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| Attitude Data Message test Plan/Report |

CCSDS Record

CCSDS 504.2-Y-1

Yellow Book

FOREWORD

This document records the plans for prototype testing and results of that testing for the Attitude Data Message, CCSDS 504.0-P-2.0, Pink Book. As a record of prototype testing, it is expected that expansion, deletion, or modification of this document will **not** occur. This document is subject to CCSDS document management and change control procedures, which are defined in the *Organization and Processes for the Consultative Committee for Space Data Systems*. Current versions of CCSDS documents are maintained at the CCSDS Web site:

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# Introduction

## PURPOSE

The purpose of this document is to describe the prototype testing conducted on the CCSDS Attitude Data Messages (ADM), CCSDS 504x0p-1.1 (reference [3]). An initial draft of this plan was prepared by the members of the CCSDS Navigation Working Group at the CCSDS Spring 2022 meetings conducted on-line.

## SCOPE

The scope of this document is testing of the Attitude Data Messages version 2. The ADM is part of the technical program of the CCSDS Navigation Working Group. Document 504x0p-1.1 is an update to the existing CCSDS/ISO Standard Attitude Data Messages CCSDS 504.0-B-1 (reference [2]). ADM document CCSDS 504x0p-1.1 completed a joint CCSDS Agency Review; the process is described in reference [1]. In applicable places the prototyping includes results based on modifications to the reference [3] provided via the Review Item Discrepancy (RID) process described in reference [1].

## APPLICABILITY

The ADM describes standard formats for the interagency exchange of data required for spacecraft tracking and navigation (specifically, attitude parameters and attitude ephemeris). There are three distinct message types that make up the Attitude Data Messages. These are:

* Attitude Parameter Message (APM)
* Attitude Ephemeris Message (AEM)
* Attitude Comprehensive Message (ACM)

This document applies to the prototype testing required to advance the ADM version 2 and its three constituent messages from Pink Book to Blue Book status.

In its new revision, the ADM now includes an additional message type, the Attitude Comprehensive Message or ACM. The APM and AEM are still present but have changed. Testing of the APM and AEM will be adapted to the changes made.

## RATIONALE

The CCSDS Procedures Manual states that for a Recommendation to become a Blue Book, the standard must be tested in an operational manner. The following requirements for an implementation exercise were excerpted from reference [1]:

“At least two independent and interoperable prototypes or implementations must have been developed and demonstrated in an operationally relevant environment, either real or simulated.”

This document outlines the Navigation Working Group’s approach to meeting this requirement for the ADM 504x0p-1.1.

## DOCUMENT STRUCTURE

The first sections of this document describe the Test Plan for the prototyping activity; the last sections of the document provide a Test Report of the realized plan. Acronyms are provided in Annex A.

## References

The following documents are referenced in this document. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this document are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS documents.

[1] *Organization and Processes for the Consultative Committee for Space Data Systems*, CCSDS A02.1-Y-4. Yellow Book. Issue 4. Washington, D.C.: CCSDS, April 2014.

[2] *Attitude Data Messages*. Recommendation for Space Data System Standards, CCSDS 504.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2004.

[3] *Attitude Data Messages*. Draft Recommendation for Space Data System Standards, CCSDS 504x0p-1.1 Pink Book. Washington, D.C.: CCSDS, June 2022.

[4] *Orbit Data Messages V3 Test Plan*, CCSDS 502.1-Y-2

# Summary Conclusion/Recommendation

The test plan and test reports documented herein substantiate that the organizations participating in the CCSDS Navigation Working Group have successfully conducted prototype testing of the Attitude Parameter Message, Attitude Ephemeris Message, and Attitude Comprehensive Message described in the Attitude Data Messages (ADM) 504x0p-1.1 document. During the testing, messages of the various types were produced by several different organizations, and the ability to read/process the messages was demonstrated. Based on the diversity of agencies able to read/write the messages, and the positive test results, the Navigation Working Group recommends that the revised 504x0p-1.1 document be promoted to a Blue Book CCSDS Recommended Standard.

# Attitude Data Messages (ADM) Testing Goals

The test of the ADM will exercise the following three message types that together constitute the Attitude Data Messages:

* Attitude Parameter Message (updated from version 1 (reference [2]))
* Attitude Ephemeris Message (updated from version 1 (reference [2]))
* Attitude Comprehensive Message (new in version 2 (reference [3]))

The tests described in Section 5 of this test plan will be conducted in order to meet the CCSDS requirements described in Section 1. The results of the testing are presented in Section 7.

## APM Overview

The APM is an ASCII file in “keyword=value” format. An XML format is also available. It contains a single state that must be propagated by the recipient. The file is organized into 3 sections: the Header section, Metadata section, and the Data section. The Header section contains identification information (version, creation date, originator). The Metadata section contains information regarding the object to which the state applies, applicable reference frame and time system. The Data section contains the attitude state in quaternion or Euler form, or other quantities as required (angular momentum vector, physical characteristics, spin). There is also an optional section that can contain user defined parameters.

## AEM Overview

The AEM is an ASCII file in a hybrid “keyword=value” format (header and metadata are keyword=value, data lines have a positional field layout). An XML format is also available. The AEM contains attitude states for an object at multiple points in time. The file is organized into 3 sections: the Header section, Metadata section, and the Data section. The Header section contains identification information (version, creation date, originator). The Metadata section contains information regarding the object to which the attitude applies, applicable reference frame, time system, interpolation parameters, and data start/stop times. The Data section contains the attitude state components at each epoch, plus additional derivatives or angular momentum coordinates. The recipient must interpolate to obtain arbitrary states between ephemeris points.

## ACM Overview

The ACM is an ASCII file in a hybrid “keyword=value” format (header and metadata are keyword=value, data lines have a positional field layout). An XML format is also available. The ACM is comprehensive, in allowing users to exchange attitude, uncertainty data, maneuver, and many others. The file is organized into six distinct sections, as shown in the table below (excerpted from Table 5-1 of the draft standard Reference [3]): the Header section, Metadata section, and the Data section with its six subsections as listed.

The Header section contains identification information (version, creation date, originator). The Metadata section contains information regarding the object to which the attitude applies, applicable reference frame, time system, interpolation parameters, and data start/stop times. The Data Section contains attitude and covariance time histories, as well as detailed specificity of physical properties, maneuver data, attitude determination data, and user-defined parameters.

