***DCN. No***	***Changed Pages / Paragraphs***
			in functions and personnel. Chapter 1.1. MMAM distribution option “via e-mail” deleted from list.
6B	07 Oct 2013		SOG chairman approval added to document signature table

Table of Contents

1 Introduction 9
1.1 Purpose and Scope 9
1.2 Document Structure 9
1.3 Applicable Documents 9
1.4 Reference Documents 9
2 Multi-Mission Administrative Message Structure and Logic 10
2.1 Multi-Mission and Multi Satellite 10
2.2 Announcement Logic 11
3 Multi-Mission Administrative Message Definition 14
3.1 General 14
3.2 Root Element 15
3.3 Element issuer-contact-information 15
3.4 Element message 16
3.5 Element message/announcements 17
3.6 Element message/announcements/announcement 17
3.7 Element message/status 19
3.8 Element message/status/subsystem 20
3.9 Element message/status/subsystem/component 20
3.10 Element message/navigation 21
3.11 Element message/navigation/two-line-elements 22
3.12 Element message/navigation/statevectors-at-anx 23
3.13 Element message/navigation/statevectors-at-anx/statevector-at-anx 24
3.14 Element message/navigation/orbit-ephemeris 25
3.15 Element message/navigation/orbit-ephemeris/statevector 26
3.16 Element message/navigation/events 26
3.17 Element message/navigation/events/ascending-node-crossings 27
3.18 Element message/navigation/events/ascending-node-crossings/ascending-node-crossing 28
3.19 Element message/navigation/events/subsatellite-daytimes 28
3.20 Element message/navigation/events/subsatellite-daytime 28
3.21 Element message/navigation/events/hrpt-on-times 29
3.22 Element message/navigation/events/hrpt-on-time 29
3.23 Element message/navigation/yaw-steering-coefficients 30
3.24 Element message/navigation/attitude-bias 30
3.25 Element message/processing 31
3.26 Element message/processing/obt-utc-correlation 31
3.27 Element message/processing/instrument 32
3.28 Element message/processing/instrument/attitude-bias 33
4 MMAM and Version Compatibility 34
5 Multi-Mission Administrative Message Application Guidelines 35
5.1 Orbit Ephemeris and Geolocation 35
5.1.1 Interpolate the original ephemeris table 36
5.1.2 Ephemeris Conversion from Earth-fixed to pseudo-inertial frame 40
5.1.3 Determine Satellite attitude 40
5.1.4 Determine the argument of latitude 41
5.1.5 Apply the yaw-steering law 43
5.1.6 Line-of-sight determination in the satellite frame 45
5.1.7 Determination of the intersection point between line-of-sight and earth ellipsoid 46
5.2 Two Line Elements (TLE) 50
5.2.1 TLE for the issuing Metop 50
5.2.2 TLE for the non-issuing Metop(s) 51
5.3 OBT-UTC Correlation 51
6 Multi-Mission Administrative Message in Metop HRPT Data Stream 54
7 Metop Specific MMAM values 55
7.1 Metop Subsystems or Components 55
8 Multi-Mission Adminitrative Message Example for Metop 57

8.1 Example Message 1 (no manoeuvre) 57
8.2 Example Message 2 (presence of a double manoeuvre) 66

1 INTRODUCTION

1.1 Purpose and Scope

This document defines the content and lay-out of the Multi-Mission Administrative Message containing operational information relevant to users of the Metop HRPT direct read out service. The document also provides guidelines on the application of the content of the Multi-Mission Administrative Message.

The Multi-Mission Administrative Message is formatted as an XML document and transmitted to Users via the HRPT data stream. The messages will also be made available via EUMETSAT's User Notification System (UNS) providing access via the EUMETSAT web site.

1.2 Document Structure

Section 2 provides an overview of the Multi-Mission Administrative Message (MMAM) structure and logic.

Section 3 provides a detailed definition of the MMAM XML lay-out.

Section 4 discusses the MMAM and forward compatibility

Section 5 provides guidelines for the interpretation and application of the MMAM parameters in support of navigation and instrument data processing.

Section 6 describes how the MMAM is imbedded in the Metop HRPT Data Stream.

Section 7 lists the Metop specific value definitions

Section 8 provides Multi-Mission Administrative Message examples

1.3 Applicable Documents

N/A

1.4 Reference Documents

RD. 1 CCSDS Orbit Data Messages CCSDS 502.0-B-1 Blue Book, September 2004

RD. 2 Wertz, J. R., Mission Geometry; Orbit and Constellation Design and Management, Kluwer Academic Publishers Dordrecht, The Netherlands, 2001, Chapter 1, 14.

RD. 3 Admin Message Tech Note EPS/GGS/TN/980021 version 2, 03-OCT-2003

RD.4 OBT-to-UTC Correlation EPS.SYS.TEN.990036: DJD Appendix A 7-3:, Issue 1. 4, dated 8 Sep 2004

***RD.*5** XML Schema Part 2: Datatypes Second Edition, W3C Recommendation 28 October 2004, http://www.w3.org/

2 MULTI-MISSION ADMINISTRATIVE MESSAGE STRUCTURE AND LOGIC

2.1 Multi-Mission and Multi Satellite

The Multi-Mission Administrative Message (MMAM) is intended to supersede the current Administrative Message (see RD. 3). The MMAM is structured to contain administrative information for multiple satellites from multiple missions or programmes. An overview of the structure is given in Figure 1. A wide range of information is contained for the satellite transmitting the MMAM via its HRPT direct read out signal. For the other satellites a smaller set of data, typically just the basic navigation data required for pass scheduling and antenna pointing, is contained in the MMAM.

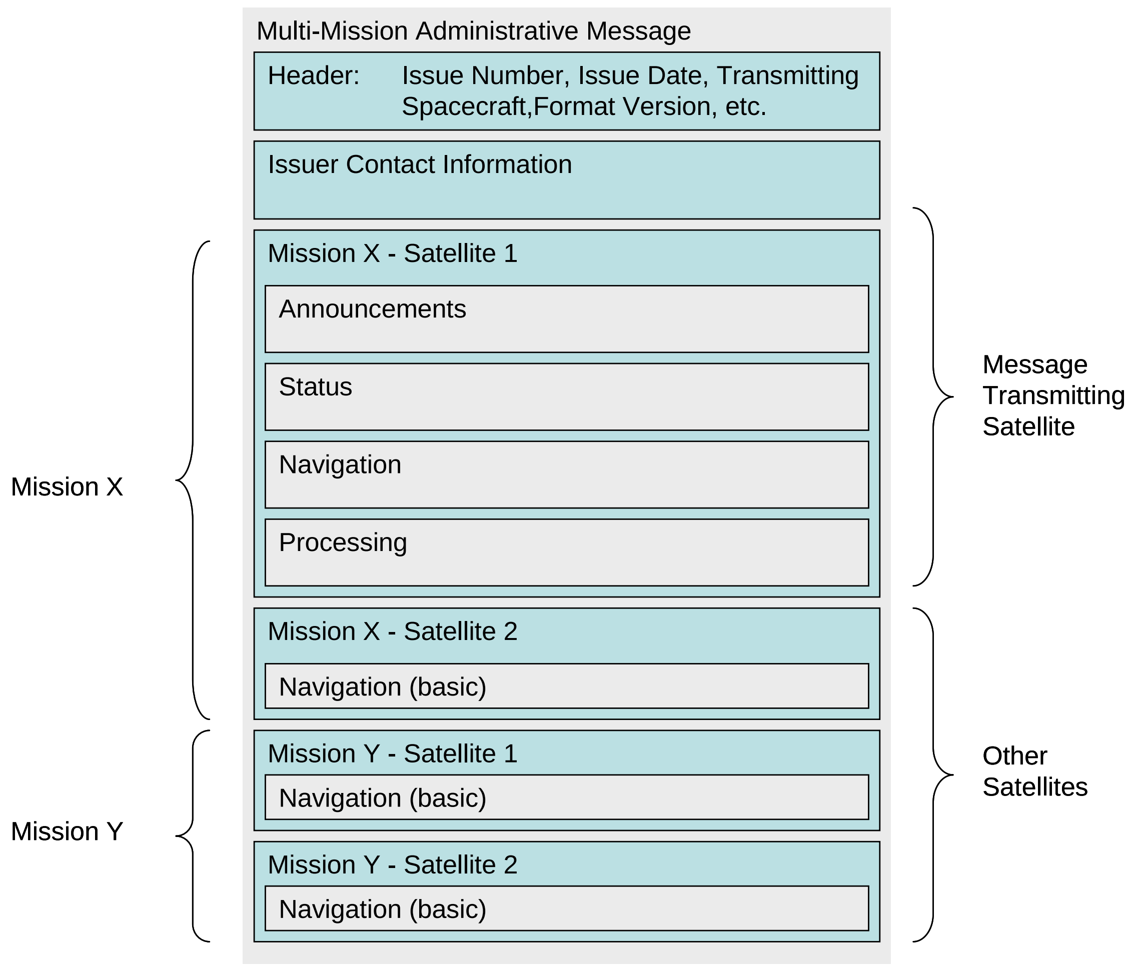

Figure 1. Structure of the Multi-Mission Administrative Message

2.2 Announcement Logic

Individual announcements are uniquely identified, for each satellite, by an integer announcement sequence number that is incremented by one for each new announcement issued.

Once issued as part of an MMAM, an announcement is immutable, i.e. it cannot be changed. An update or correction to an announcement can be made by issuing a new announcement that explicitly references the original announcement using the *update-to-sequence-number* attribute. In this way, an announcement with the status *scheduled*, can be updated to announce that the activity has been *completed*.

A particular instance of the full MMAM will contain all individual announcements that have not yet expired. An announcement that relates to a future event or activity will expire 48 hours after the announced end of that event or activity unless an update to the announcement has been issued, in which case the announcement will expire 48 hours after its time of issue. All other announcements will expire 48 hours after the time of issue. The 48 hours period will ensure that all local HRPT Reception Stations will have sufficient time to acquire each individual announcement.

An illustration of an operational timeline and the associated announcements is shown in Figure 2. The figure also shows the time of issue of two the Multi-Mission Administrative Messages, A and B. The announcements contained in the two MMAMs are explained in Table 1. The *status* referred to in the table is the XML attribute defined in section 3.6 for an announcement. Its possible values are *scheduled, cancelled, ongoing* and *completed.*

The section 8 of this document contains two full XML files corresponding to the Multi-Mission Administrative Messages A and B illustrated in Figure 2 and Table 1.

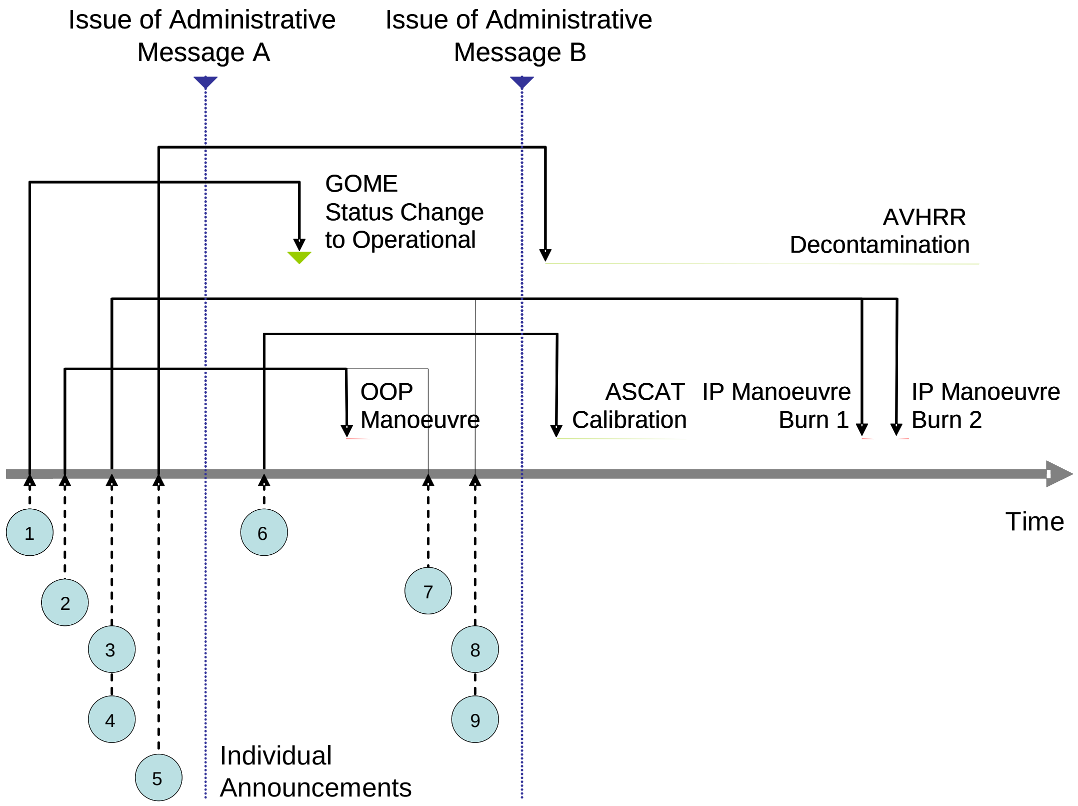

Figure 2. Example of individual announcements within a Multi-Mission Administrative Message announcing satellite events and activities

Ann. Num.	Announcement	Announcements included in Administrative Message A	Announcements included in Administrative Message B
1	GOME Status Change To Operational	Included, with status *scheduled*	Excluded, as the announcement has expired GOME status now set to *operational.*
2	OOP Manoeuvre	Included, with status *scheduled*	Excluded, as the announcement has now been updated by announcement 7.
3	IP Manoeuvre	Included, with status *scheduled*	Excluded, as the announcement has now been updated by announcement 8.
4	IP Manoeuvre	Included, with status *scheduled*	Excluded, as the announcement has now been updated by announcement 9.
5	AVHRR Decontamination	Included, with status *scheduled*	Included as activity is still in the future. Status *scheduled.*

Ann. Num.	Announcement	Announcements included in Administrative Message A	Announcements included in Administrative Message B
6	ASCAT Calibration	Not included, announcement not yet issued	Included, with status *scheduled.*
7	OOP Manoeuvre	Not included, announcement not yet issued	Included, with status *completed.* Updates announcement 2
8	IP Manoeuvre	Not included, announcement not yet issued	Included, with status *scheduled.* Updates announcement 3.
9	IP Manoeuvre	Not included, announcement not yet issued	Included, with status *scheduled.* Updates manoeuvre announcement 4.

Table 1. Example of individual announcements within two Multi-Mission Administrative Message announcing satellite events and activities.

3 MULTI-MISSION ADMINISTRATIVE MESSAGE DEFINITION

3.1 General

The Multi-Mission Administrative Messages shall be a well-formed XML document.

The datatypes and their definitions used within the MMAM XML document are taken from W3C XML Schema Language (RD.5). The subset of datatypes used in the MMAM is:

Datatype According to RD.5	Short Description, See RD.5 for full definition	Example
int	Integer number in the range $-2^{31} \ldots 2^{31}-1$	-1, 0, 126789675, +100000
long	Integer number in the range $-2^{63} \ldots 2^{63}-1$	-1, 0, 12678967543233, +100000
double	Equivalent to IEEE double-precision 64-bit floating point	-1, 0, 1.234, -3.45E4
dateTime	Without the use of the optional time zone offset, meaning that the time is in UTC.	2011-01-05T15:30:00 2011-01-05T15:30:00.123 2011-01-05T15:30:00.123456
string	A string of characters	The manoeuvres will be executed on 2011-01-05T15:30:00 and 2011-01-05T16:30:00
token	Represents a string not containing the carriage return, line feed nor tab characters, that have no leading or trailing spaces and that have no internal sequences of two or more spaces.	Metop-A

The XML elements and attributes are defined in the tables in the following sections using the following definitions of multiplicity:

The multiplicity (Mult.) of an XML attribute indicates:
- 0,1 Attribute is optional;
- 1 Attribute is mandatory.

The multiplicity (Mult.) of an XML element indicates:
- 0 No instances permitted.
- 0,1 Zero or one element instance required;
- 1 One element instance required;
- 0-n Any number of element instances permitted;
- 1-n At least one element instance required;
- m-n At least m element instances required.