Table ‑ ACM Layout and Ordering Specification

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Section** | | | **Content** | **Status**  **M/O** |
| Header | | | A single header of the message | M |
| Metadata | | | A single Metadata section (data about data) | M |
| Data | attitude data #1 | data description | One or more attitude state time histories (each consisting of one or more attitude states) | O |
| data lines |
| **⁝** | |
| attitude data #n | data description |
| data lines |
| physical properties |  | A single space object  physical characteristics section | O |
| covariance data #1 | data description | One or more covariance time histories (each consisting of one or more covariance matrix diagonals) | O |
| data lines |
| **⁝** | |
| covariance data #n | data description |
| data lines |
| maneuver data #1 |  | One or more maneuver specification sections | O |
| **⁝** | |
| maneuver data #n |  |
| attitude determination data |  | A single attitude determination Data section | O |
| user-defined data |  | A single user-defined Data section | O |

# Test Plan Overview

## Testing philosophy

The prototyping of the ADM is designed to be consistent with the changes made between ADM versions 1 and 2.

The tests described in the next sections are data oriented (not format oriented). The messages that are exchanged can be either XML or KVN messages.

Classically, all prototypes of the APM, AEM, ACM use KVN syntax. The messages are also converted to XML to check the consistency between XML and KVN formats.

## APM

The APM version 1 has already been proved to be useable in an operational context. By analogy, the APM – version 2 is also useable in an operational context if the data present in the message are the same, or if it can be shown that the data in a version 1 message can be converted into data in a version 2 message.

Here is a close examination of the changes between version 1 and 2, and the subsequent need for testing.

Note that explicit subsection START/STOP keywords were added for each subsection to more clearly delineate the logical block boundaries.

| **Differences between versions 1 and 2** | **Specific test needed ?  (and justification)** |
| --- | --- |
| **Header**  MESSAGE\_ID added (optional) | No  Additional information (MESSAGE\_ID) is present, but it is not essential for attitude processing (it is effectively a comment). |
| **MetaData**  No change | No |
| **Quaternion Data**  Direction: in version 2, the direction is implicitly from A to B. | No: the data are the same.  Frame A and B have to be swapped in version 2 if the direction is B2A in version 1. |
| **Euler Data**  Direction: in version 2, the direction is implicitly from A to B.  Rotation sequence: format change  Angle names: format change  Rates are not provided in Euler blocks in version 2. | No: the data are the same.  The data from a version 1 message should be sent as 2 blocks in version 2 if rates are present. Rates should now be provided in a specific “ANGVEL” bloc  Rotation sequence 123 is written XYZ in version 2.  X\_ANGLE is now written ANGLE\_1.  (similar changes for Y and Z components) |
| **Spin Data**  In version 2, the direction is implicitly from A to B.  The version 1 spin block is still present in version 2.  An alternative form has been added. | Test of the additional features needed. |
| **Angular Velocity**  This block has been added. | Test of added keywords needed. |
| **Inertia Block** | No  (no change) |
| **Maneuver block**  Delta\_mass added. | No as delta mass was not needed in version 1. |

The following tests are then proposed:

|  |  |  |  |
| --- | --- | --- | --- |
| **Test #** | **Purpose** | **Agencies, Direction** | **Msg Type** |
| APM#1 | Spin Data test  Test of the new features | X => Y => X | APM |
| APM#2 | Angular momentum test  Test of the new features | X => Y => X | APM |
| APM#3 | Full message, will include test of added angular velocity block.  (in particular for KVN-XML format consistency check) | X => Y => X | APM |

Note: all tests include KVN <-> XML conversion.

## AEM

The AEM version 1 has already been proved to be useable in an operational context. By analogy, the AEM version 2 is also useable in an operational context if the data present in the message are the same, or if it can be shown that the data in a version 1 message can be converted into data in a version 2 message.

Here is a close examination of the changes between version 1 and 2, and the subsequent need for testing.

| **Differences between versions 1 and 2** | **Specific test needed ?  (and justification)** |
| --- | --- |
| **Header**  MESSAGE\_ID added (optional) | No  Additional information (MESSAGE\_ID) is present, but it is not essential for attitude processing (it is effectively a comment). |
| **MetaData**  QUATERNION\_TYPE: removed in version 2 as the order is imposed (Q1, Q2, Q3, QC ⬄ “LAST”).  EULER\_ROT\_SEQ: format change in version 2 (as in APM)  ATTITUDE\_DIR removed in version 2: the direction is A2B implicitly in version 2 (as in APM)  RATE\_FRAME: can be any frame in version 2, and not just REF\_FRAME\_A or REF\_FRAME\_B) | No: the information is the same  QUATERNION\_TYPE: elements should be reordered if QC was “FIRST” in version 1.  EULER\_ROT\_SEQ: value should be changed. Example “XYZ” instead of “123”.  ATTITUDE\_DIR: swap A and B if the value is “B2A” in version 1.  RATE\_FRAME/ANGVEL\_FRAME: possibilities in version 2 include those allowed in version 1 |
| **Data lines**  QUATERNION/RATE: now called QUATERNION/ANGVEL (same information)  EULER\_ANGLE/RATE: now called EULER\_ANGLE/ANGVEL (same information)  EULER\_ANGLE/DERIVATIVE: new in version 2  SPIN/NUTATION\_MOM: new in version 2 | “EULER\_ANGLE/DERIVATIVE” is a new type of line.  “SPIN/NUTATION\_MOM” is a new type of line. |

The following tests are then proposed:

|  |  |  |  |
| --- | --- | --- | --- |
| **Test #** | **Purpose** | **Agencies, Direction** | **Msg Type** |
| AEM#1 | Euler angles / derivative test | X => Y => X | AEM |
| AEM#2 | Spin / nutation + angular momentum | X => Y => X | AEM |
| AEM#3 | Complex message  (containing at least 2 blocks) | X => Y => X | AEM |

Note: all tests include KVN <-> XML conversion.

## ACM

The ACM contains 6 different data blocks that are: Attitude State Time History, Space Object Physical Characteristics, Covariance Time History, Maneuver Specification, Attitude Determination Data, and User-Defined Parameters.

The testing strategy is inspired by what is done for the ODM V3 (OCM), see Reference [4]:

- 1 round-trip test for each data block (only one block in the message).

- 1 test with a full message.

Some of the tests will implement specific features:

- data lines with relative or absolute times

- content with values taken from SANA registry

The objectives of all these tests are to check that :

- the standard contains accurate descriptive information of the data contained in the message, and that the messages that are exchanged are compliant with the description,

- the data present in the message can be used effectively in a (real or simulated) operational context, and that, in particular, no important information is missing.

Here is a summary of the tests that are planned:

| **Test #** | **Purpose** | **Agencies, Direction** | **Msg Type** |
| --- | --- | --- | --- |
| ACM#1 | Attitude states history | X => Y => X | ACM |
| ACM#2 | Physical data | X => Y => X | ACM |
| ACM#3 | Covariance data | X => Y => X | ACM |
| ACM#4 | Maneuver | X => Y => X | ACM |
| ACM#5 | Attitude determination | X => Y => X | ACM |
| ACM#6 | User defined data | X => Y => X | ACM |
| ACM#7 | Full message | X => Y => X | ACM |

Note: All tests include KVN <-> XML conversion.

# Test Plan Details

## TEST CASE APM#1: SPIN DATA Unit Test

### Test description

In this test, X will create an APM message for a spinning object and send it to Y. The message will contain the appropriate header information, as well as reference frame information, and spin data (containing angular momentum vector coordinates). The spin data are the following:

|  |  |
| --- | --- |
| Epoch | 1 jan 2023 0h TAI |
| SPIN\_ALPHA | 10 deg |
| SPIN\_DELTA | 30 deg |
| SPIN\_ANGLE | 0 deg |
| SPIN\_ANGLE\_VEL | 1 deg/s |
| MOMENTUM\_ALPHA | 80 deg |
| MOMENTUM\_DELTA | 10 deg |
| NUTATION\_VEL | 0.5 deg/s |

Y will generate a quaternion at a different epoch (1 jan 2023 12h TAI) using the method described in the standard. Y will send an APM containing the quaternion to X and will also report to X about potential issues. X then will analyze the results obtained by Y by comparing with their own results.

### Expected results

It is anticipated that X and Y will successfully write and read the message and that the round-trip consistency test will yield a match. It is expected that the quaternions computed by X and Y will be the same (to some negligible accuracy). Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

## TEST CASE APM#2: Angular velocity Unit Test

### Test description

In this test, X will create an APM message and send it to Y. The message will contain the appropriate header information, as well as quaternion and angular momentum data. The quaternion represents the attitude of the body frame in EME2000. The angular velocity data give the coordinates of the angular velocity vector in the body frame.

The data are the following:

|  |  |
| --- | --- |
| Epoch | 1 jan 2023 0h TAI |
| *Quaternion:* | |
| REF\_FRAME\_A | EME2000 |
| REF\_FRAME\_B | SC\_BODY |
| QC | 0.925417 |
| Q1 | 0.171010 |
| Q2 | -0.030154 |
| Q3 | 0.336824 |
| *Angular velocity:* | |
| ANGVEL\_FRAME | SC\_BODY |
| ANGVEL\_X | 0.0001 deg/sec |
| ANGVEL\_Y | 0.05 deg/sec |
| ANGVEL\_Z | 0.00003 deg/sec |

Y will ingest the message, compute the angular velocity vector in EME2000, and transmit a message containing the computed coordinates to X for comparison and verification.

### EXPECTED RESULTS

It is anticipated that X and Y will successfully write and read the messages and that the round-trip consistency test will yield a match. Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

## TEST CASE APM#3: Full message

### Test description

In this test, X will create an APM message that contains all data blocks and send it to Y. The message will contain the appropriate header and metadata information. In particular, the message will contain the following Euler data describing the orientation of the body frame in EME2000 and the angular velocity in the spacecraft body frame:

|  |  |
| --- | --- |
| Epoch | 1 jan 2023 0h TAI |
| EULER\_ROT\_SEQ | ZXZ |
| ANGLE\_1 | 10 deg |
| ANGLE\_2 | 20 deg |
| ANGLE\_3 | 0 deg |

Y will generate a quaternion describing the orientation of the body frame in EME2000 using the data above and send it to X. Y will also report about potential issues. X will compare their results with Y and report back to Y.

### Expected results

It is anticipated that X and Y will successfully write and read the merged data blocks and that the round-trip consistency test will yield a match. It is expected that the quaternions computed by X and Y will be the same, as will all logical blocks exchanged. Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

## TEST CASE AEM#1: Euler angle + derivatives unit test

### Test description

In this test, X will create an AEM message containing Euler angles and associated derivatives. The message will contain the appropriate header information, as well as reference frame information and attitude data (Euler angles and derivatives). The data will be the following:

|  |  |
| --- | --- |
| Initial epoch | 1 jan 2023 0h TAI |
| EULER\_ROT\_SEQ | ZXZ |
| ANGLE\_1 | 10 deg |
| ANGLE\_2 | 20 deg |
| ANGLE\_3 | -10 deg |
| ANGLE\_1\_DOT | 1 deg/s |
| ANGLE\_2\_DOT | 1 deg/s |
| ANGLE\_3\_DOT | -1 deg/s |

The AEM will contain the data for 10 different epochs every 30 seconds (TAI).

Y will ingest the message and will generate an AEM containing quaternion and angular velocity data (with QUATERNION/ANGVEL data line type). Y will send it to X and will also report about potential issues. X will compare results with Y and report back to Y.

5.3.2 EXPECTED RESULTS

It is anticipated that the quaternion and angular velocity ephemeris determined by Y and sent to X will be consistent with the reference data computed by X using the same inputs. Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test

## TEST CASE AEM#2: Spin / nutation + angular momentum unit test

### Test description

In this test, X will create an AEM message for a spinning object and send it to Y. The message will contain the appropriate header and metadata information, as well as reference frame information, and spin data (containing angular momentum vector coordinates). The spin data at initial epoch are the following:

|  |  |
| --- | --- |
| Epoch | 1 jan 2023 0h TAI |
| SPIN\_ALPHA | 10 deg |
| SPIN\_DELTA | 30 deg |
| SPIN\_ANGLE | 0 deg |
| SPIN\_ANGLE\_VEL | 1 deg/s |
| MOMENTUM\_ALPHA | 80 deg |
| MOMENTUM\_DELTA | 10 deg |
| NUTATION\_VEL | 0.5 deg/s |

The AEM will contain the data for 10 different epochs every 30 seconds (TAI). At each epoch the spin\_angle will be incremented by 1 deg.

Y will ingest the message, and transmit the message back to X for comparison and verification.

### Expected results

It is anticipated that X and Y will successfully write and read the spacecraft attitude data and that the round-trip consistency test will yield a match. Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

## TEST CASE AEM#3: complex message

### Test description

In this test, X will create an AEM message containing all data blocks. The message will contain the appropriate header and metadata information, as well as reference frame information, and the appropriate data. Y will ingest the message. The message will in particular contain the following data describing the attitude of the body frame in EME2000:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Time offset (seconds) | QC | Q1 | Q2 | Q3 |
| 0 | 0.925417 | 0.171010 | -0.030154 | 0.336824 |
| 30 | 0.851651 | 0.397131 | 0.144544 | 0.309976 |
| 60 | 0.719846 | 0.413176 | 0.492404 | 0.262003 |
| 90 | 0.538986 | 0.142244 | 0.806707 | 0.196175 |
| 120 | 0.321394 | -0.321394 | 0.883022 | 0.116978 |
| 150 | 0.081900 | -0.763129 | 0.640342 | 0.029809 |
| 180 | -0.163176 | -0.969846 | 0.171010 | -0.059391 |
| 210 | -0.397131 | -0.851651 | -0.309976 | -0.144544 |
| 240 | -0.604023 | -0.492404 | -0.586824 | -0.219846 |
| 270 | -0.769751 | -0.099601 | -0.564863 | -0.280166 |
| 300 | -0.883022 | 0.116978 | -0.321394 | -0.321394 |

Using the data at the initial epoch, Y will convert the coordinates of some vector given in the inertial frame into coordinates in the body frame. The coordinates in the inertial frame are [1; 1; 1]. Y will send the results to X and will also report to X about potential issues.