3.2 Root Element

Element Name:		multi-mission-administrative-message	
Parent Element:		None, is root element.	
Attributes			
Name	Mult.	Type	Description
issue-number	1	int	Issue number of this MMAM.
issued-on	1	dateTime	Time of issue of this MMAM.
issued-by	1	token	Issuing organisation.
transmitted-via	1	token	Satellite transmitting this MMAM via HRPT. The permitted values are: Metop-A Metop-B Metop-C
format-version	1	token	MMAM format version in the style "major-version.minor-version". The initial version will be 1.0 and subsequent releases will be 1.1, 1.2... Version updates will preserve forward compatibility as described in section 4.
Child Elements			
Name	Mult.	Type	Description
issuer-contact-information	1	See section 3.3.	Element containing contact information of the organisation that issued this Multi-Mission Administrative Message.
message	1 - n	See section 3.4.	One element for each satellite covered by this Multi-Mission Administrative Message. As a minimum one message element for the satellite defined by the attribute "transmitted-via" is provided. Additional message elements may be provided for other satellites depending on the satellite status and navigation data availability.

3.3 Element issuer-contact-information

Element Name:		issuer-contact-information	
Parent Element:		multi-mission-administrative-message	
Attributes			
Name	Mult.	Type	Description
-	-	-	No attributes defined.
Child Elements			
Name	Mult.	Type	Description

name	1-n	string	Name of issuing organisation No attributes or child elements defined.
address	1-n	string	Address of issuing organisation. No attributes or child elements defined.
telephone	1	string	Telephone number of issuing organisations user service. No attributes or child elements defined.
e-mail	1	string	E-mail address of issuing organisations user service. No attributes or child elements defined.
internet	1	string	Main web address of issuing organisation. No attributes or child elements defined.

3.4 Element message

Element Name:	message		
Parent Element:	multi-mission-administrative-message		
Attributes			
Name	Mult.	Type	Description
satellite	1	token	Common name of satellite. The list of satellites covered by the Multi-Mission Administrative Message may be changed by EUMETSAT from time to time depending on the satellite status and navigation data availability During operations conducted from the Back-up Control Centre the NOAA TLE vectors shall be omitted from the MMAM. The intended values include: NOAA-15 NOAA-16 NOAA-17 NOAA-18 NOAA-19 Metop-A Metop-B Metop-C NPP
mission	1	token	Satellite programme or mission. The list of programmes and missions covered by the Multi-Mission Administrative Message may be changed by EUMETSAT from time to time depending on the satellite status and navigation data availability. The intended values include: POES EPS NPP

			JPSS
satellite-number	1	int	Satellite Number. Example value for Metop-A: “29499”
international-spacecraft-designator	1	token	International Spacecraft Designator. Example value for Metop-A: “2006-44A”
Child Elements			
Name	Mult.	Type	Description
announcements	1 (*)	See section 3.5	List of current announcements for this “satellite”.
status	1 (*)	See section 3.7	Satellite, subsystem and component status information.
navigation	1	See section 3.10	Orbit and attitude information in support of pass satellite pass scheduling, HRPT antenna pointing and product geolocation.
processing	1 (*)	See section 3.25	Information supporting time conversion and product processing.

(*) Multiplicity indicated is for *transmitting* satellite only. For all other satellites the multiplicity is 0.

3.5 Element message/announcements

Element Name:	announcements		
Parent Element:	multi-mission-administrative-message/message		
Attributes			
Name	Mult.	Type	Description
-	-	-	No attributes defined.
Child Elements			
Name	Mult.	Type	Description
announcement	0-n	See section 3.6	Current announcements for this satellite. Ordered according to announcement sequence-number.

3.6 Element message/announcements/announcement

Element Name:	announcement

Parent Element:		multi-mission-administrative-message/message/announcements	
Attributes			
Name	Mult.	Type	Description
sequence-number	1	int	Integer announcement number, uniquely identifying this announcement for this satellite. The number is incremented by one for each new announcement.
update-to-sequence-number	0,1	int	Integer reference to the announcement number that this announcement is an update to.
issued-on	1	dateTime	Time of issue of this announcement.
subject	1	token	Announcement subject. The permitted values are: general-announcement in-plane-manoeuvre out-of-plane-manoeuvre instrument-decontamination instrument-calibration instrument-maintenance data-denial anomaly
subsystem	0,1	token	If applicable, subsystem or instrument addressed in this announcement. The permitted values are spacecraft specific and are defined in section 7.1.
component	0,1	token	If applicable, component of subsystem or instrument addressed in this announcement. This attribute is only permitted if the attribute “subsystem” is set. The permitted values are spacecraft and subsystem specific and are defined in section 7.1.
impact	0,1	token	If applicable, impact of announced activity/event on subsystem/instrument. The permitted values are: — Description: data-degraded — Data in full or in part degraded data-unavailable — Data in full or part unavailable
start	0,1	dateTime	If applicable, time of event or change of status. If applicable, start time of activity addressed in this announcement.
end	0,1	dateTime	If applicable, end time of activity addressed in this announcement.

status	0,1	token	Optional status of subject activity or event. The permitted values are: scheduled ongoing completed cancelled
Child Elements			
Name	Mult.	Type	Description
text	0-1	string	Optional free text providing details on the event or activity addressed in this announcement. No attributes or child elements defined.

3.7 Element message/status

Element Name:	status		
Parent Element:	multi-mission-administrative-message/message		
Attributes			
Name	Mult.	Type	Description
satellite-status	1	token	General status of this satellite. The permitted values are: commissioning operational-primary operational-secondary
last-updated-on	1	dateTime	Indicates the date and time when an update to this status element or any of its child elements was last made.
Child Elements			
Name	Mult.	Type	Description
text	0-1	string	Optional free text providing details on the status of this satellite No attributes or child elements defined.
subsystem	0-n	See section 3.8	Status information of each subsystem and instrument.

3.8 Element message/status/subsystem

Element Name:	subsystem		
Parent Element:	multi-mission-administrative-message/message/status		
Attributes			
Name	Mult.	Type	Description
name	1	token	Subsystem or instrument addressed in this status. The permitted values are spacecraft specific and are defined in section 7.1.
status	1	token	Current status of subsystem or instrument. Permitted values are: / Description: operational: Operational and nominally switched on operational-with-limitations: Operational with limitations or degraded performance and nominally switched on not-operational: Failed and/or nominally switched off
Child Elements			
Name	Mult.	Type	Description
text	0-1	string	Optional free text providing details on the status of this subsystem. No attributes or child elements defined.
component	0-n	See section 3.9	If applicable, status information for each component of this subsystem. A component not explicitly contained in this list can be assumed to have the status operational.

3.9 Element message/status/subsystem/component

Element Name:	component
Parent Element	multi-mission-administrative-message/message/status/subsystem

Attributes			
Name	Mult.	Type	Description
name	1	token	Component of subsystem or instrument addressed in this status. The permitted values are spacecraft and subsystem specific and are defined in section 7.1.
status	1	token	Current status of component Permitted Values are: / Description: operational / Operational operational-with-limitations / Operational with limitations or degraded performance not-operational / Failed and/or nominally switched off
Child Elements			
Name	Mult.	Type	Description
text	0-1	string	Optional free text providing details on the status of this component. No attributes or child elements defined.

3.10 Element message/navigation

Note: in the following the term ANX indicates "ascending node crossing": the point of the satellite orbit where the sub-satellite point crosses the Earth equator going from the south pole to the north pole.

Element Name:	navigation		
Parent Element:	multi-mission-administrative-message/message		
Attributes			
Name	Mult.	Type	Description
-	-	-	No attributes defined.
Child Elements			
Name	Mult.	Type	Description

two-line-elements	1-n	See section 3.11	One or, in case of manoeuvres, multiple Two Line Elements sets for this satellite. Elements are chronologically ordered. Two Line Elements are intended for: • Prediction of satellite passes for a given reception station for period of several weeks; • Antenna pointing during HRPT acquisition; • Medium precision instrument product navigation.
statevectors-at-anx	1	See section 3.13	State vector at ascending node Elements are chronologically ordered. One state vector-at-ANX per ANX. State vector at last ANX before MMAM validity start time is included.
orbit-ephemeris	1-n (*)	See section 3.14	One or, in case of manoeuvres, multiple Orbit Ephemeris data sets for this satellite, defined according to the guidelines of CCSDS [ref.1]. Elements are chronologically ordered. The Orbit Ephemeris is intended for high precision instrument product navigation.
events	1 (*)	See section 3.16	Events element.
yaw-steering-coefficients	1 (*)	See section 3.23	Yaw-steering amplitude coefficients
attitude-bias	1 (*)	See section 3.24	Element containing the yaw, roll and pitch bias values.

(*) Multiplicity indicated is for *transmitting* satellite only. For all other satellites the multiplicity is 0.

3.11 Element message/navigation/two-line-elements

Element Name:	two-line-elements
Parent Element:	multi-mission-administrative-message/message/navigation
Attributes	

Name	Mult.	Type	Description
valid-from	0,1	dateTime	If this two-line-elements set is only valid after the execution of a satellite manoeuvre, the valid-from time indicates the start of validity.
valid-until	0,1	dateTime	If this two-line-elements set is only valid until the execution of a satellite manoeuvre, the valid-until time indicates the end of validity.
Child Elements			
Name	Mult.	Type	Description
line-1	1	string	Line 1 of the Two Line Element set ASCII string. No attributes or child elements defined.
line-2	1	string	Line 2 of the Two Line Element set ASCII string. No attributes or child elements defined.

3.12 Element message/navigation/statevectors-at-anx

Element Name:	statevectors-at-anx		
Parent Element:	multi-mission-administrative-message/message/navigation		
Attributes			
Name	Mult.	Type	Description
valid-from	1	dateTime	Epoch of first child element
valid-until	1	dateTime	Epoch of last child element
reference-frame-keplerian	1	token	reference frame TOD
reference-frame-cartesian	1	token	reference frame Earth fixed
Child Elements			
Name	Mult.	Type	Description
statevector-at-anx	1-n	See section 3.13	State vector at ANX to be used to generate L0 header

3.13 Element message/navigation/statevectors-at-anx/statevector-at-anx

Element Name:		statevector-at-anx	
Parent Element:		multi-mission-administrative-message/message/navigation/state-vectors-at-anx	
Attributes			
Name	Mult.	Type	Description
epoch	1	dateTime	Epoch of this statevector at ANX, the numerical resolution is integer seconds (milliseconds set to zero)
orbit-number	1	integer	Orbit number
Child Elements			
Name	Mult.	Type	Description
semi-major-axis	1	double	Semi-major Axis in TOD frame in units of km
eccentricity	1	double	Eccentricity in TOD frame (dimensionless)
inclination	1	double	Inclination in TOD frame in units of degrees
perigee	1	double	Argument of Perigee in TOD frame in units of degrees
right-ascension	1	double	Right Ascension of Ascending Node in TOD frame in units of degrees
mean-anomaly	1	double	Mean Anomaly in TOD frame in units of degrees
x-pos	1	double	Satellite x-position in EF frame at epoch in units of km. No attributes or child elements defined.
y-pos	1	double	Satellite y-position in EF frame at epoch in units of km. No attributes or child elements defined.
z-pos	1	double	Satellite z-position in EF frame at epoch in units of km. No attributes or child elements defined.
x-vel	1	double	Satellite x-velocity in EF frame at epoch in units of km/s. No attributes or child elements defined.
y-vel	1	double	Satellite y-velocity in EF frame at epoch in units of km/s. No attributes or child elements defined.
z-vel	1	double	Satellite z-velocity in EF frame at epoch in units of km/s. No attributes or child elements defined.

Note: for the state vectors at ascending node the numerical resolution of the Keplerian representation is 6 decimal digits for semi-major axis and eccentricity, 3 decimal digits for angles; the numerical resolution for the Cartesian position elements is 6 decimal digits, for the velocity elements it is 6 decimal digits.
To achieve the reduced decimal resolution, proper arithmetical rounding has to be applied to the input values (e.g. 125.872500 is rounded up to 125.873, whereas 125.872499 is rounded down to 125.872). The rounding is to be symmetric around 0.

3.14 Element message/navigation/orbit-ephemeris

Element Name:		orbit-ephemeris	
Parent Element:		multi-mission-administrative-message/message/navigation	
Attributes			
Name	Mult.	Type	Description
valid-from	1	dateTime	Start of validity of this orbit-ephemeris.
valid-until	1	dateTime	End of validity of this orbit-ephemeris.
reference-frame	1	token	Name of the reference frame in which the ephemeris data are given. Permitted values: Description Earth-Fixed ITRF2000
interpolation-method	1	token	Recommended interpolation method for this orbit-ephemeris. Permitted values: Lagrange
interpolation-degree	1	int	Recommended interpolation degree for this orbit-ephemeris. Default value: 8
time-step	1	int	Time-step for the ephemeris, in minutes l Default value: 8
Child Elements			
Name	Mult.	Type	Description
statevector	m-n	See section 3.15	State vectors for orbit interpolation, in order of increasing epoch of the statevector. At least m=interpolation-degree statevector instances required.

3.15 Element message/navigation/orbit-ephemeris/statevector

Element Name:		statevector	
Parent Element:		multi-mission-administrative-message/message/navigation/orbit-ephemeris	
Attributes			
Name	Mult.	Type	Description
epoch	1	dateTime	Epoch of this statevector.
Child Elements			
Name	Mult.	Type	Description
x-pos	1	double	Satellite x-position at epoch in units of km. No attributes or child elements defined.
y-pos	1	double	Satellite y-position at epoch in units of km. No attributes or child elements defined.
z-pos	1	double	Satellite z-position at epoch in units of km. No attributes or child elements defined.
x-vel	1	double	Satellite x-velocity at epoch in units of km/s. No attributes or child elements defined.
y-vel	1	double	Satellite y-velocity at epoch in units of km/s. No attributes or child elements defined.
z-vel	1	double	Satellite z-velocity at epoch in units of km/s. No attributes or child elements defined.

Note: for the state vector ephemeris the numerical resolution of the position elements is 2 decimal digits, for the velocity elements it is 4 decimal digits.

3.16 Element message/navigation/events

Events having a start-time and end-time are included if they in part or in full are inside the validity period valid-from to valid-to defined by the events element.

Element Name:	events

Parent Element:	multi-mission-administrative-message/message/navigation		
Attributes			
Name	Mult.	Type	Description
valid-from	1	dateTime	Start of time period covered by these events.
valid-until	1	dateTime	End of time period covered by these events.
Child Elements			
Name	Mult.	Type	Description
ascending-node-crossings	1	See section 3.17	List of ascending node crossings times.
subsatellite-daytimes	1	See section 3.19	List of subsatellite daytimes.
hrpt-on-times	0-1	See section 3.21	List of periods when HRPT is on.

3.17 Element message/navigation/events/ascending-node-crossings

Element Name:	ascending-node-crossings		
Parent Element:	multi-mission-administrative-message/message/navigation/events		
Attributes			
Name	Mult.	Type	Description
-	-	-	No attributes defined
Child Elements			
Name	Mult.	Type	Description
ascending-node-crossing	0-n	See section 0	Element containing parameters for each ascending node crossing in the validity period of this ascending-node-crossings. Elements are chronologically ordered.

Note: the first ANX in this element is the ANX immediately before the MMAM validity start time. This solution allows the proper handling of state vectors inside level 0 data header packets for the data received between MMAM validity start time and first ANX available in the current MMAM.

3.18 Element message/navigation/events/ascending-node-crossings/ascending-node-crossing

Element Name:		ascending-node-crossing	
Parent Element:		multi-mission-administrative-message/message/navigation/ascending-node-crossings	
Attributes			
Name	Mult.	Type	Description
time	1	dateTime	Ascending Node Crossing time.
orbit-number	1	int	Satellite orbit number of the orbit starting at this Ascending Node Crossing.
Child Elements			
Name	Mult.	Type	Description
-	-	-	No elements defined.

3.19 Element message/navigation/events/subsatellite-daytimes

Element Name:		subsatellite-daytimes	
Parent Element:		multi-mission-administrative-message/message/navigation/events	
Attributes			
Name	Mult.	Type	Description
-	-	-	No attributes defined.
Child Elements			
Name	Mult.	Type	Description
subsatellite-daytime	0-n	See section 3.20	Start-time and end-time of sunlight on Earth surface at sub-satellite point. Elements are chronologically ordered.

3.20 Element message/navigation/events/subsatellite-daytime

Element Name:	subsatellite-daytime

Parent Element:		multi-mission-administrative-message/message/navigation/events/ subsatellite-daytimes	
Attributes			
Name	Mult.	Type	Description
start-time	1	dateTime	Time of day start (sunlight start on Earth surface at sub-satellite point).
end-time	1	dateTime	Time of day end (sunlight end on Earth surface at sub-satellite point).
Child Elements			
Name	Mult.	Type	Description
-	-	-	No child elements defined.

3.21 Element message/navigation/events/hrpt-on-times

Element Name:		hrpt-on-times	
Parent Element:		multi-mission-administrative-message/message/navigation/events	
Attributes			
Name	Mult.	Type	Description
-	-	-	No attributes defined.
Child Elements			
Name	Mult.		Description
hrpt-on-time	0-n	See section 3.22	Element containing the start time, the end time and the flight direction. Elements are chronologically ordered.

3.22 Element message/navigation/events/hrpt-on-time

Element Name:		hrpt-on-time	
Parent Element:		multi-mission-administrative-message/message/navigation/events/hrpt-on-times	
Attributes			

Name	Mult.	Type	Description
start-time	1	dateTime	Start time of HRPT on period
end-time	1	dateTime	End time of HRPT on period
flight-direction	1	token	Satellite flight direction during the HRPT on period. The permitted values are: ascending descending
Child Elements			
Name	Mult.	Type	Description
-	-	-	No child elements defined.

3.23 Element message/navigation/yaw-steering-coefficients

Element Name:			yaw-steering coefficients
Parent Element:			multi-mission-administrative-message/message/navigation
Attributes			
Name	Mult.	Type	Description
pitch-cx	1	double	Pitch amplitude used in attitude control loop (radians)
roll-cy	1	double	Roll amplitude used in attitude control loop (radians)
yaw-cz	1	double	Yaw amplitude used in attitude control loop (radians)
Child Elements			
Name	Mult.	Type	Description
-	-	-	No child elements defined.

3.24 Element message/navigation/attitude-bias

Element Name:			attitude-bias
Parent Element:			multi-mission-administrative-message/message/navigation
Attributes			
Name	Mult.	Type	Description

pitch	1	double	Platform pitch angle bias (radians). No attributes or child elements defined.
roll	1	double	Platform roll angle bias (radians). No attributes or child elements defined.
yaw	1	double	Platform yaw angle bias (radians). No attributes or child elements defined.
Child Elements			
Name	Mult.	Type	Description
-	-	-	No child elements defined.

3.25 Element message/processing

Element Name:		processing	
Parent Element:		multi-mission-administrative-message/message	
Attributes			
Name	Mult.	Type	Description
-	-	-	No attributes defined.
Child Elements			
Name	Mult.	Type	Description
obt-utc-correlation	1	See section 3.26	Processing parameters required for OBT to UTC conversion and OBT wrap around.
instrument	0-n	See section 3.27	Instrument specific processing information.

3.26 Element message/processing/obt-utc-correlation

Element Name:	obt-utc-correlation
Parent Element:	multi-mission-administrative-message/message/processing

Attributes			
Name	Mult.	Type	Description
utc-0	1	dateTime	UTC time when the on-board clock counter has the value ccu-obt-0. The value for utc-0 is given to the resolution of 1 millisecond.
ccu-obt-0	1	long	Value of on-board clock counter at time utc-0 The value for ccu-obt-0 is given in counts
clock-step	1	long	Gradient of time correlation function in picoseconds The clock-step is the time in picoseconds for one increment of the on-board clock.
estimated-obt-utc-wrap-around-time	1	dateTime	Estimated UTC time of the occurrence of on-board counter wrap-around. This is provided for information only. The counter has range hex00000000 to hexFFFFFFFF and the nominal counter increment rate is 1 count every 1/256s. Therefore the counter wrap-around is expected every 194.18 days.
Child Elements			
Name	Mult.	Type	Description
-	-	-	No child elements defined.

Some formulas are given in section 5.3 to compute the UTC from the parameters provided in the MAMM and to predict the epoch of the next OBT wrap-around event.

3.27 Element message/processing/instrument

Element Name:	instrument		
Parent Element:	multi-mission-administrative-message/message/processing		
Attributes			
Name	Mult.	Type	Description
name	1	token	Instrument name The permitted values are spacecraft specific and includes the instruments names defined in section 7.1.
Child Elements			

Name	Mult.		Description
attitude-bias	0,1	See section 3.28	Instrument FOV angles relative to spacecraft pitch, roll, yaw axis (radians).

3.28 Element message/processing/instrument/attitude-bias

Element Name:	attitude-bias		
Parent Element:	multi-mission-administrative-message/message/processing/instrument		
Attributes			
Name	Mult.	Type	Description
none	-	-	No attributes defined.
Child Elements			
Name	Mult.	Type	Description
pitch	1	double	Angle between FOV normal and spacecraft pitch axis (radians) No attributes or child elements defined.
roll	1	double	Angle between FOV normal and spacecraft roll axis (radians) No attributes or child elements defined.
yaw	1	double	Angle between FOV normal and spacecraft yaw axis (radians) No attributes or child elements defined.

4 MMAM AND VERSION COMPATIBILITY

It is intended to keep the MMAM definition as stable as possible throughout the lifetime of the Metop-A, -B and –C series of satellites. Nevertheless, it may be required to add new information to the MMAM in response to new User requirements or changed performance of a satellite.

Such updates to the MMAM definition, if required, will be done in a way that will enable existing software that reads the MMAM to remain compatible with the newer versions of the MMAM definition. This is achieved by placing constraints on the way EUMETSAT can introduce new information in the MMAM and by placing requirements on the software reading the MMAM.

EUMETSAT will ensure that new information is added only as new XML attributes to existing MMAM XML elements or as new and differently named XML child elements within existing MMAM XML elements. Thereby all existing MMAM elements and attributes, their meaning, permitted values and logic will be maintained.

The requirement on the MMAM reading software is that it ignores and is not impacted by any new attributes or elements that have been introduced after the MMAM version for which the software was originally designed.

This requirement is best met by basing the MMAM reading software on one of the available standard libraries for reading XML documents and by accessing the MMAM elements and attributes only by name through this library. Specifically, no assumptions may be made about the order of attributes and the order of elements except when defined in this document. Reading the XML data by any means other than an XML parser is strongly discouraged.

In addition, the MMAM reading software should not attempt to validate the MMAM document against the XML schema definition of the MMAM version for which it was originally designed. Such validation would fail with a new version.

With the above constraints and requirements, a well-designed MMAM reader will be compatible with newer versions of the MMAM that may be introduced in the future.

An update of the MMAM definition will be marked by an increment in the minor version part of the format-version attribute of the MMAM XML root element defined in section 3.2. As an example, the format-version may be changed from 1.0 to 1.1 at the time of introducing new information into the MMAM.

5 MULTI-MISSION ADMINISTRATIVE MESSAGE APPLICATION GUIDELINES

This section provides a detailed description on the interpretation and application of the navigation and processing parameters provided in the Multi-Mission Administrative Message.

5.1 Orbit Ephemeris and Geolocation

This section describes how the spacecraft position and velocity can be computed from the orbit ephemeris data provided in the MMAM as well as the process of geolocating an instrument observation based on the computed spacecraft orbit and attitude.

The orbital position calculated following the guidelines here can be expected to be consistent with the spacecraft position determined by EUMETSAT to within 15m. The absolute accuracy of the orbit determined by EUMETSAT is normally in the order of 20m, but may be degraded in periods following spacecraft manoeuvres.

The high-level break-down of the geolocation process is:

- Obtain the satellite position and velocity at the desired time by interpolation.
- Determine the satellite attitude, including yaw-steering effects.
- Compute the instrument swath line-of-sight.
- Find out the latitude, longitude and height of the intersection between the line-of-sight and the Earth, modelled as an ellipsoid.

The process is actually split into several steps:

1) Interpolate the original ephemeris table to obtain position, velocity at the user-desired epoch.
2) Convert the original ephemeris into a pseudo inertial frame by removing the Earth rotational velocity.
3) Determine the MetOp orbit reference frame in the pseudo-inertial frame; Radial aligned with the position vector, Along-Track normal to Radial on the position-velocity plane (orbital plane), Cross-Track normal to the orbital plane.
4) Determine through spherical geometry the argument of latitude (angle between orbital ascending node and satellite position along the orbital plane); this angle is also called PSO (Position sur L' Orbite)
5) Knowing the argument of latitude, compute the attitude laws for the MetOp yaw, pitch and roll steering and apply it to the satellite attitude to align the satellite frame with the normal to the earth ellipsoid and the yaw to the Earth-fixed velocity.

6) Compute the direction of the line-of-sight at epoch in the satellite frame considering rotation between instrument frame and satellite frame and line-of-sight position in the instrument frame. The former (static) component is provided in the MMAM message/processing section (see 3.25).The latter (dynamic) component is derived from the instrument TM, depending on the individual instrument. A typical example is the start of scan epoch in instrument time, initial scan offset and scan rate. Details on how to extract the required line-of-sight into instrument frame are found in the documentation of the single instrument. The OBT (On-Board Time count) to UTC correlation coefficients are provided in the MMAM section message/processing/obt-utc-correlation (see 3.26). No displacement is considered between satellite centre of mass and instrument centre of frame.

7) Compute the latitude and longitude of the intersection of the line-of-sight from satellite to Earth surface (modelled as flat ellipsoid).

5.1.1 Interpolate the original ephemeris table

The orbital ephemeris is provided at a time-step of N minutes (nominally N=8) as specified inside the MMAM, whereas the geolocation must be performed for any possible time. This is obtained by interpolating the original ephemeris table.
The lines with a coloured background are the ones considered in the interpolation example described here-below. This example considers a 8th order interpolation.

	Epoch	Px(km)	Py(km)	Pz(km)	Vx(km/s)	Vy(km/s)	Vz(km/s)
1	2007/07/27 00:00:00.000	-5744.17	4069.27	1508.35	-0.3028	2.2543	-7.1884
2	2007/07/27 00:08:00.000	-5169.27	4607.43	-1984.30	2.6206	-0.0917	-7.0638
3	2007/07/27 00:16:00.000	-3358.59	3957.16	-4998.16	4.7391	-2.5860	-5.2365
4	2007/07/27 00:24:00.000	-828.89	2208.94	-6809.41	5.5629	-4.5588	-2.1570
5	2007/07/27 00:32:00.000	1751.44	-244.85	-6986.36	4.9593	-5.4503	1.4346
6	2007/07/27 00:40:00.000	3738.96	-2800.12	-5487.05	3.1586	-4.9584	4.6857
7	2007/07/27 00:48:00.000	4674.24	-4788.71	-2668.43	0.6790	-3.1279	6.8182
8	2007/07/27 00:56:00.000	4389.53	-5652.45	793.66	-1.8094	-0.3670	7.3097
9	2007/07/27 01:04:00.000	3039.79	-5101.55	4063.65	-3.6639	2.6372	6.0338
10	2007/07/27 01:12:00.000	1045.51	-3208.23	6350.92	-4.4461	5.0987	3.3003
11	2007/07/27 01:20:00.000	-1035.11	-402.36	7103.85	-4.0310	6.3481	-0.2275
12	2007/07/27 01:28:00.000	-2663.08	2629.85	6141.34	-2.6171	6.0107	-3.7007
13	2007/07/27 01:36:00.000	-3458.71	5115.70	3694.83	-0.6521	4.1111	-6.2830
14	2007/07/27 01:44:00.000	-3291.66	6394.60	354.60	1.2981	1.0855	-7.3469
15	2007/07/27 01:52:00.000	-2299.78	6097.31	-3071.58	2.7094	-2.3140	-6.6346
16	2007/07/27 02:00:00.000	-831.84	4253.07	-5757.21	3.2475	-5.2181	-4.3268

Table 2: Example of Earth-Fixed Ephemeris in MMAM Navigation Section. The square bracket shows the elements needed to interpolate for a time within the epochs corresponding to the lines with coloured background.

Any ephemeris set contains four state vectors before the validity start time and four state vectors after the validity end time to allow the interpolation for instants close to the start and end of the ephemeris validity.

It should be noted that interpolating ephemeris outside its validity time may lead to incorrect results.

The Lagrange interpolator considers 8 points $P_1(t_1,k_1)$ to $P_8(t_8,k_8)$, where k can be any one of the P_x, P_y, P_z ,V_x ,V_y,V_z elements and builds the interpolating polynomial:

$$P(t,k) = \frac{(t-t_2)(t-t_3)...(t-t_8)}{(t_1-t_2)(t_1-t_3)...(t_1-t_8)}k_1 + \frac{(t-t_1)(t-t_3)...(t-t_8)}{(t_2-t_1)(t_2-t_3)...(t_2-t_8)}k_2 + ... + \frac{(t-t_1)(t-t_2)...(t-t_7)}{(t_8-t_1)(t_8-t_2)...(t_8-t_7)}k_8$$

Equation 1 : Generic interpolating polynomial

The interpolator outputs the results given in Table 3.
For sake of brevity only the first lines at 1-minute interval are shown here. The lines with coloured background are the original ephemeris as found in the MMAN navigation section (see paragraph 3.15)

For instance the interpolation for P_x at 2007/07/27 00:41:00.000 is performed taking the 8 values for P_x from line 3 to line 10, as numbered in the left-most column in

	Epoch	Px(km)	Py(km)	Pz(km)	Vx(km/s)	Vy(km/s)	Vz(km/s)
1	2007/07/27 00:00:00.000	-5744.17	4069.27	1508.35	-0.3028	2.2543	-7.1884
2	2007/07/27 00:08:00.000	-5169.27	4607.43	-1984.30	2.6206	-0.0917	-7.0638
3	2007/07/27 00:16:00.000	-3358.59	3957.16	-4998.16	4.7391	-2.5860	-5.2365
4	2007/07/27 00:24:00.000	-828.89	2208.94	-6809.41	5.5629	-4.5588	-2.1570
5	2007/07/27 00:32:00.000	1751.44	-244.85	-6986.36	4.9593	-5.4503	1.4346
6	2007/07/27 00:40:00.000	3738.96	-2800.12	-5487.05	3.1586	-4.9584	4.6857
7	2007/07/27 00:48:00.000	4674.24	-4788.71	-2668.43	0.6790	-3.1279	6.8182
8	2007/07/27 00:56:00.000	4389.53	-5652.45	793.66	-1.8094	-0.3670	7.3097
9	2007/07/27 01:04:00.000	3039.79	-5101.55	4063.65	-3.6639	2.6372	6.0338
10	2007/07/27 01:12:00.000	1045.51	-3208.23	6350.92	-4.4461	5.0987	3.3003
11	2007/07/27 01:20:00.000	-1035.11	-402.36	7103.85	-4.0310	6.3481	-0.2275
12	2007/07/27 01:28:00.000	-2663.08	2629.85	6141.34	-2.6171	6.0107	-3.7007
13	2007/07/27 01:36:00.000	-3458.71	5115.70	3694.83	-0.6521	4.1111	-6.2830
14	2007/07/27 01:44:00.000	-3291.66	6394.60	354.60	1.2981	1.0855	-7.3469
15	2007/07/27 01:52:00.000	-2299.78	6097.31	-3071.58	2.7094	-2.3140	-6.6346
16	2007/07/27 02:00:00.000	-831.84	4253.07	-5757.21	3.2475	-5.2181	-4.3268

Table 2.

Epoch	Px(km)	Py(km)	Pz(km)	Vx(km/s)	Vy(km/s)	Vz(km/s)
2007/07/27 00:40:00.000	3738.960000	-2800.120000	-5487.050000	3.158600	-4.958400	4.685700
2007/07/27 00:41:00.000	3919.945412	-3092.908934	-5195.553059	2.872808	-4.797762	5.027312
2007/07/27 00:42:00.000	4083.492708	-3375.430634	-4884.130016	2.577466	-4.616231	5.349790
2007/07/27 00:43:00.000	4229.068292	-3646.448903	-4553.968080	2.273869	-4.414404	5.651880
2007/07/27 00:44:00.000	4356.216724	-3904.766011	-4206.326924	1.963340	-4.192969	5.932406
2007/07/27 00:45:00.000	4464.562203	-4149.228036	-3842.533991	1.647222	-3.952700	6.190270
2007/07/27 00:46:00.000	4553.809744	-4378.730086	-3463.979549	1.326878	-3.694457	6.424457
2007/07/27 00:47:00.000	4623.746040	-4592.221352	-3072.111505	1.003678	-3.419183	6.634044
2007/07/27 00:48:00.000	4674.240000	-4788.710000	-2668.430000	0.679000	-3.127900	6.818200

Table 3 : Example of 8th Lagrange Interpolation results.

5.1.1.1 Interpolating the original ephemeris table across manoeuvres

In case a manoeuvre is found in section “Announcements” (see 2.2) with a “scheduled” status, two ephemeris data-sets are generated, the first one describing the orbit before the manoeuvre (validity end-time is set to manoeuvre time) and the second one describing the orbit after the manoeuvre (validity start-time set to manoeuvre time).
A standard Legendre symmetrical interpolation should be used to determine the point of interest (4 points before and 4 points after the point of interest) as long as the available number of ephemeris data allows it. On approaching the ephemeris discontinuity (manoeuvre) the number of available data points after the point of interest will become less than 4. In this case an asymmetrical interpolation should be used. The same happens for the first epochs after the discontinuity (less than 4 points available before the point of interest).
A pseudo-code for asymmetric interpolation at discontinuity border is described here:

```
Set Nb data points before the point of interest
Set Na data points after the point of interest

If Nb >= 4 and Na >= 4
        Interpolate using centred interpolation formula
Else
        If Nb < 4 and Na >= 4
                interpolate using Nb points before and 8-Nb points after the point of interest
        Else if Na < 4 and Nb >= 4
                interpolate using Na points after and 8-Na points before the point of interest
        Else if Na < 4 and Nb < 4
                interpolate using Na points after and Nb points before the point of interest
End if
```

Never perform interpolation across the manoeuvre, using points belonging to mixed two orbit-ephemeris sets. Huge geolocation errors would otherwise be created.