X will compare their results with Y and report back to Y.

### Expected results

It is anticipated that X and Y will successfully write and read the spacecraft attitude data and that the round-trip consistency test will yield a match. Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

## TEST CASE ACM#1: ACM attitude DATA UNIT TEST

### Test description

For this test, X will send an ACM describing a sequence of spacecraft attitude states as a function of relative time to Y. The attitude states will consist of a DCM (matrix from the inertial frame to the body frame). X will send the message to Y, Y will compute a quaternion from the DCM and send it back to X (the format does not matter). Y will also report about potential issues. X will compare results with Y and report back to Y.

Epoch: 2023-01-01T00:00:00 UTC

Time offset: 0 sec

DCM = [ -0.3333 0.9020 -0.2745

-0.6667 -0.0196 0.7451

0.6667 0.4314 0.6078]

Time offset: 1 sec

DCM = [-0.3347 0.9017 -0.2736

-0.6655 -0.0206 0.7461

0.6672 0.4318 0.6070]

### Expected results

It is anticipated that X and Y will successfully write and read the attitude state time history and that the round-trip consistency test will yield a match. Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

## TEST CASE ACM#2: ACM PHYSICAL CHARACTERISTICS UNIT TEST

### TEST DESCRIPTION

For this test, X will send an ACM describing space object physical characteristics to Y. In this simple case, an inertia matrix and wet mass will be shared. Y will ingest the message, and transmit the message back to Y for comparison and verification.

Inertia Matrix in the Spacecraft body frame:

[770.8 -74.5 -80.2

-74.5 1277.4 -25.4

-80.2 -25.4 1497.5] kg.m2

Wet mass: 1900 kg

### EXPECTED RESULTS

It is anticipated that X and Y will successfully write and read the space object physical characteristics and that the round-trip consistency test will yield a match. Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

## TEST CASE ACM#3: Covariance data UNIT TEST

### TEST DESCRIPTION

For this test, X will send an ACM describing a sequence of spacecraft attitude covariances as a function of absolute time to Y. In this simple case, two covariance blocks will be included: (1) covariance containing quaternion errors; and (2) covariance containing angle and gyro bias errors. Y will ingest the message, and transmit the message back to X for comparison and verification.

1)

Epoch = 2022-09-27T00:00:00 UTC

Time = 2022-09-27T00:09:00

Covariance = 2.70e-10 1.48e-10 5.18e-12 1.80e-10

Time = 2022-09-27T00:10:00

Covariance = 2.72e-10 1.51e-10 5.19e-12 1.83e-10

2)

Epoch = 2022-09-27T00:00:00 UTC

Time = 2022-09-27T00:09:00

Covariance = 8.50-e-9 deg2 1.99e-8 deg2 5.34e-8 deg2 1.66e-13 (deg/sec)2 2.88e-13 (deg/sec)2 5.36e-13 (deg/sec)2

Time = 2022-09-27T00:10:00

Covariance = 8.11e-9 deg2 1.86e-8 deg2 4.86e-8 deg2 1.41e-13(deg/sec)2 2.76e-13(deg/sec)2 4.96e-13(deg/sec)2

Note that units for Covariance are specified in Annex B of 504x0p-1.1.

### EXPECTED RESULTS

It is anticipated that X and Y will successfully write and read the sequence of spacecraft attitude and gyro bias covariances as a function of absolute time and that the round-trip consistency test will yield a match. Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

## TEST CASE ACM#4: Maneuver data UNIT TEST

### TEST DESCRIPTION

For this test, X will send an ACM describing space object attitude maneuvers to Y. In this simple case, a “target momentum” maneuver in the spacecraft body frame will be shared. Y will ingest the message, and transmit the message back to X for comparison and verification.

Time = 2022-11-02T00:00:00 UTC

Target momentum = [0 10 0] Nms

### EXPECTED RESULTS

It is anticipated that X and Y will successfully write and read the space object maneuvers and that the round-trip consistency test will yield a match. Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

## TEST CASE ACM#5: Attitude determination data UNIT TEST

### TEST DESCRIPTION

For this test, X will send an ACM describing attitude determination characteristics for the LRO spacecraft’s onboard Extended Kalman Filter (EKF) to Y. Y will ingest the message, and transmit the message back to X for comparison and verification.

|  |  |
| --- | --- |
| AD\_METHOD | EKF |
| ATTITUDE\_SOURCE | OBC |
| NUMBER\_STATES | 7 |
| ATTITUDE\_STATES | QUATERNION |
| REF\_FRAME\_A | J2000 |
| REF\_FRAME\_B | SC\_BODY\_1 |
| RATE\_STATES | GYRO\_BIAS |
| SIGMA\_U | 1.9e-8 deg/s\*\*1.5 |
| SIGMA\_V | 8.3e-5 deg/s\*\*0.5 |
| SENSOR\_START |  |
| SENSOR\_NUMBER | 1 |
| SENSOR\_USED | AST |
| NUMBER\_SENSOR\_NOISE\_COVARIANCE | 3 |
| SENSOR\_NOISE\_STDDEV | 0.003 deg 0.003 deg 0.010 deg |
| SENSOR\_STOP |  |
| SENSOR\_START |  |
| SENSOR\_NUMBER | 2 |
| SENSOR\_USED | AST |
| NUMBER\_SENSOR\_NOISE\_COVARIANCE | 3 |
| SENSOR\_NOISE\_STDDEV | 0.003 deg 0.003 deg 0.010 deg |
| SENSOR\_STOP |  |

### EXPECTED RESULTS

It is anticipated that X and Y will successfully write and read the attitude determination data and that the round-trip consistency test will yield a match. Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

## TEST CASE ACM#6: User-DEFINED parameters UNIT TEST

### TEST DESCRIPTION

For this test, X will send an ACM describing user-defined parameters to Y. In this simple case, additional satellite characteristics will be shared (thruster direction in body frame for 2 thrusters). Y will ingest the message, and transmit the message back to X for comparison and verification.

Thruster 1 direction = [-0.97 0.003 -0.2431]

Thruster 2 direction = [-0.96 -0.001 -0.28]

### EXPECTED RESULT

It is anticipated that X and Y will successfully write and read the user-defined parameters and that the round-trip consistency test will yield a match. Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

## TEST CASE ACM#7: Full message

### TEST DESCRIPTION

For this test, X will send an ACM containing the merged data blocks of all of the previous unit test content to Y. Y will ingest the message, and transmit the message back to X for comparison and verification.