In case of double in-plane manoeuvres (separated by half an orbit) three ephemeris data-sets are generated, the first one describing the orbit before the first manoeuvre (validity end-time is set to first manoeuvre time), the second one describing the orbit between the two manoeuvres (validity start-time is set to first manoeuvre time and validity end-time set to second manoeuvre time) and the third one describing the orbit after the manoeuvre (validity start time set to second manoeuvre time).
In case of double out-of-plane manoeuvres the second manoeuvre is performed several hours after the first one. In this case the MMAM generated in the morning will only contain the first manoeuvre (one orbit discontinuity). Upon proper calibration of the first manoeuvre, the second manoeuvre will be finalised. The evening MMAM, distributed in asynchronous mode shall contain this manoeuvre (one orbit discontinuity).

5.1.2 Ephemeris Conversion from Earth-fixed to pseudo-inertial frame

The conversion takes the Earth-fixed co-ordinates to a pseudo-inertial frame by subtracting the Earth angular velocity.

In the following explanation Px, Py, Pz corresponds to the x-pos, y-pos, z-pos elements found in the MMAM; similarly for Vy, Vy, Vz which corresponds to x-vel, y-vel, z-vel.

P=(Px,Py,Pz) position (km),
Ve=(Vex, Vey, Vez) earth-fixed velocity (km/s),
Vi=(Vix, Viy, Viz) pseudo-inertial velocity (km/s),
ω=Earth angular velocity= 7.2921154E-05 (rad/s)

$$V_{ix} = V_{ex} - P_y * \omega_e$$
$$V_{iy} = V_{ey} + P_x * \omega_e$$
$$V_{iz} = V_{ez}$$

Equation 2 Transition from Earth-fixed to pseudo-inertial velocity

The following the numerical example for the times given above, the conversion provides the following data:

Epoch	Vix(km/s)	Viy(km/s)	Viz(km/s)
2007/07/27 00:40:00.000	3.362788	-4.685751	4.685700
2007/07/27 00:41:00.000	3.098346	-4.511915	5.027312
2007/07/27 00:42:00.000	2.823606	-4.318458	5.349790
2007/07/27 00:43:00.000	2.539773	-4.106016	5.651880
2007/07/27 00:44:00.000	2.248080	-3.875309	5.932406
2007/07/27 00:45:00.000	1.949789	-3.627139	6.190270
2007/07/27 00:46:00.000	1.646180	-3.362388	6.424457
2007/07/27 00:47:00.000	1.338548	-3.082014	6.634044
2007/07/27 00:48:00.000	1.028198	-2.787049	6.818200

Table 4: Example of Earth-Fixed to pseudo-inertial frame conversion

5.1.3 Determine Satellite attitude

The orbit reference frame is defined as: Radial aligned with the position vector, Along-Track normal to it on the position-velocity plane (orbital plane), Normal to the orbital plane.

First find out the orbit angular momentum vector, where:
P=position vector (km)
V=pseudo-inertial velocity vector (km/s)
W= orbit angular momentum vector (km^2/s)

$$\vec{W} = \vec{P} \times \vec{V}$$

Equation 3 Orbit Angular Velocity Vector

The interpolated values have therefore the following angular velocity vector components:

Epoch	Px(km)	Py(km)	Pz(km)	Vix(km/s)	Viy(km/s)	Viz(km/s)	ωx	ωy	ωz
2007/07/27 00:40:00.000	3738.960000	-2800.120000	-5487.050000	3.362788	-4.685751	4.685700	-38831.470777	-35971.430672	-8103.624630
2007/07/27 00:41:00.000	3919.945412	-3092.908934	-5195.553059	3.098346	-4.511915	5.027312	-38990.912947	-35804.411044	-8103.558380
2007/07/27 00:42:00.000	4083.492708	-3375.430634	-4884.130016	2.823606	-4.318458	5.349790	-39149.755226	-35636.688166	-8103.504802
2007/07/27 00:43:00.000	4229.068292	-3646.448903	-4553.968080	2.539773	-4.106016	5.651880	-39307.958671	-35468.232204	-8103.470326
2007/07/27 00:44:00.000	4356.216724	-3904.766011	-4206.326924	2.248080	-3.875309	5.932406	-39465.474570	-35299.007732	-8103.458276
2007/07/27 00:45:00.000	4464.562203	-4149.228036	-3842.533991	1.949789	-3.627139	6.190270	-39622.245422	-35128.974384	-8103.468693
2007/07/27 00:46:00.000	4553.809744	-4378.730086	-3463.979549	1.646180	-3.362388	6.424457	-39778.206910	-34958.088304	-8103.498543
2007/07/27 00:47:00.000	4623.746040	-4592.221352	-3072.111505	1.338548	-3.082014	6.634044	-39933.290692	-34786.304260	-8103.542287
2007/07/27 00:48:00.000	4674.240000	-4788.710000	-2668.430000	1.028198	-2.787049	6.818200	-40087.427748	-34613.578253	-8103.592735

Table 5 Angular velocity ω components (ω is is computed using the inertial velocity)

The satellite frame is found by computing the following formulas, where :
N=orbit normal
R=radial vector
T=along-track vector

$$\vec{N} = \vec{\omega} / |\vec{\omega}|$$
$$\vec{R} = \vec{P} / |\vec{P}|$$
$$\vec{T} = \vec{R} \times \vec{N}$$

Equation 4: Satellite Frame

And the following N, R, T vector components (note that computations for vector N require ω calculated using the inertial velocity):

Epoch	Nx	Ny	Nz	Rx	Ry	Rz	Tx	Ty	Tz
2007/07/27 00:40:00.000	-0.725158	-0.671748	-0.151331	0.518859	-0.388575	-0.761443	-0.452694	0.630685	-0.630320
2007/07/27 00:41:00.000	-0.728082	-0.668580	-0.151319	0.543987	-0.429216	-0.721008	-0.417103	0.607268	-0.676203
2007/07/27 00:42:00.000	-0.730993	-0.665398	-0.151306	0.566697	-0.468434	-0.677808	-0.380135	0.581218	-0.719502
2007/07/27 00:43:00.000	-0.733892	-0.662203	-0.151294	0.586917	-0.506060	-0.632007	-0.341953	0.552622	-0.760051
2007/07/27 00:44:00.000	-0.736777	-0.658994	-0.151283	0.604581	-0.541926	-0.583779	-0.302722	0.521577	-0.797694
2007/07/27 00:45:00.000	-0.739649	-0.655771	-0.151272	0.619639	-0.575874	-0.533307	-0.262614	0.488194	-0.832286
2007/07/27 00:46:00.000	-0.742508	-0.652535	-0.151262	0.632049	-0.607749	-0.480786	-0.221800	0.452592	-0.863693
2007/07/27 00:47:00.000	-0.745353	-0.649285	-0.151252	0.641782	-0.637407	-0.426413	-0.180455	0.414900	-0.891793
2007/07/27 00:48:00.000	-0.748185	-0.646022	-0.151244	0.648820	-0.664709	-0.370398	-0.138752	0.375257	-0.916477

Table 6. Normal, Radial, Tangential components.

5.1.4 Determine the argument of latitude

The attitude determination including the yaw-steering mode requires the knowledge of the argument of latitude (also known as PSO, short for “Position sur l’Orbite”). This angle is measured from the orbital ascending node to the current satellite position, along the orbital plane. The following computations aim to determine the argument of latitude angle. The full procedure is: from the inertial Cartesian ephemeris find the inclination, then the satellite latitude, then using three auxiliary variables (beta1, slope, beta2), find argument of latitude. In the following inclination, latitude and argument of latitude are given in (deg).

$$
\begin{aligned}
&incl = a\cos(N_z) \\
&lat = a\sin(R_z) \\
&\beta_1 = a\sin\left[\frac{\sin(180° - lat)}{\sin(incl)}\right] \\
&slope_N = \beta_{1(N+1)} - \beta_{1(N-1)} \\
&\\
&\text{if slope}_N < 0 \\
&\beta_2 = 180 - \beta_1 \\
&\text{else} \\
&\beta_2 = \beta_1 \\
&\\
&PSO = \text{mod}(\beta_2, 360)
\end{aligned}
$$

Equation 5 argument of latitude Determination

The mod (x,y) function indicates that the remainder from x divided by y is to be computed.

For the given epochs the values for the quantities reported in *Equation 5* are:

Epoch	inclination	sin(i)	latitude	sin(180-l)	beta1	slope	beta2	PSO(deg)
2007/07/27 00:40:00.000	98.704068	0.988483	-49.591550	-0.761443	-50.382122	7.090380	-50.382122	309.617878
2007/07/27 00:41:00.000	98.703356	0.988485	-46.137763	-0.721008	-46.836710	7.091248	-46.836710	313.163290
2007/07/27 00:42:00.000	98.702642	0.988487	-42.672580	-0.677808	-43.290875	7.092107	-43.290875	316.709125
2007/07/27 00:43:00.000	98.701942	0.988489	-39.198327	-0.632007	-39.744603	7.092992	-39.744603	320.255397
2007/07/27 00:44:00.000	98.701268	0.988491	-35.716753	-0.583779	-36.197882	7.093899	-36.197882	323.802118
2007/07/27 00:45:00.000	98.700632	0.988492	-32.229200	-0.533307	-32.650704	7.094827	-32.650704	327.349296
2007/07/27 00:46:00.000	98.700042	0.988494	-28.736721	-0.480786	-29.103056	7.095775	-29.103056	330.896944
2007/07/27 00:47:00.000	98.699507	0.988495	-25.240153	-0.426413	-25.554928	7.096747	-25.554928	334.445072
2007/07/27 00:48:00.000	98.699030	0.988496	-21.740177	-0.370398	-22.006309	7.097824	-22.006309	337.993691

Table 7 argument of latitude (PSO) ephemeris for the given numerical example

5.1.5 Apply the yaw-steering law

The argument of latitude and the amplitudes for the satellite motion about the attitude axes are used to compute the instantaneous pitch, roll, yaw angles.
Those amplitudes are:
C_x pitch amplitude (radians)
C_y roll amplitude (radians)
C_z yaw amplitude (radians)

They are extracted from the MMAM message/navigation/yaw-steering section (see 3.23) and allow determining the yaw-steering law in the following way:

$$pitch = C_x \sin(2(PSO))$$

Equation 6 : Pitch commanded value

$$roll = C_y \sin(PSO)$$

Equation 7 : Roll commanded value

$$yaw = C_z \cos(PSO)\left[1 - \frac{(C_z \cos(PSO))^2}{3}\right]$$

Equation 8: Yaw commanded value

Note that the Cx, Cy, Cz, PSO numerical values must be input to the formulas in radians. In this example:

Cx Pitch (rad): +0.0028980
Cy Roll (rad): -0.0008870
Cz Yaw (rad): +0.0689925

The commanded angles for the ephemeris in the example are therefore:

Epoch	PSO	Yaw	Pitch	Roll
2007/07/27 00:40:00.000	309.617878	0.043966	-0.002847	0.000683
2007/07/27 00:41:00.000	313.163290	0.047161	-0.002892	0.000647
2007/07/27 00:42:00.000	316.709125	0.050176	-0.002893	0.000608
2007/07/27 00:43:00.000	320.255397	0.052999	-0.002849	0.000567
2007/07/27 00:44:00.000	323.802118	0.055618	-0.002762	0.000524
2007/07/27 00:45:00.000	327.349296	0.058025	-0.002633	0.000479
2007/07/27 00:46:00.000	330.896944	0.060209	-0.002463	0.000431
2007/07/27 00:47:00.000	334.445072	0.062163	-0.002256	0.000383
2007/07/27 00:48:00.000	337.993691	0.063879	-0.002014	0.000332

Table 8: Yaw-steering law angles vs. time

The overall roll angle is therefore the sum of the value computed via *Equation 7* and a possible platform roll bias operationally used. That roll bias is currently set to 0.0 degrees in the satellite control loop, but this value can be changed at any time if operational reasons require it. The numerical value is found in the MMAM navigation/attitude section (see 3.24). Of course the same applies for pitch and yaw.

The overall angles:

r=roll+roll-bias,
p=pitch+pitch-bias,
y=yaw+yaw-bias

modify the satellite <u>inertial</u> frame (N, T, R) in the following way:

$$N'_x = N_x - rR_x + yT_x$$
$$N'_y = N_y - rR_y + yT_y$$
$$N'_z = N_z - rR_z + yT_z$$

Equation 9 Modifications to Normal vector due to yaw-steering

$$R'_x = R_x - pT_x + rN_x$$
$$R'_y = R_y - pT_y + rN_y$$
$$R'_z = R_z - pT_z + rN_z$$

Equation 10 Modifications to Radial vector due to yaw-steering

$$T'_x = T_x + pR_x - yN_x$$
$$T'_y = T_y + pR_y - yN_y$$
$$T'_z = T_z + pR_z - yN_z$$

Equation 11 Modifications to Tangential vector due to yaw-steering

N', R', T' for this example are given here below

Epoch	Nx'	Ny'	Nz'	Tx'	Ty'	Tz'	Rx'	Ry'	Rz'
2007/07/27 00:40:00.000	-0.745415	-0.643754	-0.178523	-0.422289	0.661326	-0.621499	0.517074	-0.387239	-0.763341
2007/07/27 00:41:00.000	-0.748105	-0.639663	-0.182743	-0.384339	0.640041	-0.666981	0.542309	-0.427892	-0.723061
2007/07/27 00:42:00.000	-0.750412	-0.635950	-0.186996	-0.345096	0.615960	-0.709949	0.565153	-0.467158	-0.679981
2007/07/27 00:43:00.000	-0.752348	-0.632628	-0.191218	-0.304730	0.589160	-0.750232	0.585526	-0.504861	-0.634258
2007/07/27 00:44:00.000	-0.753931	-0.629701	-0.195343	-0.263414	0.559726	-0.787668	0.603359	-0.540831	-0.586061
2007/07/27 00:45:00.000	-0.755184	-0.627168	-0.199310	-0.221328	0.527761	-0.822104	0.618594	-0.574902	-0.535571
2007/07/27 00:46:00.000	-0.756135	-0.625023	-0.203056	-0.178651	0.493377	-0.853401	0.631183	-0.606916	-0.482978
2007/07/27 00:47:00.000	-0.756816	-0.623250	-0.206525	-0.135569	0.456699	-0.881429	0.641090	-0.636719	-0.428483
2007/07/27 00:48:00.000	-0.757264	-0.621830	-0.209664	-0.092265	0.417862	-0.906070	0.648292	-0.664168	-0.372294

Table 9 Normal, Radial, Tangential components rotated by yaw-steering (N', T', R') frame

The angles between the axes of the original and rotated frames (N-N', R-R', T-T') are:

$$N \forall N' = a\cos(1/|N'|)$$
$$R \forall R' = a\cos(1/|R'|)$$
$$T \forall T' = a\cos(1/|T'|)$$

Equation 12 Angles between satellite frame axes rotated by yaw-steering

The numerical values for this example are:

Epoch	angle NN'(rad)	angle TT'(rad)	angle RR'(rad)
2007/07/27 00:40:00.000	0.043943	0.044029	0.002928
2007/07/27 00:41:00.000	0.047131	0.047215	0.002964
2007/07/27 00:42:00.000	0.050138	0.050217	0.002956
2007/07/27 00:43:00.000	0.052952	0.053026	0.002905
2007/07/27 00:44:00.000	0.055563	0.055629	0.002812
2007/07/27 00:45:00.000	0.057962	0.058019	0.002676
2007/07/27 00:46:00.000	0.060138	0.060187	0.002501
2007/07/27 00:47:00.000	0.062084	0.062124	0.002288
2007/07/27 00:48:00.000	0.063793	0.063824	0.002041

Table 10 : Angles between satellite frame axes rotated by yaw-steering

5.1.6 Line-of-sight determination in the satellite frame

The computation of line-of-sight in satellite frame for a given instant is a function of the line-of-sight components in the instrument frame $(u_R, u_N\ u_T)_{inst,}$ which are obviously instrument-specific. The cosines u_R, u_N, u_T are generally functions of time, the special case of (u_R, u_N, u_T) not changing with time means that the instrument has a line-of-sight fixed w.r.t. the satellite body. Conversely, a (u_R, u_N, u_T) triplet exhibiting a periodic time law defines a sweeping line-of-sight.

In order to go from the instrument frame to the satellite frame one needs the frame transformation matrix M such that

$U_{inst}\, M = U_{sat}$

Alternatively:

$$(u_R, u_N, u_T)_{inst} \begin{pmatrix} R' \\ N' \\ T' \end{pmatrix}_{inst} = (u_R, u_N, u_T)_{sat} \begin{pmatrix} R' \\ N' \\ T' \end{pmatrix}_{sat}$$

Equation 13

In either case of fixed or sweeping line-of-sight, one can always determine the intersection of this line-of-sight with an ellipsoid describing the Earth surface.
Defining the line-of-sight in the satellite frame (including yaw-steering) as L (L_x,L_y,L_z) and defining the components in the instrument reference frame:

u_R=line-of-sight component in radial direction (positive outwards)
u_N=line-of-sight component in normal direction (positive towards orbit angular velocity)
u_T=line-of-sight component in along-track direction (positive in the anti-velocity direction)

the line-of-sight in Earth-Fixed-frame is:

$$L_x = u_{RSAT} R'_x + u_{NSAT} N'_x + u_{TSAT} T'_x$$
$$L_y = u_{RSAT} R'_y + u_{NSAT} N'_y + u_{TSAT} T'_y$$
$$L_z = u_{RSAT} R'_z + u_{NSAT} N'_z + u_{TSAT} T'_z$$

Equation 14 : Definition of Line-of-Sight

Assuming a spacecraft

Equation 18 Coefficients of the line-of-sightnadir-pointing attitude (u_{RSAT}=-1, u_{NSAT}=0, u_{TSAT}=0) the numerical values for this example are:

Epoch	Lx(rad)	Ly(rad)	Lz(rad)
2007/07/27 00:40:00.000	-0.517074	0.387239	0.763341
2007/07/27 00:41:00.000	-0.542309	0.427892	0.723061
2007/07/27 00:42:00.000	-0.565153	0.467158	0.679981
2007/07/27 00:43:00.000	-0.585526	0.504861	0.634258
2007/07/27 00:44:00.000	-0.603359	0.540831	0.586061
2007/07/27 00:45:00.000	-0.618594	0.574902	0.535571
2007/07/27 00:46:00.000	-0.631183	0.606916	0.482978
2007/07/27 00:47:00.000	-0.641090	0.636719	0.428483
2007/07/27 00:48:00.000	-0.648292	0.664168	0.372294

Table 11 Line-of-Sight Lx, Ly, Lz

5.1.7 Determination of the intersection point between line-of-sight and earth ellipsoid

This method assumes that the Earth is shaped as a flat ellipsoid, having two of the three axes (the equatorial ones) of the same size.
The coefficients A, B, C of the quadratic curve must be found:

$$Aq^2 + Bq + C = 0$$

Equation 15 Quadratic Curve

They are obtained by connecting the line-of-sight to the ellipsoid, with:
P=(Px, Py, Pz) satellite position
L=(Lx, Ly, Lz) line-of-sight vector

$$
\begin{aligned}
& R(q) = P + Lq \\
& alternatively: \\
& x(q) = P_x + L_x q \\
& y(q) = P_y + L_y q \\
& z(q) = P_z + L_z q
\end{aligned}
$$

Equation 16 Intersection of Line-of-Sight with Earth

The ellipsoid equation is:

$$
\frac{(x - x_c)^2}{\alpha^2} + \frac{(y - y_c)^2}{\beta^2} + \frac{(z - z_c)^2}{\gamma^2} = 1
$$

Equation 17 Ellipsoid Equation

The A, B, C coefficients are found in
Equation 18, where:
α=β=Earth equatorial radius =6378.1370 (km)
γ=Earth polar radius =6356.7523 (km)
K=(Earth polar radius/Earth equatorial radius ratio)= γ/α= 0.99664718710
Note that in this formulation $x_c, y_c, z_c = 0$ (Earth-fixed centre)

$$
\begin{aligned}
& A = K^2 L_x^{\ 2} + K^2 L_y^{\ 2} + L_z^{\ 2} \\
& B = 2(K^2 L_x P_x + K^2 L_y P_y + L_z P_z) \\
& C = K^2 P_x^{\ 2} + K^2 P_y^{\ 2} + P_z^{\ 2} - \gamma^2
\end{aligned}
$$

Equation 18 Coefficients of the line-of-sight

$$
q = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}
$$

Equation 19 parametric solution of the intersection line-of-sight to ellipsoid

which provides two solutions, q_1 and q_2. The suitable solution is the one corresponding to the "nearest" intersection, which has the lowest numerical value. Let's say that q1 satisfies this criterion.

The ray-to-ellipsoid intersection is at:

$$x_{INT} = P_x + q_1 L_x$$
$$y_{INT} = P_y + q_1 L_y$$
$$z_{INT} = P_z + q_1 L_z$$

Equation 20 Cartesian co-ordinates of the intersection between line-of-sight and ellipsoid

The intersection occurs at a distance from the Earth centre ("Inters. Alt" in the following table) equal to:

$$D = \sqrt{x_{INT}^{\ 2} + y_{INT}^{\ 2} + z_{INT}^{\ 2}}$$

Equation 21 Intersection Distance from Earth Centre

The ephemeris in the example provides the following intersections:

Epoch	A	B	C	q+	q-	IntersX (km)	IntersY (km)	IntersZ (km)	Inters.Alt (km)
2007/07/27 00:40:00.000	0.997215	-14371.843987	11373837.020090	13571.579673	840.403500	3304.408832	-2474.683399	-4845.535855	6365.720177
2007/07/27 00:41:00.000	0.996814	-14365.734545	11350624.709267	13572.689145	838.956822	3464.971256	-2733.926166	-4588.935700	6367.001566
2007/07/27 00:42:00.000	0.996410	-14359.536087	11326969.906281	13573.798200	837.480014	3610.188303	-2984.195545	-4314.659255	6368.293894
2007/07/27 00:43:00.000	0.996007	-14353.337530	11303192.016290	13574.886922	835.992684	3739.572816	-3224.389058	-4023.732912	6369.577395
2007/07/27 00:44:00.000	0.995613	-14347.226400	11279600.708656	13575.934483	834.513819	3852.705252	-3453.435307	-3717.250638	6370.832401
2007/07/27 00:45:00.000	0.995233	-14341.287441	11256490.897809	13576.919468	833.061470	3949.235611	-3670.299195	-3396.370285	6372.039643
2007/07/27 00:46:00.000	0.994873	-14335.601387	11234138.898561	13577.820292	831.652521	4028.885081	-3873.987079	-3062.309491	6373.180549
2007/07/27 00:47:00.000	0.994540	-14330.243911	11212799.749381	13578.615700	830.302534	4091.447346	-4063.551801	-2716.341196	6374.237532
2007/07/27 00:48:00.000	0.994238	-14325.284738	11192705.606828	13579.285339	829.025670	4136.789551	-4238.097553	-2359.788829	6375.194270

Table 12 Intersection between Line-of-Sight and Earth Ellipsoid

In order to find geocentric latitude and longitude of the intersection point one computes the following:

$$geoc\_lat_{INT} = a\sin(\mathrm{z_{INT}/D})$$
$$geoc\_long_{INT} = a\tan 2(x_{INT}, y_{INT})$$

Equation 22 Geocentric Latitude and Longitude of Intersection Point.

The <u>geodetic</u> latitude is found by using the Earth flattening factor:
f=1/298.25642 taken from RD. 2

$$geod\_lat_{INT} = a\tan(\tan(geoc\_lat_{INT})/(1-f)^2) = \tan(1.006739515(\tan(geoc\_lat_{INT})))$$
$$geod\_long_{INT} = geoc\_long_{INT}$$

Equation 23 Geocentric vs. Geodetic Longitude

These are the latitudes and longitudes for the provided example:

Epoch	IntersGeocentricLong (deg)	IntersGeocentricLat (deg)	IntersGeodeticLat (deg)
2007/07/27 00:40:00.000	-36.829669	-49.569403	-49.759297
2007/07/27 00:41:00.000	-38.274091	-46.115389	-46.307656
2007/07/27 00:42:00.000	-39.577267	-42.650306	-42.842149
2007/07/27 00:43:00.000	-40.769049	-39.176479	-39.365083
2007/07/27 00:44:00.000	-41.871980	-35.695652	-35.878225
2007/07/27 00:45:00.000	-42.903449	-32.209155	-32.382980
2007/07/27 00:46:00.000	-43.877134	-28.718024	-28.880503
2007/07/27 00:47:00.000	-44.804011	-25.223078	-25.371770
2007/07/27 00:48:00.000	-45.693053	-21.724972	-21.857639

Table 13 Geocentric Latitude and Longitude of Intersection between Line-.of-Sight and Earth Ellipsoid

A useful check is the comparison between the satellite geodetic latitude, longitude given by the current algorithm for the nadir (sub-satellite) point and by the EUMETSAT operational Flight Dynamics Facility for the geodetic earth-fixed co-ordinates for MetOp-A:
The following table shows that comparison.

Epoch	DeltaLat (deg)	Delta Long (deg)	DeltaLat (km)	DeltaLong (km)	GeolocErr: non-interpolated vs interpolated Eph (km)
2007/07/27 00:40:00.000	-0.000017	-0.000069	-0.001823	-0.004940	0.005266
2007/07/27 00:41:00.000	0.000004	-0.000121	0.000461	-0.009195	0.009206
2007/07/27 00:42:00.000	0.000021	-0.000157	0.002262	-0.012667	0.012867
2007/07/27 00:43:00.000	0.000047	-0.000179	0.005213	-0.015252	0.016118
2007/07/27 00:44:00.000	0.000065	-0.000170	0.007184	-0.015231	0.016841
2007/07/27 00:45:00.000	0.000070	-0.000149	0.007658	-0.013838	0.015816
2007/07/27 00:46:00.000	0.000047	-0.000104	0.005183	-0.010044	0.011302
2007/07/27 00:47:00.000	0.000000	-0.000051	-0.000040	-0.005067	0.005067
2007/07/27 00:48:00.000	-0.000059	0.000007	-0.006456	0.000749	0.006499

Table 14 Geocentric Latitude and Longitude of Intersection between Line-.of-Sight and Earth Ellipsoid: comparison of algorithm results with the operational Flight Dynamics Facility.

5.2 Two Line Elements (TLE)

5.2.1 TLE for the issuing Metop

Two-line elements are typically needed as input to user's antenna control units and are used to acquire and track the satellite during the pass over the antenna.

TLE extracted from MMAM shall only be used for times after the start of MMAM validity.

In case of manoeuvre, the TLE containing the effects of the planned manoeuvre is inserted into the MMAM section "element message/navigation/two-line-elements" with a clear indication of the start time of the validity for this TLE (see 3.11). In the current MetOp operational concept the epoch for the TLE related to manoeuvres is five minutes after the manoeuvre end time.

In case of single manoeuvre two TLE are included in the MMAM, one for the pre-manoeuvre phase and one for the post-manoeuvre phase.

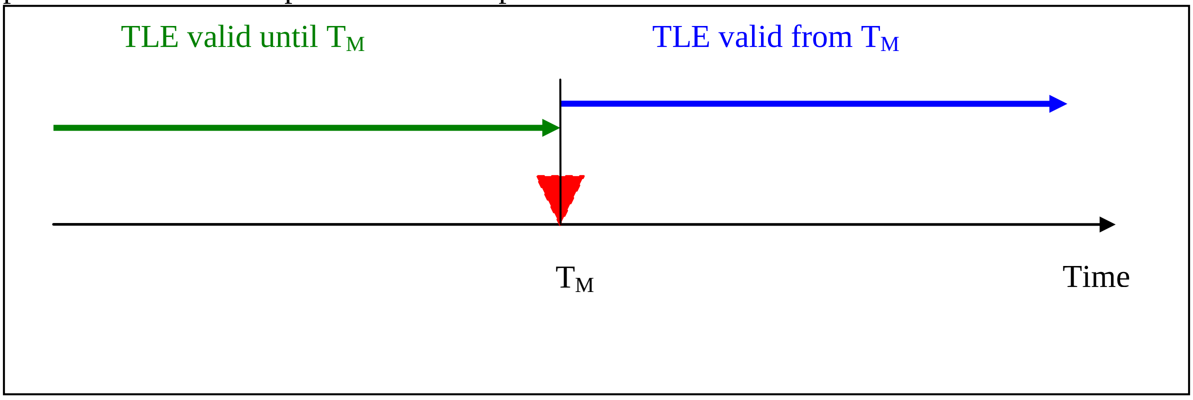

Figure 3 Schematic usage of Two-Line Element vectors contained in MMAM across a single manoeuvre, planned at time T_M.

In case of a manoeuvre pair, with two burns half an orbit apart, the first TLE is valid until the mid-time between the first and second manoeuvre. The second TLE is valid from the mid-time between the first and second manoeuvre onwards.
This solution provides TLE accuracy between the two manoeuvres which is of the order of magnitude of the standard TLE accuracy, while at the same time eliminating the need to introduce one more TLE for the time between manoeuvres, thus rendering the MMAM "leaner".

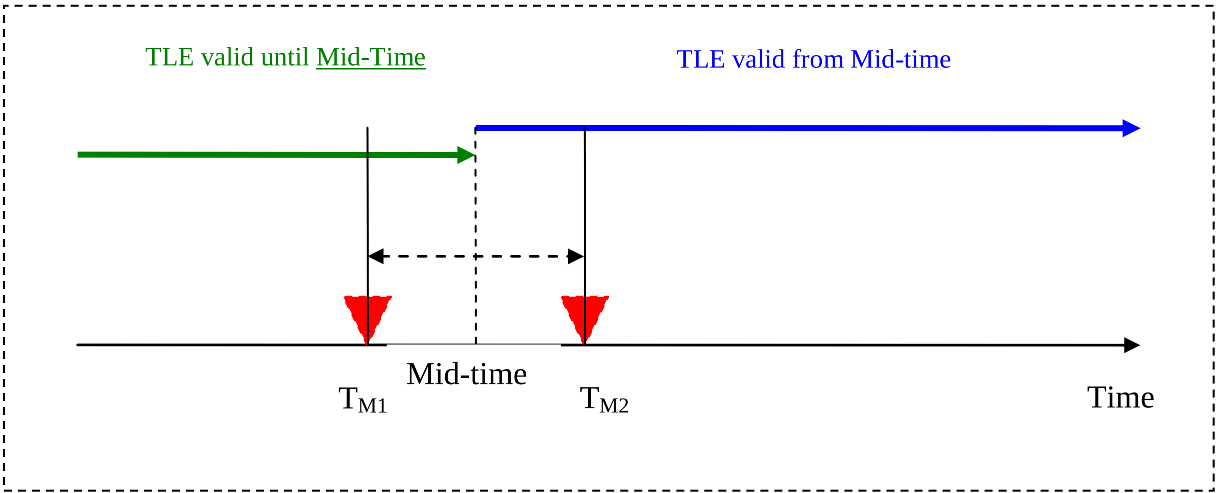

Figure 4 Schematic usage of Two-Line Element vectors contained in MMAM across a double manoeuvre, planned at time T_{M1} and T_{M2}

Note that TLE for issuing Metop can be used not only for satellite acquisition in the short-term but also for long-term planning of operations.

5.2.2 TLE for the non-issuing Metop(s)

During routine operations the MMAM for the issuing Metop provides a TLE vector also for the remaining (non-issuing) Metop flight model(s), if any. The MMAM of the issuing Metop shall contain the short-term TLE for the non-issuing Metop. In case a manoeuvre is foreseen for the non issuing satellites on the same day the MMAM is issued, that TLE shall include the manoeuvre effects.
Note that TLE for non-issuing Metop shall be only used for satellite acquisition in the short-term, and never for long-term planning.

5.3 OBT-UTC Correlation

All clocks onboard Metop are synchronised to the clock of the Central Communication Unit (CCU) inside the Service Module (SVM) of Metop. The CCU clock (aka. CCU_OBT) is a 2^8 Hz counter with a range of 32 bits causing it to rollover after 16777216 s (approx. 194 days). This clock is sometimes also called OBT or SBT; in telemetry it is labelled UZHB. The value of CCU_OBT can be found in the realtime telemetry frames of the S-band downlink and in the VCDU 34 downlinked via the HRPT direct broadcast links and the Global X Band Data Stream.

The clock count values found in the Instrument Source Packets (ISP) are called ISP_OBT. They are incremented by a 2^16 Hz counter using a 40 bit range, hence they roll over after the same time period as the CCU_OBT.
Since all onboard clocks are synched to the CCU the rollover (or "wrap-around") for the CCU_OBT and the ISP_OBT occurs (after every 194 days) at the same instant.