### EXPECTED RESULTS

It is anticipated that X and Y will successfully write and read the merged data blocks and that the round-trip consistency test will yield a match. Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

## Message formats

The messages are typically exchanged in KVN format. All messages will be separately converted from KVN to XML for validation against the schemas.

Note:   
The messages that are exchanged can also be in XML format.

# Test Report Overview

Engineers at X and Y will prepare test data sheets as applicable, and send them to the Navigation Working Group via email.

The Test Report Details will be consolidated in Section 7 of this document. A summarization of the test process and the recommendation of the Navigation Working Group may be found in Section 2 of the report. The report will be submitted to the CCSDS Engineering Steering Group (CESG) and CCSDS Management Council (CMC), along with results of the Agency Reviews. At that time, a formal request will be submitted to the CMC for progression of the ADM to CCSDS Blue Book status.

The next page contains a format for the test data sheets that will be used to report the results of individual tests. The form includes sections for the producer of the message and the consumer of the message (producing agency, producing test engineer, consuming agency, and consuming test engineer).

**SAMPLE**



**Attitude Data Messages P-1.1 Prototype Test Data Sheet**

|  |  |  |
| --- | --- | --- |
| 1 | Report Date: |  |
| 2 | Program Under Test: | Attitude Data Messages P1.1 (ADM) Prototype |
| 3 | Test Case Number: |  |
| 4 | Agencies Participating in this Test Case: |  |
| 5 | Agency Responsible for Producing Test Message |  |
| 6 | Producing Test Engineer: |  |
| 7 | Agency Responsible for Consuming Test Message |  |
| 8 | Consuming Test Engineer: |  |
| 9 | Spacecraft: |  |
| 10 | Results (Pass, Partial Pass, Fail): |  |
| 11 | Variances from Expected Result: |  |
| 12 | Comments: |  |

# Test Report Details

## KVN tests

### Test Case APM#1

|  |  |  |
| --- | --- | --- |
| 1 | Report Date: | 5 February 2023 |
| 2 | Program Under Test: | Attitude Data Messages P1.1 (ADM) Prototype |
| 3 | Test Case Number: | APM#1 |
| 4 | Agencies Participating in this Test Case: | NASA/GSFC, CNES |
| 5 | Agency Responsible for Producing Test Message | NASA/GSFC |
| 6 | Producing Test Engineer: | Julie Halverson |
| 7 | Agency Responsible for Consuming Test Message | CNES |
| 8 | Consuming Test Engineer: | Alain Lamy |
| 9 | Spacecraft: | MMS1 |
| 10 | Results (Pass, Partial Pass, Fail): | Pass |
| 11 | Variances from Expected Result: | Less than 1.e-10 difference on quaternion components (consistent with number of digits in files) |
| 12 | Comments: | NASA:GSFC sent an APM in KVN format to CNES. The file contained the expected keywords and values. The file also contained some unexpected non ASCII characters (visible white spaces), so the file was regenerated with a different tool and resent. The second version of the file was correct.  No syntax anomalies were detected (correct keyword and values as defined in the test, no ordering problem). The processing of KVN files was made easier thanks to a tool generated by CNES.  CNES generated an APM file containing a quaternion at the epoch defined in the test plan, and sent it to NASA/GSFC. In addition, a second file was generated containing quaternions every second for more accurate comparisons. The comparison of the quaternions sent by CNES and recomputed by NASA/GSFC shows differences of less than 1.e-10 on the quaternion components (which is consistent with the data accuracy in the files). The APM sent by CNES was also successfully read and processed by NASA/GFSC.  The test proves that the standard describes the data and the processings accurately enough as 2 independent entities have been able to obtain the same computation results from the exchanged data. |

### Test Case APM#2

|  |  |  |
| --- | --- | --- |
| 1 | Report Date: | 5 February 2023 |
| 2 | Program Under Test: | Attitude Data Messages P1.1 (ADM) Prototype |
| 3 | Test Case Number: | APM#2 |
| 4 | Agencies Participating in this Test Case: | NASA/GSFC, CNES |
| 5 | Agency Responsible for Producing Test Message | NASA/GSFC |
| 6 | Producing Test Engineer: | Julie Halverson |
| 7 | Agency Responsible for Consuming Test Message | CNES |
| 8 | Consuming Test Engineer: | Alain Lamy |
| 9 | Spacecraft: | LRO |
| 10 | Results (Pass, Partial Pass, Fail): | Pass |
| 11 | Variances from Expected Result: | Less than 1.e-10 deg/s on components of angular velocity (consistent with accuracy in files) |
| 12 | Comments: | NASA/GSFC sent an APM in KVN format to CNES. The file contained data as defined in the test APM#2.  The file was ingested by CNES and verified. The file contained the expected keywords and values. No syntax anomalies were detected (correct keyword and values as defined in the test, no ordering problem). The processing of KVN files was made easier thanks to a tool generated by CNES.  CNES generated an APM file the containing angular velocity vector in EME2000 and sent it to NASA/GSFC. NASA/GFSC processed the file and compared the components of the angular velocity vector with their own results.  The comparison of the 2 vectors shows a difference of 1.e-8 which is consistent with the data accuracy (number of digits present in the files). A more accurate comparison between NASA and CNES results made afterwards shows differences less than 1.e-15.  The test proves that the standard describes the data and the processings accurately enough as 2 independent entities have been able to obtain the same computation results from the exchanged data. |

### Test Case APM#3

|  |  |  |
| --- | --- | --- |
| 1 | Report Date: | 11 February 2023 |
| 2 | Program Under Test: | Attitude Data Messages P1.1 (ADM) Prototype |
| 3 | Test Case Number: | APM#3 |
| 4 | Agencies Participating in this Test Case: | NASA/GSFC, CNES |
| 5 | Agency Responsible for Producing Test Message | NASA/GSFC |
| 6 | Producing Test Engineer: | Julie Halverson |
| 7 | Agency Responsible for Consuming Test Message | CNES |
| 8 | Consuming Test Engineer: | Alain Lamy |
| 9 | Spacecraft: | MMS1 |
| 10 | Results (Pass, Partial Pass, Fail): | Pass |
| 11 | Variances from Expected Result: | Less than 1.e-15 on quaternion components |
| 12 | Comments: | NASA/GSFC sent an APM in KVN format to CNES. The file contained 4 different blocks: EULER, SPIN, INERTIA, MAN (data block not present in other APM tests, or not containing the same keywords).  All the data are consistent.  The EULER block contains data as defined in APM version 1 (and so different from what has already been tested in APM#1 test).  The file was ingested by CNES and verified. The file contained the expected keywords and values. No syntax anomalies were detected (correct keywords and values as defined in the test, no ordering problem). All the expected data were present. The processing of KVN files was made easier thanks to a tool generated by CNES.  CNES generated an APM file the containing a quaternion computed from the Euler angles describing the attitude of the spacecraft in EME2000. The message was sent to NASA/GSFC. NASA/GFSC processed the file and compared the components of the quaternion with their own results.  The comparison of the 2 quaternions shows a very good match. The difference between the 2 quaternion appears negligible (1.e-15).  The test proves that the standard describes the data and the processings accurately enough as 2 independent entities have been able to obtain the same computation results from the exchanged data. |