The relationship between the onboard clocks and the UTC are given via a linear equation.

UTCcalculated = clock-step * (CCU_OBT – ccu-obt-0) + utc-0

UTCcalculated = clock-step * (ISP_OBT/256 – ccu-obt-0) + utc-0

The ISP_OBT count is produced by a 2^16 Hz counter. Therefore it has to be divided by 256 to match the units of ccu-obt-0 and the clock-step (as shown in the above equation).

The following figure visualises the correlation parameters available in the MMAM

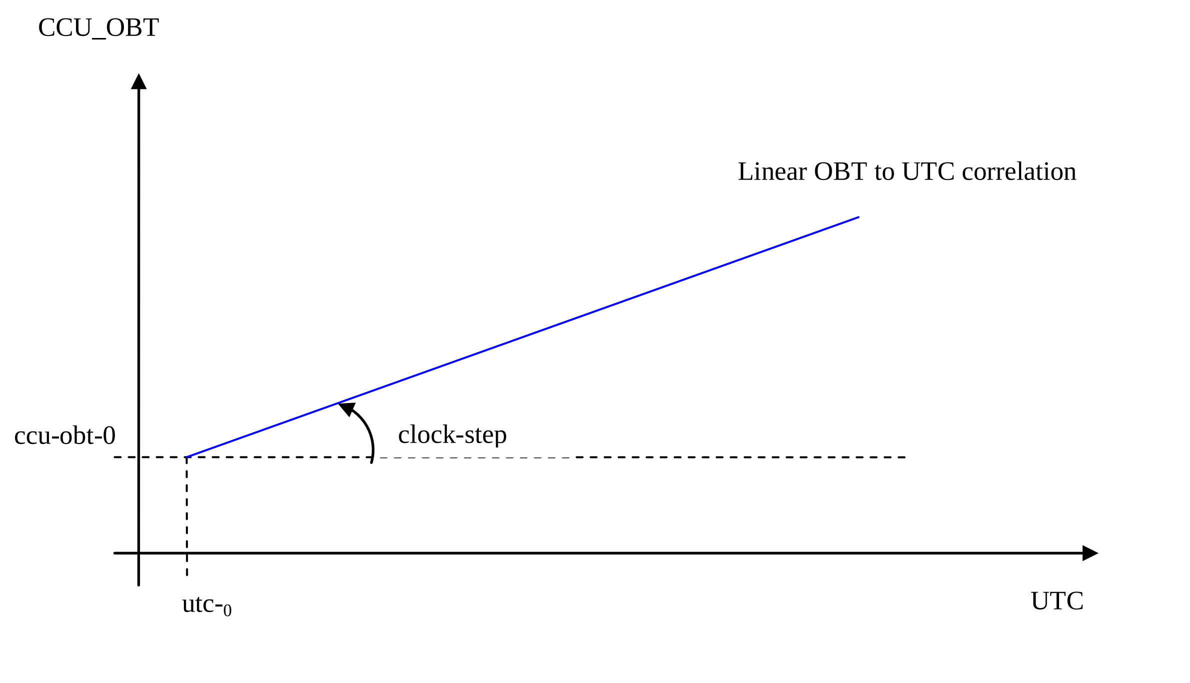

Figure 5

The parameters clock-step, ccu-obt-0 and utc-0 are calculated by the EUMETSAT ground segment by correlating the Earth Received Time (ERT) stamps to the CCU_OBT while taking into account the one-way-light time of the signal from satellite to ground (plus any other signal delays).
utc-0, ccu-obt-0 and clock-step are included in the MMAM.
The uncertainty of the calculated UTC versus the true UTC has been estimated to be less than 7 ms for a given set of coefficients within a duration of about 36 hours from utc-0 (see RD.4).

$$\left| UTC_{true} - UTC_{calculated} \right| < 7 \text{ ms} \quad \text{(within the time period from utc-0 to utc-0 + 36h)}$$

The UTC corresponding to the provided parameters utc-0, ccu-obt-0, clock-step is obtained by reading the obt from TM and using the formula:

$$utc = utc0 + clockstep * \left[\mathrm{mod}(obt - ccuobt0 + \frac{3}{2} * 16^8, 16^8) - \frac{1}{2} * 16^8 \right]$$

Equation 25

The mod (x,y) function indicates that the remainder from x divided by y is to be computed.

This formula is valid for UTC time spans (utc minus utc-0) which are less than half a counter cycle (97.09 days); this is the operational case.

The formula to compute the time (in UTC) of the next wrap-around event is:

$$utc = utc0 + clockstep * \left[16^8 - ccuobt0\right]$$

Equation 26

6 MULTI-MISSION ADMINISTRATIVE MESSAGE IN METOP HRPT DATA STREAM

This section describes how the MMAM is imbedded in the Metop HRPT Data Stream.

The administrative message contained in the Metop HRPT stream consists of 8032 bytes and is structured as indicated in Table 15.

Record 1-4 are identical to the first four records of the old Metop Administrative Message as defined in RD.3. They are included for reasons of compatibility with the EUMETSAT ground systems and can be ignored by users of the MMAM.

Record 6 contains the MMAM itself compressed using BZIP2. The size of this record is contained in record 5.

Record 7 contains filler data to ensure a total size of 8032 bytes.

Record	Description	Type	Size (bytes)
1	Packet Header	See RD.3	20
2	Message Number	See RD.3	1
3	Starting Time of Validity for this Admin Message.	See RD.3	12
4	Metop Satellite ID (International Designator)	See RD.3	10
5	size_indication: the size of record 6 in bytes, encoded as big-endian.	unsigned long integer	4
6	XML-formatted MMAM message compressed using BZIP2. Starts with the characters “BZ”.	BZIP2	size_indication
7	Filler data “0”	byte	7985-size_indication
	Total Size:		8032

Table 15 MMAM Message Structure

7 METOP SPECIFIC MMAM VALUES

7.1 Metop Subsystems or Components

The Table 16 below list the Metop subsystems relevant to the MMAM

Metop Subsystems and Components					
Metop-A	Metop-B	Metop-C	Subsystem	Component	Comment
✓	✓	✓	HRPT	frequency-1701.300-MHz frequency-1707.000-MHz	
✓			LRPT	frequency-137.1000-MHz frequency-137.9125-MHz	It is not foreseen to be operate LRPT on Metop-B and Metop-C.
✓	✓	✓	all-instruments	-	
✓	✓	✓	AVHRR	channel-1 channel-2 channel-3A channel-3B channel-4 channel-5	
✓	✓	✓	AMSU-A	channel-1 through channel-15	
✓	✓	✓	MHS	channel-1 through channel-5	
✓	✓		HIRS	channel-1 through channel-20	The HIRS Instrument will not be available on Metop-C.
✓	✓	✓	IASI	band-1 band-2 band-3	
✓	✓	✓	GRAS	-	
✓	✓	✓	ASCAT	-	
✓	✓	✓	GOME-2	-	
✓	✓	✓	SEM	TED MEPED	
✓	✓	✓	A-DCS	-	
✓	✓	✓	SAR	SARR SARP	

Table 16 Metop Subsystems and Components

8 MULTI-MISSION ADMINITRATIVE MESSAGE EXAMPLE FOR METOP

This section contains two examples of Metop-A Multi-Mission Administrative Messages, the first one corresponding to routine operations, the second one referring to a pre-manoeuvre situation. The latter example shows the presence of pre-manoeuvre and post-manoeuvre TLE vectors, as well as the satellite ephemeris split in presence of a manoeuvre. In this case the manoeuvre is a double in-plane manoeuvre with two burns performed half an orbit apart. The example is valid for Metop-B, too, with due changes in satellite-number and international-spacecraft-designator.

Please note that in the examples the data contained in the xml element navigation/orbit-ephemeris has been shortened.

8.1 Example Message 1 (no manoeuvre)


```xml
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet type="text/xsl" href="mmam.xsl"?>

<multi-mission-administrative-message issue-number="68" issued-on="2012-08-06T09:55:31.159" issued-by="EUMETSAT" transmitted-via="Metop-A" format-version="1.0">
 <issuer-contact-information>
  <name>EUMETSAT MCC-G2</name>
  <name>User Service</name>
  <address>EUMETSAT-Allee 1</address>
  <address>D-64295 Darmstadt</address>
  <address>Germany</address>
  <telephone>+49 6151 807 3660</telephone>
  <e-mail>ops@eumetsat.int</e-mail>
  <internet>http://www.eumetsat.int</internet>
 </issuer-contact-information>
 <message satellite="Metop-A" satellite-number="29499" mission="EPS" international-spacecraft-designator="2006-044A">
  <announcements/>
  <status last-updated-on="2012-06-06T13:37:20" satellite-status="operational-prime">
   <subsystem name="A-DCS" status="operational"/>
   <subsystem name="AMSU-A" status="operational-with-limitations">
    <component name="channel-7" status="not-operational"/>
   </subsystem>
   <subsystem name="ASCAT" status="operational-with-limitations"/>
   <subsystem name="AVHRR" status="operational-with-limitations"/>
   <subsystem name="GOME-2" status="operational"/>
   <subsystem name="GRAS" status="operational"/>
   <subsystem name="HIRS" status="operational"/>
   <subsystem name="HRPT" status="operational">
```

```xml
      <component name="frequency-1701.300-MHz" status="operational"/>
      <component name="frequency-1707.000-MHz" status="not-operational"/>
    </subsystem>
    <subsystem name="IASI" status="operational"/>
    <subsystem name="LRPT" status="not-operational">
      <component name="frequency-137.1000-MHz" status="not-operational"/>
      <component name="frequency-137.9125-MHz" status="not-operational"/>
    </subsystem>
    <subsystem name="MHS" status="operational"/>
    <subsystem name="SAR" status="operational"/>
    <subsystem name="SEM" status="operational"/>
  </status>
  <navigation>
    <two-line-elements>
      <line-1>1 29499U 06044A   12220.25000000  .00000000  00000+0  46715-4 0 00011</line-1>
      <line-2>2 29499  98.6973 278.7633 0000609 172.5379 295.5154 14.21485317300989</line-2>
    </two-line-elements>
    <statevectors-at-anx valid-from="2012-08-06T12:36:00.000" valid-until="2012-08-07T03:48:15.000" reference-frame-keplerian="TOD" reference-frame-cartesian="Earth-Fixed">
      <statevector-at-anx epoch="2012-08-06T12:36:00.000" orbit="30088">
        <semi-major-axis>7204.688657</semi-major-axis>
        <eccentricity>0.001114</eccentricity>
        <inclination>98.692</inclination>
        <perigee>67.760</perigee>
        <right-ascension>278.052</right-ascension>
        <mean-anomaly>292.313</mean-anomaly>
        <x-pos>-4966.803889</x-pos>
        <y-pos>5214.840192</y-pos>
        <z-pos>-5.613116</z-pos>
        <x-vel>1.195930</x-vel>
        <y-vel>1.136365</y-vel>
        <z-vel>7.355761</z-vel>
      </statevector-at-anx>
      <statevector-at-anx epoch="2012-08-06T14:17:22.000" orbit="30089">
        <semi-major-axis>7204.626243</semi-major-axis>
        <eccentricity>0.001107</eccentricity>
        <inclination>98.691</inclination>
        <perigee>68.875</perigee>
        <right-ascension>278.121</right-ascension>
        <mean-anomaly>291.223</mean-anomaly>
        <x-pos>-2256.374674</x-pos>
        <y-pos>6839.146667</y-pos>
        <z-pos>-2.510781</z-pos>
        <x-vel>1.568058</x-vel>
        <y-vel>0.511946</y-vel>
        <z-vel>7.355656</z-vel>
      </statevector-at-anx>
      <statevector-at-anx epoch="2012-08-06T15:58:44.000" orbit="30090">
```

```
  &lt;semi-major-axis&gt;7204.490015&lt;/semi-major-axis&gt;
  &lt;eccentricity&gt;0.001092&lt;/eccentricity&gt;
  &lt;inclination&gt;98.690&lt;/inclination&gt;
  &lt;perigee&gt;69.760&lt;/perigee&gt;
  &lt;right-ascension&gt;278.190&lt;/right-ascension&gt;
  &lt;mean-anomaly&gt;290.358&lt;/mean-anomaly&gt;
  &lt;x-pos&gt;888.486121&lt;/x-pos&gt;
  &lt;y-pos&gt;7146.742675&lt;/y-pos&gt;
  &lt;z-pos&gt;0.007795&lt;/z-pos&gt;
  &lt;x-vel&gt;1.635834&lt;/x-vel&gt;
  &lt;y-vel&gt;-0.211059&lt;/y-vel&gt;
  &lt;z-vel&gt;7.355590&lt;/z-vel&gt;
&lt;/statevector-at-anx&gt;
&lt;statevector-at-anx epoch="2012-08-06T17:40:05.000" orbit="30091"&gt;
  &lt;semi-major-axis&gt;7204.526319&lt;/semi-major-axis&gt;
  &lt;eccentricity&gt;0.001094&lt;/eccentricity&gt;
  &lt;inclination&gt;98.690&lt;/inclination&gt;
  &lt;perigee&gt;69.148&lt;/perigee&gt;
  &lt;right-ascension&gt;278.259&lt;/right-ascension&gt;
  &lt;mean-anomaly&gt;290.930&lt;/mean-anomaly&gt;
  &lt;x-pos&gt;3860.833238&lt;/x-pos&gt;
  &lt;y-pos&gt;6079.365181&lt;/y-pos&gt;
  &lt;z-pos&gt;-4.866929&lt;/z-pos&gt;
  &lt;x-vel&gt;1.390962&lt;/x-vel&gt;
  &lt;y-vel&gt;-0.886484&lt;/y-vel&gt;
  &lt;z-vel&gt;7.355646&lt;/z-vel&gt;
&lt;/statevector-at-anx&gt;
&lt;statevector-at-anx epoch="2012-08-06T19:21:27.000" orbit="30092"&gt;
  &lt;semi-major-axis&gt;7204.569142&lt;/semi-major-axis&gt;
  &lt;eccentricity&gt;0.001107&lt;/eccentricity&gt;
  &lt;inclination&gt;98.692&lt;/inclination&gt;
  &lt;perigee&gt;68.815&lt;/perigee&gt;
  &lt;right-ascension&gt;278.329&lt;/right-ascension&gt;
  &lt;mean-anomaly&gt;291.286&lt;/mean-anomaly&gt;
  &lt;x-pos&gt;6091.544561&lt;/x-pos&gt;
  &lt;y-pos&gt;3841.522463&lt;/y-pos&gt;
  &lt;z-pos&gt;-2.115844&lt;/z-pos&gt;
  &lt;x-vel&gt;0.875289&lt;/x-vel&gt;
  &lt;y-vel&gt;-1.398300&lt;/y-vel&gt;
  &lt;z-vel&gt;7.355671&lt;/z-vel&gt;
&lt;/statevector-at-anx&gt;
&lt;statevector-at-anx epoch="2012-08-06T21:02:49.000" orbit="30093"&gt;
  &lt;semi-major-axis&gt;7204.596851&lt;/semi-major-axis&gt;
  &lt;eccentricity&gt;0.001114&lt;/eccentricity&gt;
  &lt;inclination&gt;98.693&lt;/inclination&gt;
  &lt;perigee&gt;68.935&lt;/perigee&gt;
  &lt;right-ascension&gt;278.399&lt;/right-ascension&gt;
```