### Test Case AEM#1

|  |  |  |
| --- | --- | --- |
| 1 | Report Date: | 11 February 2023 |
| 2 | Program Under Test: | Attitude Data Messages P1.1 (ADM) Prototype |
| 3 | Test Case Number: | AEM#1 |
| 4 | Agencies Participating in this Test Case: | NASA/GSFC, CNES |
| 5 | Agency Responsible for Producing Test Message | NASA/GSFC |
| 6 | Producing Test Engineer: | Julie Halverson |
| 7 | Agency Responsible for Consuming Test Message | CNES |
| 8 | Consuming Test Engineer: | Alain Lamy |
| 9 | Spacecraft: | MMS1 |
| 10 | Results (Pass, Partial Pass, Fail): | Pass |
| 11 | Variances from Expected Result: | Difference less than 1.e-13 on quaternion components and less than 1.e-12 deg/s on angular velocity components. |
| 12 | Comments: | NASA/GSFC sent an AEM in KVN format to CNES. The file contained EULER\_ANGLE/DERIVATIVE data lines for 10 different epochs as specified in the test plan.  The file was ingested by CNES and verified. The file contained the expected keywords and values.  An anomaly was detected in the Metadata section: the ordering was not as defined in the standard (“TIME\_SYSTEM” keyword appeared in a wrong place.  A new KVN file was generated by NASA/GSFC and sent to CNES. No anomaly was detected for this second file.  CNES generated an AEM file containing QUATERNION/ANGVEL data lines. The quaternion and angular velocity vectors were computed from the data in the AEM file generated by NASA.  NASA/GFFC detected no anomaly in the generated AEM file. NASA/GSFC compared the data with their own computation result: the agreement was excellent.  The test proves that the standard describes the data and the processings accurately enough as 2 independent entities have been able to obtain the same computation results from the exchanged data. |

### Test Case AEM#2

|  |  |  |
| --- | --- | --- |
| 1 | Report Date: | 06 March 2023 |
| 2 | Program Under Test: | Attitude Data Messages P1.1 (ADM) Prototype |
| 3 | Test Case Number: | AEM#2 |
| 4 | Agencies Participating in this Test Case: | NASA/GSFC, CNES |
| 5 | Agency Responsible for Producing Test Message | NASA/GSFC |
| 6 | Producing Test Engineer: | Julie Halverson |
| 7 | Agency Responsible for Consuming Test Message | CNES |
| 8 | Consuming Test Engineer: | Alain Lamy |
| 9 | Spacecraft: | MMS1 |
| 10 | Results (Pass, Partial Pass, Fail): | Pass |
| 11 | Variances from Expected Result: | Not relevant |
| 12 | Comments: | NASA/GSFC sent an AEM in KVN format to CNES. The file contained SPIN/NUTATION\_MOM data lines for 10 different epochs as specified in the test plan.  The file was ingested by CNES and verified. The file contained the expected keywords and values. No anomaly was detected: the ordering of the keywords was correct as well as the values.  A new KVN file was generated by CNES and sent to NASA/GSFC.  The format of this second KVN file was slightly different as in the initial KVN file, and new keywords were added.  The file was ingested and verified by NASA/GSFC, and no anomaly was detected. |

### Test Case AEM#3

|  |  |  |
| --- | --- | --- |
| 1 | Report Date: | 06 March 2023 |
| 2 | Program Under Test: | Attitude Data Messages P1.1 (ADM) Prototype |
| 3 | Test Case Number: | AEM#3 |
| 4 | Agencies Participating in this Test Case: | NASA/GSFC, CNES |
| 5 | Agency Responsible for Producing Test Message | NASA/GSFC |
| 6 | Producing Test Engineer: | Julie Halverson |
| 7 | Agency Responsible for Consuming Test Message | CNES |
| 8 | Consuming Test Engineer: | Alain Lamy |
| 9 | Spacecraft: | MMS |
| 10 | Results (Pass, Partial Pass, Fail): | Pass |
| 11 | Variances from Expected Result: | Negligible difference on components difference. |
| 12 | Comments: | NASA:GSFC sent an AEM in KVN format to CNES. The file contained 5 different types of data blocks (“ATTITUDE\_TYPE” keyword):  - EULER\_ANGLE/DERIVATIVE  - SPIN/NUTATION\_MOM  - QUATERNION  - QUATERNION/ANGVEL  - EULER\_ANGLE/ANGVEL  The “QUATERNION” block contained the appropriate data as specified in the test plan.  The attitude types were chosen because either they are new in the version 2 of the standard (EULER\_ANGLE/DERIVATIVE, SPIN/NUTATION\_MOM: already tested in AEM test #1 and #2), or their name has changed in version 2 (QUATERNION/ANGVEL, EULER\_ANGLE/ANGVEL). The other types (QUATERNION, QUATERNION/DERIVATIVE, EULER\_ANGLE, SPIN, SPIN/NUTATION) were already present in version 1 and have not been retested.  The KVN file was ingested by CNES and verified. The file contained the expected keywords and values. No anomaly was detected.  CNES generated a text file containing the coordinates of a vector in the body frame, using the data in the “QUATERNION’ data block. The file was sent to NASA/GSFC which compared the results with their own results.  The agreement was excellent as the difference in vector components was negligible. |

### Test Case ACM#1

|  |  |  |
| --- | --- | --- |
| 1 | Report Date: | 03 April 2023 |
| 2 | Program Under Test: | Attitude Data Messages P1.1 (ADM) Prototype |
| 3 | Test Case Number: | ACM#1 |
| 4 | Agencies Participating in this Test Case: | NASA/GSFC, CNES |
| 5 | Agency Responsible for Producing Test Message | NASA/GSFC |
| 6 | Producing Test Engineer: | Julie Halverson |
| 7 | Agency Responsible for Consuming Test Message | CNES |
| 8 | Consuming Test Engineer: | Alain Lamy |
| 9 | Spacecraft: | LRO |
| 10 | Results (Pass, Partial Pass, Fail): | Pass |
| 11 | Variances from Expected Result: | Negligible difference (consistent with data accuracy) |
| 12 | Comments: | NASA/GSFC sent an ACM in KVN format to CNES. The file contained 1 block type as specified in the test plan: attitude state time history. The data consisted in direction cosine matrix components as function of relative time.  The KVN file was ingested by CNES and verified. The file contained the expected keywords and values in the correct order. No anomaly was detected.  Using the data in the file, CNES generated a quaternion at the initial epoch and sent it to NASA/GSSFC.  NASA/GSFC compared the quaternion with their own result: the agreement was excellent. The difference on the quaternion components was negligible, which proves that the data exchanged by the 2 entities had the same meaning.  This test proves that an ACM can be used effectively for real applications.  It has been noted that the description about quaternion (real part first or last). It is suggested to add additional information in annex B (B4). |