<mean-anomaly>291.194</mean-anomaly>
<x-pos>7149.668126</x-pos>
<y-pos>864.151959</y-pos>
<z-pos>1.228879</z-pos>
<x-vel>0.189040</x-vel>
<y-vel>-1.638964</y-vel>
<z-vel>7.355637</z-vel>
</statevector-at-anx>
<statevector-at-anx epoch="2012-08-06T22:44:10.000" orbit="30094">
<semi-major-axis>7204.590118</semi-major-axis>
<eccentricity>0.001117</eccentricity>
<inclination>98.693</inclination>
<perigee>69.345</perigee>
<right-ascension>278.469</right-ascension>
<mean-anomaly>290.755</mean-anomaly>
<x-pos>6831.944664</x-pos>
<y-pos>-2278.083328</y-pos>
<z-pos>-2.553938</z-pos>
<x-vel>-0.526783</x-vel>
<y-vel>-1.563477</y-vel>
<z-vel>7.355589</z-vel>
</statevector-at-anx>
<statevector-at-anx epoch="2012-08-07T00:25:32.000" orbit="30095">
<semi-major-axis>7204.546308</semi-major-axis>
<eccentricity>0.001113</eccentricity>
<inclination>98.693</inclination>
<perigee>70.058</perigee>
<right-ascension>278.538</right-ascension>
<mean-anomaly>290.070</mean-anomaly>
<x-pos>5199.085438</x-pos>
<y-pos>-4983.519798</y-pos>
<z-pos>1.003735</z-pos>
<x-vel>-1.147950</x-vel>
<y-vel>-1.184878</y-vel>
<z-vel>7.355517</z-vel>
</statevector-at-anx>
<statevector-at-anx epoch="2012-08-07T02:06:53.000" orbit="30096">
<semi-major-axis>7204.601544</semi-major-axis>
<eccentricity>0.001109</eccentricity>
<inclination>98.691</inclination>
<perigee>69.529</perigee>
<right-ascension>278.607</right-ascension>
<mean-anomaly>290.566</mean-anomaly>
<x-pos>2566.783718</x-pos>
<y-pos>-6728.861424</y-pos>
<z-pos>-3.002334</z-pos>
<x-vel>-1.542889</x-vel>

```
      <y-vel>-0.583559</y-vel>
      <z-vel>7.355579</z-vel>
    </statevector-at-anx>
    <statevector-at-anx epoch="2012-08-07T03:48:15.000" orbit="30097">
      <semi-major-axis>7204.605217</semi-major-axis>
      <eccentricity>0.001116</eccentricity>
      <inclination>98.690</inclination>
      <perigee>68.800</perigee>
      <right-ascension>278.677</right-ascension>
      <mean-anomaly>291.317</mean-anomaly>
      <x-pos>-560.498012</x-pos>
      <y-pos>-7179.845907</y-pos>
      <z-pos>-0.298331</z-pos>
      <x-vel>-1.643812</x-vel>
      <y-vel>0.135781</y-vel>
      <z-vel>7.355720</z-vel>
    </statevector-at-anx>
  </statevectors-at-anx>
  <orbit-ephemeris valid-from="2012-08-06T13:00:00.000" valid-until="2012-08-07T04:00:00.000" reference-frame="Earth-Fixed" interpolation-method="Lagrange" interpolation-degree="8"
time-step="8">
    <statevector epoch="2012-08-06T13:00:00.000">
      <x-pos>499.83</x-pos>
      <y-pos>1128.25</y-pos>
      <z-pos>7084.31</z-pos>
      <x-vel>4.6809</x-vel>
      <y-vel>-5.8579</y-vel>
      <z-vel>0.6012</z-vel>
    </statevector>
    <statevector epoch="2012-08-06T13:08:00.000">
      <x-pos>2497.02</x-pos>
      <y-pos>-1777.28</y-pos>
      <z-pos>6506.15</z-pos>
      <x-vel>3.4688</x-vel>
      <y-vel>-5.9864</y-vel>
      <z-vel>-2.9610</z-vel>
    </statevector>
    <statevector epoch="2012-08-06T13:16:00.000">
      <x-pos>3702.76</x-pos>
      <y-pos>-4368.53</y-pos>
      <z-pos>4356.59</z-pos>
      <x-vel>1.4685</x-vel>
      <y-vel>-4.5654</y-vel>
      <z-vel>-5.8113</z-vel>
    </statevector>
    <statevector epoch="2012-08-06T13:24:00.000">
      <x-pos>3872.86</x-pos>
      <y-pos>-5958.77</y-pos>
```

```
      <z-pos>1153.62</z-pos>
      <x-vel>-0.7430</x-vel>
      <y-vel>-1.8986</y-vel>
      <z-vel>-7.2587</z-vel>
    </statevector>
[ephemeris intentionally omitted for brevity in this example]
    <statevector epoch="2012-08-07T03:56:00.000">
      <x-pos>-1211.85</x-pos>
      <y-pos>-6286.10</y-pos>
      <z-pos>3289.56</z-pos>
      <x-vel>-1.0640</x-vel>
      <y-vel>3.6280</y-vel>
      <z-vel>6.5199</z-vel>
    </statevector>
  </orbit-ephemeris>
  <events valid-from="2012-08-06T13:00:00.000" valid-until="2012-08-07T04:00:00.000">
    <ascending-node-crossings>
      <ascending-node-crossing time="2012-08-06T14:17:22.535" orbit-number="30089"/>
      <ascending-node-crossing time="2012-08-06T15:58:44.194" orbit-number="30090"/>
      <ascending-node-crossing time="2012-08-06T17:40:05.858" orbit-number="30091"/>
      <ascending-node-crossing time="2012-08-06T19:21:27.485" orbit-number="30092"/>
      <ascending-node-crossing time="2012-08-06T21:02:49.030" orbit-number="30093"/>
      <ascending-node-crossing time="2012-08-06T22:44:10.545" orbit-number="30094"/>
      <ascending-node-crossing time="2012-08-07T00:25:32.063" orbit-number="30095"/>
      <ascending-node-crossing time="2012-08-07T02:06:53.609" orbit-number="30096"/>
      <ascending-node-crossing time="2012-08-07T03:48:15.243" orbit-number="30097"/>
    </ascending-node-crossings>
    <subsatellite-daytimes>
      <subsatellite-daytime start-time="2012-08-06T13:44:26.894" end-time="2012-08-06T14:35:20.595"/>
      <subsatellite-daytime start-time="2012-08-06T15:25:48.952" end-time="2012-08-06T16:16:42.657"/>
      <subsatellite-daytime start-time="2012-08-06T17:07:11.038" end-time="2012-08-06T17:58:04.673"/>
      <subsatellite-daytime start-time="2012-08-06T18:48:33.017" end-time="2012-08-06T19:39:26.645"/>
      <subsatellite-daytime start-time="2012-08-06T20:29:54.915" end-time="2012-08-06T21:20:48.562"/>
      <subsatellite-daytime start-time="2012-08-06T22:11:16.780" end-time="2012-08-06T23:02:10.468"/>
      <subsatellite-daytime start-time="2012-08-06T23:52:38.655" end-time="2012-08-07T00:43:32.399"/>
      <subsatellite-daytime start-time="2012-08-07T01:34:00.643" end-time="2012-08-07T02:24:54.338"/>
    </subsatellite-daytimes>
    <hrpt-on-times>
      <hrpt-on-time start-time="2012-08-06T13:10:42.000" end-time="2012-08-06T13:23:58.000" flight-direction="descending"/>
      <hrpt-on-time start-time="2012-08-06T14:10:17.000" end-time="2012-08-06T14:28:45.000" flight-direction="ascending"/>
      <hrpt-on-time start-time="2012-08-06T14:56:37.000" end-time="2012-08-06T15:07:44.000" flight-direction="descending"/>
      <hrpt-on-time start-time="2012-08-06T15:51:39.000" end-time="2012-08-06T16:10:06.000" flight-direction="ascending"/>
      <hrpt-on-time start-time="2012-08-06T16:37:59.000" end-time="2012-08-06T16:51:30.000" flight-direction="descending"/>
      <hrpt-on-time start-time="2012-08-06T17:28:43.000" end-time="2012-08-06T17:51:28.000" flight-direction="ascending"/>
      <hrpt-on-time start-time="2012-08-06T18:19:21.000" end-time="2012-08-06T18:41:05.000" flight-direction="descending"/>
      <hrpt-on-time start-time="2012-08-06T19:10:05.000" end-time="2012-08-06T19:32:49.000" flight-direction="ascending"/>
      <hrpt-on-time start-time="2012-08-06T20:00:42.000" end-time="2012-08-06T20:21:12.000" flight-direction="descending"/>
```

```
        <hrpt-on-time start-time="2012-08-06T21:01:34.000" end-time="2012-08-06T21:14:11.000" flight-direction="ascending"/>
        <hrpt-on-time start-time="2012-08-06T21:42:04.000" end-time="2012-08-06T22:01:21.000" flight-direction="descending"/>
        <hrpt-on-time start-time="2012-08-06T22:46:50.000" end-time="2012-08-06T22:54:29.000" flight-direction="ascending"/>
        <hrpt-on-time start-time="2012-08-06T23:22:39.000" end-time="2012-08-06T23:41:52.000" flight-direction="descending"/>
        <hrpt-on-time start-time="2012-08-07T00:28:44.000" end-time="2012-08-07T00:34:03.000" flight-direction="ascending"/>
        <hrpt-on-time start-time="2012-08-07T01:02:29.000" end-time="2012-08-07T01:23:14.000" flight-direction="descending"/>
        <hrpt-on-time start-time="2012-08-07T02:08:23.000" end-time="2012-08-07T02:15:24.000" flight-direction="ascending"/>
        <hrpt-on-time start-time="2012-08-07T02:46:08.000" end-time="2012-08-07T03:04:36.000" flight-direction="descending"/>
        <hrpt-on-time start-time="2012-08-07T03:47:39.000" end-time="2012-08-07T03:56:46.000" flight-direction="ascending"/>
      </hrpt-on-times>
    </events>
    <yaw-steering-coefficients>
      <pitch-cx>0.0029001748</pitch-cx>
      <roll-cy>-0.0008798931</roll-cy>
      <yaw-cz>0.0687868501</yaw-cz>
    </yaw-steering-coefficients>
    <attitude-bias>
      <pitch>0.000</pitch>
      <roll>0.000</roll>
      <yaw>0.000</yaw>
    </attitude-bias>
  </navigation>
  <processing>
    <obt-utc-correlation utc-0="2012-08-06T06:23:46.095" ccu-obt-0="3893228802" clock-step="3906240022" estimated-obt-utc-wrap-around-time="2012-08-24T10:18:33.074"/>
    <instrument name="avhrr">
      <attitude-bias>
        <pitch>0.00000</pitch>
        <roll>-0.00000</roll>
        <yaw>0.00000</yaw>
      </attitude-bias>
    </instrument>
    <instrument name="amsua">
      <attitude-bias>
        <pitch>0.00000</pitch>
        <roll>-0.00000</roll>
        <yaw>0.00000</yaw>
      </attitude-bias>
    </instrument>
    <instrument name="hirs">
      <attitude-bias>
        <pitch>0.00000</pitch>
        <roll>-0.00000</roll>
        <yaw>0.00000</yaw>
      </attitude-bias>
    </instrument>
    <instrument name="mhs">
      <attitude-bias>
```

```
      <pitch>0.00000</pitch>
      <roll>-0.00000</roll>
      <yaw>0.00000</yaw>
    </attitude-bias>
  </instrument>
  <instrument name="iasi">
    <attitude-bias>
      <pitch>0.00000</pitch>
      <roll>-0.00000</roll>
      <yaw>0.00000</yaw>
    </attitude-bias>
  </instrument>
 </processing>
</message>
<message satellite="NOAA-15" satellite-number="25338" mission="POES" international-spacecraft-designator="1998-030A">
 <navigation>
  <two-line-elements>
   <line-1>1 25338U 98030A   12218.20419605  .00000330  00000-0  15946-3 0  3552</line-1>
   <line-2>2 25338 098.6930 204.6599 0010273 331.7162 028.3478 14.25102937739835</line-2>
  </two-line-elements>
 </navigation>
</message>
<message satellite="NOAA-16" satellite-number="26536" mission="POES" international-spacecraft-designator="2000-055A">
 <navigation>
  <two-line-elements>
   <line-1>1 26536U 00055A   12218.18825056  .00000222  00000-0  14447-3 0  8438</line-1>
   <line-2>2 26536 099.0907 261.0601 0009931 308.2173 051.8151 14.12765495611957</line-2>
  </two-line-elements>
 </navigation>
</message>
<message satellite="NOAA-17" satellite-number="27453" mission="POES" international-spacecraft-designator="2002-032A">
 <navigation>
  <two-line-elements>
   <line-1>1 27453U 02032A   12218.33279040  .00000199  00000-0  10334-3 0  7913</line-1>
   <line-2>2 27453 098.3339 242.8834 0011955 017.5180 342.6420 14.24466517525757</line-2>
  </two-line-elements>
 </navigation>
</message>
<message satellite="NOAA-18" satellite-number="28654" mission="POES" international-spacecraft-designator="2005-018A">
 <navigation>
  <two-line-elements>
   <line-1>1 28654U 05018A   12218.32536064 -.00000020  00000-0  13845-4 0  2735</line-1>
   <line-2>2 28654 099.0496 176.8329 0014858 019.9017 340.2746 14.11679858371493</line-2>
  </two-line-elements>
 </navigation>
</message>
<message satellite="NOAA-19" satellite-number="33591" mission="POES" international-spacecraft-designator="2009-005A">
```

```
  <navigation>
   <two-line-elements>
    <line-1>1 33591U 09005A   12218.34423752 -.00000105  00000-0 -33681-4 0  4627</line-1>
    <line-2>2 33591 098.8651 157.5290 0013104 241.9912 117.9946 14.11366220179949</line-2>
   </two-line-elements>
  </navigation>
 </message>
 <message satellite="NPP" satellite-number="37849" mission="POES" international-spacecraft-designator="2011-061A">
  <navigation>
   <two-line-elements>
    <line-1>1 37849U 11061A   12218.01484907  .00000134  00000-0  84412-4 0  2508</line-1>
    <line-2>2 37849 098.7159 154.7669 0000470 143.6034 216.5198 14.19550177 39961</line-2>
   </two-line-elements>
  </navigation>
 </message>
</multi-mission-administrative-message>
```

8.2 Example Message 2 (presence of a double manoeuvre)


```xml
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet type="text/xsl" href="mmam.xsl"?>

<multi-mission-administrative-message issue-number="70" issued-on="2012-08-08T07:58:47.056" issued-by="EUMETSAT" transmitted-via="Metop-A" format-version="1.0">
 <issuer-contact-information>
  <name>EUMETSAT MCC-G2</name>
  <name>User Service</name>
  <address>EUMETSAT-Allee 1</address>
  <address>D-64295 Darmstadt</address>
  <address>Germany</address>
  <telephone>+49 6151 807 3660</telephone>
  <e-mail>ops@eumetsat.int</e-mail>
  <internet>http://www.eumetsat.int</internet>
 </issuer-contact-information>
 <message satellite="Metop-A" satellite-number="29499" mission="EPS" international-spacecraft-designator="2006-044A">
  <announcements/>
  <status last-updated-on="2012-06-06T13:37:20" satellite-status="operational-prime">
   <subsystem name="A-DCS" status="operational"/>
   <subsystem name="AMSU-A" status="operational-with-limitations">
    <component name="channel-7" status="not-operational"/>
   </subsystem>
   <subsystem name="ASCAT" status="operational-with-limitations"/>
   <subsystem name="AVHRR" status="operational-with-limitations"/>
   <subsystem name="GOME-2" status="operational"/>
   <subsystem name="GRAS" status="operational"/>
   <subsystem name="HIRS" status="operational"/>
   <subsystem name="HRPT" status="operational">
    <component name="frequency-1701.300-MHz" status="operational"/>
    <component name="frequency-1707.000-MHz" status="not-operational"/>
   </subsystem>
   <subsystem name="IASI" status="operational"/>
   <subsystem name="LRPT" status="not-operational">
    <component name="frequency-137.1000-MHz" status="not-operational"/>
    <component name="frequency-137.9125-MHz" status="not-operational"/>
   </subsystem>
   <subsystem name="MHS" status="operational"/>
   <subsystem name="SAR" status="operational"/>
   <subsystem name="SEM" status="operational"/>
  </status>
  <navigation>
```

```
<two-line-elements valid-until="2012-08-08T13:30:00.000">
 <line-1>1 29499U 06044A   12220.25000000  .00000000  00000+0  46715-4 0 00011</line-1>
 <line-2>2 29499  98.6973 278.7633 0000609 172.5379 295.5154 14.21485317300989</line-2>
</two-line-elements>
<two-line-elements valid-from="2012-08-08T13:30:00.000">
 <line-1>1 29499U 06044A   12221.58343476  .00000000  00000+0  56907-4 0 00019</line-1>
 <line-2>2 29499  98.6974 280.0770 0000678 171.4472 276.3965 14.21370966301178</line-2>
</two-line-elements>
<statevectors-at-anx valid-from="2012-08-08T11:54:05.000" valid-until="2012-08-09T03:06:23.000" reference-frame-keplerian="TOD" reference-frame-cartesian="Earth-Fixed">
 <statevector-at-anx epoch="2012-08-08T11:54:05.000" orbit="30116">
  <semi-major-axis>7204.686441</semi-major-axis>
  <eccentricity>0.001122</eccentricity>
  <inclination>98.693</inclination>
  <perigee>67.743</perigee>
  <right-ascension>279.994</right-ascension>
  <mean-anomaly>292.375</mean-anomaly>
  <x-pos>-5831.857768</x-pos>
  <y-pos>4225.249262</y-pos>
  <z-pos>-0.168108</z-pos>
  <x-vel>0.974044</x-vel>
  <y-vel>1.331545</y-vel>
  <z-vel>7.355781</z-vel>
 </statevector-at-anx>
 <statevector-at-anx epoch="2012-08-08T13:04:46.383" orbit="30116">
  <semi-major-axis>7188.579096</semi-major-axis>
  <eccentricity>0.002386</eccentricity>
  <inclination>98.702</inclination>
  <perigee>74.281</perigee>
  <right-ascension>280.039</right-ascension>
  <mean-anomaly>176.941</mean-anomaly>
  <x-pos>544.612113</x-pos>
  <y-pos>-2478.111910</y-pos>
  <z-pos>-6744.228975</z-pos>
  <x-vel>-4.645708</x-vel>
  <y-vel>5.406934</y-vel>
  <z-vel>-2.362894</z-vel>
 </statevector-at-anx>
 <statevector-at-anx epoch="2012-08-08T13:05:13.617" orbit="30116">
  <semi-major-axis>7188.326408</semi-major-axis>
  <eccentricity>0.002425</eccentricity>
  <inclination>98.702</inclination>
  <perigee>75.636</perigee>
  <right-ascension>280.040</right-ascension>
  <mean-anomaly>177.196</mean-anomaly>
  <x-pos>418.187455</x-pos>
  <y-pos>-2329.657184</y-pos>
  <z-pos>-6805.912047</z-pos>
```

```
  <x-vel>-4.637912</x-vel>
  <y-vel>5.494486</y-vel>
  <z-vel>-2.166663</z-vel>
 </statevector-at-anx>
 <statevector-at-anx epoch="2012-08-08T13:35:26.000" orbit="30117">
  <semi-major-axis>7204.857089</semi-major-axis>
  <eccentricity>0.001090</eccentricity>
  <inclination>98.691</inclination>
  <perigee>68.805</perigee>
  <right-ascension>280.064</right-ascension>
  <mean-anomaly>291.277</mean-anomaly>
  <x-pos>-3463.445824</x-pos>
  <y-pos>6314.551451</y-pos>
  <z-pos>-4.363942</z-pos>
  <x-vel>1.447823</x-vel>
  <y-vel>0.790575</y-vel>
  <z-vel>7.355485</z-vel>
 </statevector-at-anx>
 <statevector-at-anx epoch="2012-08-08T13:54:46.382" orbit="30117">
  <semi-major-axis>7189.221295</semi-major-axis>
  <eccentricity>0.000822</eccentricity>
  <inclination>98.700</inclination>
  <perigee>190.392</perigee>
  <right-ascension>280.073</right-ascension>
  <mean-anomaly>238.410</mean-anomaly>
  <x-pos>-130.569066</x-pos>
  <y-pos>2796.926067</y-pos>
  <z-pos>6624.925864</z-pos>
  <x-vel>3.387396</x-vel>
  <y-vel>-6.167824</y-vel>
  <z-vel>2.665050</z-vel>
 </statevector-at-anx>
 <statevector-at-anx epoch="2012-08-08T13:55:13.618" orbit="30117">
  <semi-major-axis>7188.944038</semi-major-axis>
  <eccentricity>0.000796</eccentricity>
  <inclination>98.700</inclination>
  <perigee>194.863</perigee>
  <right-ascension>280.073</right-ascension>
  <mean-anomaly>235.550</mean-anomaly>
  <x-pos>-38.605880</x-pos>
  <y-pos>2627.676063</y-pos>
  <z-pos>6694.873847</z-pos>
  <x-vel>3.365158</x-vel>
  <y-vel>-6.259691</y-vel>
  <z-vel>2.471031</z-vel>
 </statevector-at-anx>
 <statevector-at-anx epoch="2012-08-08T15:16:48.000" orbit="30118">
```