### Test Case ACM#2

|  |  |  |
| --- | --- | --- |
| 1 | Report Date: | 03 April 2023 |
| 2 | Program Under Test: | Attitude Data Messages P1.1 (ADM) Prototype |
| 3 | Test Case Number: | ACM#2 |
| 4 | Agencies Participating in this Test Case: | NASA/GSFC, CNES |
| 5 | Agency Responsible for Producing Test Message | NASA/GSFC |
| 6 | Producing Test Engineer: | Julie Halverson |
| 7 | Agency Responsible for Consuming Test Message | CNES |
| 8 | Consuming Test Engineer: | Alain Lamy |
| 9 | Spacecraft: | LRO |
| 10 | Results (Pass, Partial Pass, Fail): | Pass |
| 11 | Variances from Expected Result: | n/a |
| 12 | Comments: | NASA/GSFC sent an ACM in KVN format to CNES. The file contained 1 block type as specified in the test plan: physical characteristics. The data consisted of inertia matrix and mass (wet mass), data that are representative of what typically has to be exchanged between agencies.  The KVN file was ingested by CNES and verified. The file contained the expected keywords and values in the correct order. No anomaly was detected.  This test proves that an ACM can be used effectively for real applications. |

### Test Case ACM#3

|  |  |  |
| --- | --- | --- |
| 1 | Report Date: | 03 April 2023 |
| 2 | Program Under Test: | Attitude Data Messages P1.1 (ADM) Prototype |
| 3 | Test Case Number: | ACM#3 |
| 4 | Agencies Participating in this Test Case: | NASA/GSFC, CNES |
| 5 | Agency Responsible for Producing Test Message | NASA/GSFC |
| 6 | Producing Test Engineer: | Julie Halverson |
| 7 | Agency Responsible for Consuming Test Message | CNES |
| 8 | Consuming Test Engineer: | Alain Lamy |
| 9 | Spacecraft: | LRO |
| 10 | Results (Pass, Partial Pass, Fail): | Pass |
| 11 | Variances from Expected Result: | n/a |
| 12 | Comments: | NASA/GSFC sent an ACM in KVN format to CNES. The file contained one block type as specified in the test plan: Attitude State Covariance Time History. Two different blocks were present in the file: 1 for quaternion covariance data, and 1 for angle and gyro bias.  The time stamps for this test consisted of absolute time, chosen so as to vary the possibilities offered by the standard.  The KVN file was ingested by CNES and verified. The file contained the expected keywords and values in the correct order. No anomaly was detected.  This test proves that an ACM can be used effectively for real applications. |

### Test Case ACM#4

|  |  |  |
| --- | --- | --- |
| 1 | Report Date: | 03 April 2023 |
| 2 | Program Under Test: | Attitude Data Messages P1.1 (ADM) Prototype |
| 3 | Test Case Number: | ACM#4 |
| 4 | Agencies Participating in this Test Case: | NASA/GSFC, CNES |
| 5 | Agency Responsible for Producing Test Message | NASA/GSFC |
| 6 | Producing Test Engineer: | Julie Halverson |
| 7 | Agency Responsible for Consuming Test Message | CNES |
| 8 | Consuming Test Engineer: | Alain Lamy |
| 9 | Spacecraft: | LRO |
| 10 | Results (Pass, Partial Pass, Fail): | Pass |
| 11 | Variances from Expected Result: | n/a |
| 12 | Comments: | NASA/GSFC sent an ACM in KVN format to CNES. The file contained one block type as specified in the test plan: Maneuver specification. The data consisted of taget momentum coordinates.  The KVN file was ingested by CNES and verified. The file contained the expected keywords and values in the correct order. No anomaly was detected.  This test proves that an ACM can be used effectively for real applications. |

### Test Case ACM#5

|  |  |  |
| --- | --- | --- |
| 1 | Report Date: | 04 April 2023 |
| 2 | Program Under Test: | Attitude Data Messages P1.1 (ADM) Prototype |
| 3 | Test Case Number: | ACM#5 |
| 4 | Agencies Participating in this Test Case: | NASA/GSFC, CNES |
| 5 | Agency Responsible for Producing Test Message | NASA/GSFC |
| 6 | Producing Test Engineer: | Julie Halverson |
| 7 | Agency Responsible for Consuming Test Message | CNES |
| 8 | Consuming Test Engineer: | Alain Lamy |
| 9 | Spacecraft: | LRO |
| 10 | Results (Pass, Partial Pass, Fail): | Pass |
| 11 | Variances from Expected Result: | n/a |
| 12 | Comments: | NASA/GSFC sent an ACM in KVN format to CNES. The file contained 1 block type as specified in the test plan: Attitude State Covariance Time History. Two different blocks were present in the file: 1 for quaternion covariance data, and 1 for angle and gyro bias.  The time stamps for this test consisted of absolute time.  The KVN file was ingested by CNES and verified. The file contained the expected keywords and values.  It was noted a typo in the proposed standard: the units specified for “RATE\_STATES” in table 5.8 should be n/a rather than “deg/s”. This shall be corrected in the final version.  A question arose about ordering. The standard specifies in section 5.3.9.5: “*In cases in which more than one sensor is used, all keywords related to sensor 1 shall be given first, then all keywords for sensor 2, and so forth*”.  This is unfortunate, as this means that the ordering may change compared to what is described in the standard.  It is proposed instead: “In cases in which more than one sensor is used, all “KEYWORD\_I” lines shall be replaced by as many lines as they are “I” values (I = 1, then 2, and so forth)”.  A new KVN file was then regenerated by NASA/GSFC and the procedure started again.  The ordering was as expected (more compliant with the standard).  The ordering of sensor parameters proved problematic in the XML testing. It is now proposed to insert a SENSOR\_START and SENSOR\_STOP around each set of sensor parameters, allowing for as many blocks as needed. Each block can contain the sensor number, sensor type, and noise covariance details.  A new KVN file was then regenerated by NASA/GSFC and the procedure started again. The ordering was as expected and allows for better compatibility with XML.  This test proves that an ACM can be used effectively for real applications. |

### Test Case ACM#6

|  |  |
| --- | --- |
| Report Date: | 06 April 2023 |
| Program Under Test: | Attitude Data Messages P1.1 (ADM) Prototype |
| Test Case Number: | ACM#6 |
| Agencies Participating in this Test Case: | NASA/GSFC, CNES |
| Agency Responsible for Producing Test Message | NASA/GSFC |
| Producing Test Engineer: | Julie Halverson |
| Agency Responsible for Consuming Test Message | CNES |
| Consuming Test Engineer: | Alain Lamy |
| Spacecraft: | LRO |
| Results (Pass, Partial Pass, Fail): | Pass |
| Variances from Expected Result: | n/a |
| Comments: | NASA/GSFC sent an ACM in KVN format to CNES. The file contained 1 block type as specified in the test plan: User Defined Parameters. The file contained 2 thruster direction in the body frame.  The KVN file was ingested by CNES and verified. The file contained the expected keywords and values.  This test proves that an ACM can be used effectively for real applications. |