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    <semi-major-axis>7204.928386</semi-major-axis>
    <eccentricity>0.001102</eccentricity>
    <inclination>98.690</inclination>
    <perigee>69.933</perigee>
    <right-ascension>280.132</right-ascension>
    <mean-anomaly>290.144</mean-anomaly>
    <x-pos>-427.450068</x-pos>
    <y-pos>7189.504223</y-pos>
    <z-pos>-5.254418</z-pos>
    <x-vel>1.646602</x-vel>
    <y-vel>0.095559</y-vel>
    <z-vel>7.355366</z-vel>
  </statevector-at-anx>
  <statevector-at-anx epoch="2012-08-08T16:58:11.000" orbit="30119">
    <semi-major-axis>7204.882385</semi-major-axis>
    <eccentricity>0.001100</eccentricity>
    <inclination>98.690</inclination>
    <perigee>69.962</perigee>
    <right-ascension>280.201</right-ascension>
    <mean-anomaly>290.163</mean-anomaly>
    <x-pos>2692.304403</x-pos>
    <y-pos>6680.014401</y-pos>
    <z-pos>0.906462</z-pos>
    <x-vel>1.526577</x-vel>
    <y-vel>-0.624552</y-vel>
    <z-vel>7.355381</z-vel>
  </statevector-at-anx>
  <statevector-at-anx epoch="2012-08-08T18:39:33.000" orbit="30120">
    <semi-major-axis>7204.939076</semi-major-axis>
    <eccentricity>0.001110</eccentricity>
    <inclination>98.691</inclination>
    <perigee>69.424</perigee>
    <right-ascension>280.271</right-ascension>
    <mean-anomaly>290.694</mean-anomaly>
    <x-pos>5292.226937</x-pos>
    <y-pos>4884.965401</y-pos>
    <z-pos>-0.118738</z-pos>
    <x-vel>1.113240</x-vel>
    <y-vel>-1.217266</y-vel>
    <z-vel>7.355424</z-vel>
  </statevector-at-anx>
  <statevector-at-anx epoch="2012-08-08T20:20:55.000" orbit="30121">
    <semi-major-axis>7204.966652</semi-major-axis>
    <eccentricity>0.001121</eccentricity>
    <inclination>98.692</inclination>
    <perigee>69.434</perigee>
    <right-ascension>280.340</right-ascension>
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<mean-anomaly>290.682</mean-anomaly>
<x-pos>6873.768151</x-pos>
<y-pos>2149.853992</y-pos>
<z-pos>-0.601509</z-pos>
<x-vel>0.485591</x-vel>
<y-vel>-1.576684</y-vel>
<z-vel>7.355406</z-vel>
</statevector-at-anx>
<statevector-at-anx epoch="2012-08-08T22:02:17.000" orbit="30122">
<semi-major-axis>7204.983620</semi-major-axis>
<eccentricity>0.001123</eccentricity>
<inclination>98.693</inclination>
<perigee>69.629</perigee>
<right-ascension>280.410</right-ascension>
<mean-anomaly>290.486</mean-anomaly>
<x-pos>7132.535381</x-pos>
<y-pos>-999.027765</y-pos>
<z-pos>-0.590045</z-pos>
<x-vel>-0.236009</x-vel>
<y-vel>-1.632889</y-vel>
<z-vel>7.355361</z-vel>
</statevector-at-anx>
<statevector-at-anx epoch="2012-08-08T23:43:39.000" orbit="30123">
<semi-major-axis>7204.945372</semi-major-axis>
<eccentricity>0.001125</eccentricity>
<inclination>98.693</inclination>
<perigee>70.238</perigee>
<right-ascension>280.480</right-ascension>
<mean-anomaly>289.879</mean-anomaly>
<x-pos>6018.616934</x-pos>
<y-pos>-3955.742477</y-pos>
<z-pos>-0.606209</z-pos>
<x-vel>-0.912210</x-vel>
<y-vel>-1.374706</y-vel>
<z-vel>7.355308</z-vel>
</statevector-at-anx>
<statevector-at-anx epoch="2012-08-09T01:25:01.000" orbit="30124">
<semi-major-axis>7204.942885</semi-major-axis>
<eccentricity>0.001117</eccentricity>
<inclination>98.692</inclination>
<perigee>70.545</perigee>
<right-ascension>280.548</right-ascension>
<mean-anomaly>289.570</mean-anomaly>
<x-pos>3746.292479</x-pos>
<y-pos>-6151.241544</y-pos>
<z-pos>-0.714518</z-pos>
<x-vel>-1.412642</x-vel>

```
      <y-vel>-0.852024</y-vel>
      <z-vel>7.355268</z-vel>
    </statevector-at-anx>
    <statevector-at-anx epoch="2012-08-09T03:06:23.000" orbit="30125">
      <semi-major-axis>7205.000679</semi-major-axis>
      <eccentricity>0.001116</eccentricity>
      <inclination>98.690</inclination>
      <perigee>69.538</perigee>
      <right-ascension>280.619</right-ascension>
      <mean-anomaly>290.572</mean-anomaly>
      <x-pos>753.163830</x-pos>
      <y-pos>-7162.693134</y-pos>
      <z-pos>-1.248868</z-pos>
      <x-vel>-1.641076</x-vel>
      <y-vel>-0.166020</y-vel>
      <z-vel>7.355411</z-vel>
    </statevector-at-anx>
  </statevectors-at-anx>
  <orbit-ephemeris valid-from="2012-08-08T13:00:00.000" valid-until="2012-08-08T13:04:51.383" reference-frame="Earth-Fixed" interpolation-method="Lagrange" interpolation-degree="8"
time-step="8">
    <statevector epoch="2012-08-08T13:00:00.000">
      <x-pos>1862.53</x-pos>
      <y-pos>-3870.28</y-pos>
      <z-pos>-5785.20</z-pos>
      <x-vel>-4.4834</x-vel>
      <y-vel>4.2460</y-vel>
      <z-vel>-4.2864</z-vel>
    </statevector>
  </orbit-ephemeris>
  <orbit-ephemeris valid-from="2012-08-08T13:04:51.383" valid-until="2012-08-08T13:54:51.382" reference-frame="Earth-Fixed" interpolation-method="Lagrange" interpolation-degree="8"
time-step="8">
    <statevector epoch="2012-08-08T13:05:00.000">
      <x-pos>481.37</x-pos>
      <y-pos>-2404.18</y-pos>
      <z-pos>-6775.74</z-pos>
      <x-vel>-4.6423</x-vel>
      <y-vel>5.4512</y-vel>
      <z-vel>-2.2650</z-vel>
    </statevector>
    <statevector epoch="2012-08-08T13:13:00.000">
      <x-pos>-1618.80</x-pos>
      <y-pos>468.04</y-pos>
      <z-pos>-7006.16</z-pos>
      <x-vel>-3.9208</x-vel>
      <y-vel>6.2644</y-vel>
      <z-vel>1.3243</z-vel>
    </statevector>
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```
    <statevector epoch="2012-08-08T13:21:00.000">
      <x-pos>-3131.42</x-pos>
      <y-pos>3355.12</y-pos>
      <z-pos>-5555.17</z-pos>
      <x-vel>-2.2620</x-vel>
      <y-vel>5.5003</y-vel>
      <z-vel>4.5988</z-vel>
    </statevector>
    <statevector epoch="2012-08-08T13:29:00.000">
      <x-pos>-3719.32</x-pos>
      <y-pos>5514.13</y-pos>
      <z-pos>-2768.37</z-pos>
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      <z-pos>685.98</z-pos>
      <x-vel>1.7930</x-vel>
      <y-vel>0.1345</y-vel>
      <z-vel>7.3211</z-vel>
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      <y-pos>5619.00</y-pos>
      <z-pos>3974.34</z-pos>
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      <y-vel>-3.1662</y-vel>
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    </statevector>
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      <x-vel>3.4448</x-vel>
      <y-vel>-5.7625</y-vel>
      <z-vel>3.4013</z-vel>
    </statevector>
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time-step="8">
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      <z-pos>6660.56</z-pos>
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  <y-vel>-6.2144</y-vel>
  <z-vel>2.5683</z-vel>
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  <y-pos>-527.39</y-pos>
  <z-pos>7039.53</z-pos>
  <x-vel>2.5594</x-vel>
  <y-vel>-6.9997</y-vel>
  <z-vel>-1.0217</z-vel>
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  <x-pos>2274.56</x-pos>
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  <z-pos>5719.26</z-pos>
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  <z-vel>-4.3666</z-vel>
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  <y-pos>-6063.31</y-pos>
  <z-pos>3017.17</z-pos>
  <x-vel>-0.4411</x-vel>
  <y-vel>-3.5024</y-vel>
  <z-vel>-6.6600</z-vel>
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  <x-pos>1902.25</x-pos>
  <y-pos>-6933.73</y-pos>
  <z-pos>-414.61</z-pos>
  <x-vel>-1.7017</x-vel>
  <y-vel>-0.0355</y-vel>
  <z-vel>-7.3436</z-vel>
 </statevector>
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  <x-pos>909.73</x-pos>
  <y-pos>-6086.31</y-pos>
  <z-pos>-3746.45</z-pos>
  <x-vel>-2.3072</x-vel>
  <y-vel>3.4996</y-vel>
  <z-vel>-6.2532</z-vel>
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  <y-pos>-3708.45</y-pos>
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      <z-pos>-6175.52</z-pos>
      <x-vel>-2.1404</x-vel>
      <y-vel>6.2026</y-vel>
      <z-vel>-3.6614</z-vel>
    </statevector>
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      <y-pos>7118.32</y-pos>
      <z-pos>881.87</z-pos>
      <x-vel>1.7280</x-vel>
      <y-vel>0.7596</y-vel>
      <z-vel>-7.2992</z-vel>
    </statevector>
  </orbit-ephemeris>
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      <ascending-node-crossing time="2012-08-08T16:58:11.119" orbit-number="30119"/>
      <ascending-node-crossing time="2012-08-08T18:39:33.260" orbit-number="30120"/>
      <ascending-node-crossing time="2012-08-08T20:20:55.326" orbit-number="30121"/>
      <ascending-node-crossing time="2012-08-08T22:02:17.326" orbit-number="30122"/>
      <ascending-node-crossing time="2012-08-08T23:43:39.329" orbit-number="30123"/>
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    </ascending-node-crossings>
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      <subsatellite-daytime start-time="2012-08-08T18:06:49.527" end-time="2012-08-08T18:57:43.431"/>
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      <subsatellite-daytime start-time="2012-08-08T21:29:34.326" end-time="2012-08-08T22:20:28.270"/>
      <subsatellite-daytime start-time="2012-08-08T23:10:56.694" end-time="2012-08-09T00:01:50.687"/>
      <subsatellite-daytime start-time="2012-08-09T00:52:19.119" end-time="2012-08-09T01:43:13.129"/>
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        <hrpt-on-time start-time="2012-08-08T20:17:10.000" end-time="2012-08-08T20:32:15.000" flight-direction="ascending"/>
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    </events>
    <yaw-steering-coefficients>
      <pitch-cx>0.0029000343</pitch-cx>
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  </navigation>
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  <navigation>
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      <line-1>1 25338U 98030A   12220.45091947  .00000027  00000-0  30485-4 0  3578</line-1>
      <line-2>2 25338 098.6940 206.8870 0010074 324.7741 035.2792 14.25102409740153</line-2>
    </two-line-elements>
  </navigation>
</message>
<message satellite="NOAA-16" satellite-number="26536" mission="POES" international-spacecraft-designator="2000-055A">
  <navigation>
    <two-line-elements>
      <line-1>1 26536U 00055A   12220.45456007  .00000445  00000-0  26465-3 0  8459</line-1>
      <line-2>2 26536 099.0904 263.3608 0009889 301.2468 058.7740 14.12768290612270</line-2>
    </two-line-elements>
  </navigation>
</message>
<message satellite="NOAA-17" satellite-number="27453" mission="POES" international-spacecraft-designator="2002-032A">
  <navigation>
    <two-line-elements>
      <line-1>1 27453U 02032A   12220.36980143  .00000265  00000-0  13180-3 0  7930</line-1>
      <line-2>2 27453 098.3334 244.8171 0011961 011.6871 348.4587 14.24467925526042</line-2>
    </two-line-elements>
  </navigation>
</message>
<message satellite="NOAA-18" satellite-number="28654" mission="POES" international-spacecraft-designator="2005-018A">
  <navigation>
    <two-line-elements>
      <line-1>1 28654U 05018A   12220.38078243  .00000347  00000-0  21538-3 0  2754</line-1>
      <line-2>2 28654 099.0502 178.9066 0014615 014.4302 345.7315 14.11682344371788</line-2>
    </two-line-elements>
  </navigation>
</message>
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    <line-2>2 33591 098.8654 159.5600 0013203 235.1023 124.8926 14.11368391180237</line-2>
   </two-line-elements>
  </navigation>
 </message>
 <message satellite="NPP" satellite-number="37849" mission="POES" international-spacecraft-designator="2011-061A">
  <navigation>
   <two-line-elements>
    <line-1>1 37849U 11061A   12220.69326104 -.00000068  00000-0 -11761-4 0  2526</line-1>
    <line-2>2 37849 098.7164 157.4048 0000568 132.3882 227.7331 14.19549970 40348</line-2>
   </two-line-elements>
  </navigation>
 </message>
</multi-mission-administrative-message>
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