### Test Case ACM#7

|  |  |
| --- | --- |
| Report Date: | 04 April 2023 |
| Program Under Test: | Attitude Data Messages P1.1 (ADM) Prototype |
| Test Case Number: | ACM#5 |
| Agencies Participating in this Test Case: | NASA/GSFC, CNES |
| Agency Responsible for Producing Test Message | NASA/GSFC |
| Producing Test Engineer: | Julie Halverson |
| Agency Responsible for Consuming Test Message | CNES |
| Consuming Test Engineer: | Alain Lamy |
| Spacecraft: | LRO |
| Results (Pass, Partial Pass, Fail): | Pass |
| Variances from Expected Result: | n/a |
| Comments: | NASA/GSFC sent an ACM in KVN format to CNES. The file contained all block types as specified in the test plan. This was to show that a combined message containing various data types could be effectively used.  The KVN file was ingested by CNES and verified.  It was check that the header was correct, as well as the metadata section.  The metadata section contained an additional keyword: “ACM\_DATA\_ELEMENTS” giving the block names as present in the file.  It was checked that each data block was exactly the same as provided in tests 1 through 6, except sometimes for the comment lines that could differ.  No other remarks was raised. The test was so considered as successful.  This test proves that an ACM can be used effectively for real applications. |

## XML tests

All the KVN messages have been converted to XML and back. Three prototypes have been used by 3 independent entities. The testing also led to some minor changes in the standard when explanations were missing, or when the data were not precisely described. The following sections give more details on the tests that were performed.

### Tests performed by entity 1 (NASA/JPL)

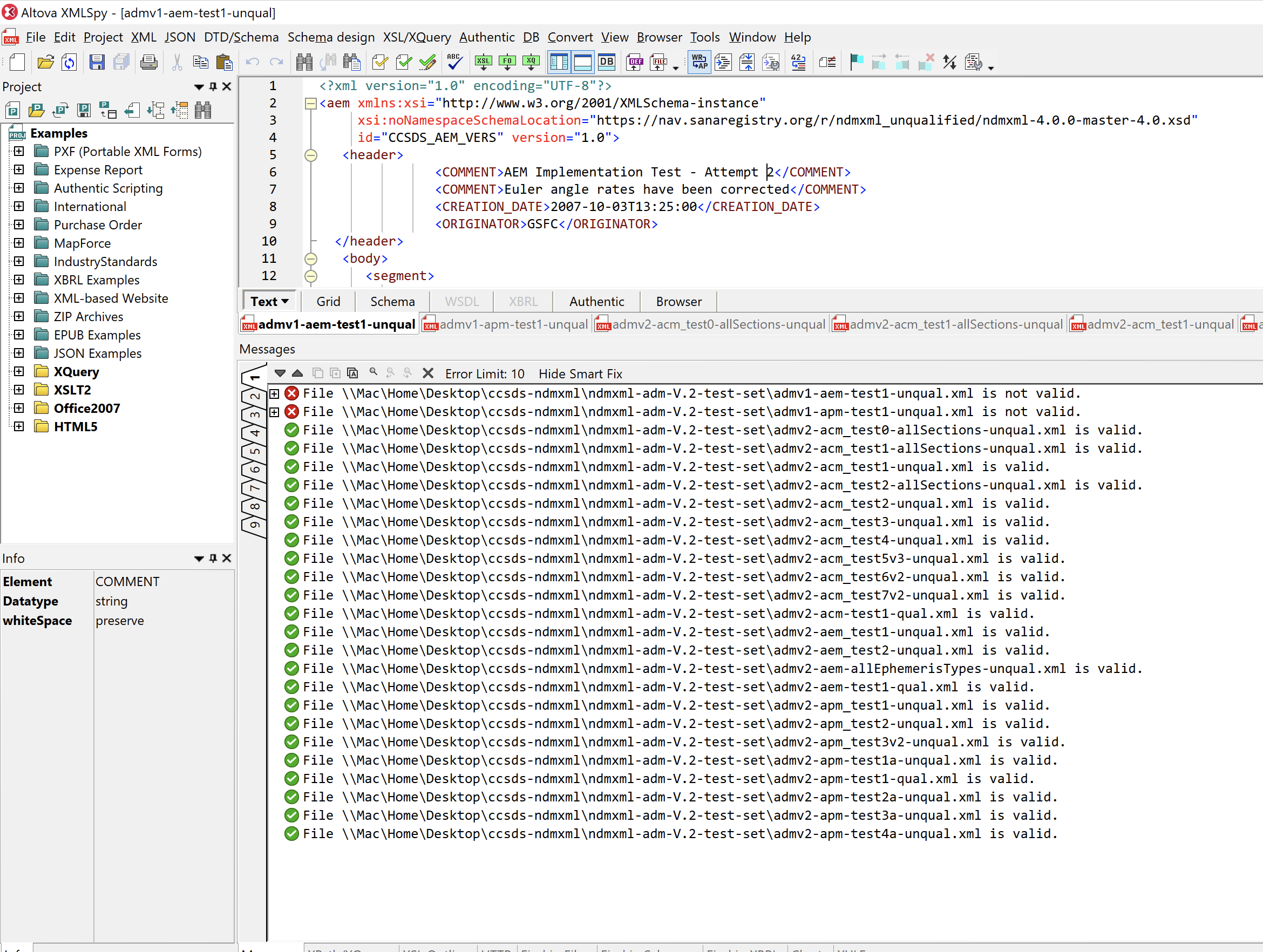
The CCSDS Navigation Working Group's Attitude Data Messages (ADM) version P-1.1 is due to become ADM 2.0 upon approval of the CCSDS Engineering Steering Group and CCSDS Management Council. This approval is contingent upon testing of the updated messages. This document will discuss the testing of the messages that was done by JPL for the XML renderings of ADMs, which is described in Section 7 of the Pink Book.

A set of schemas was updated to incorporate the changes to the Attitude Parameter Message (APM), Attitude Ephemeris Message (AEM), and the Attitude Comprehensive Message (ACM) found in the updated standard. The schemas were uploaded to a beta SANA Registry set allocated to the Navigation Working Group (https://nav.sanaregistry.org). A set of 25 tests was performed. The tests included XML conversions of the KVN tests conducted by the testing agencies, as well as a number of tests prepared by the schema developer to test the schemas during development. The source of each test is noted in the table below.

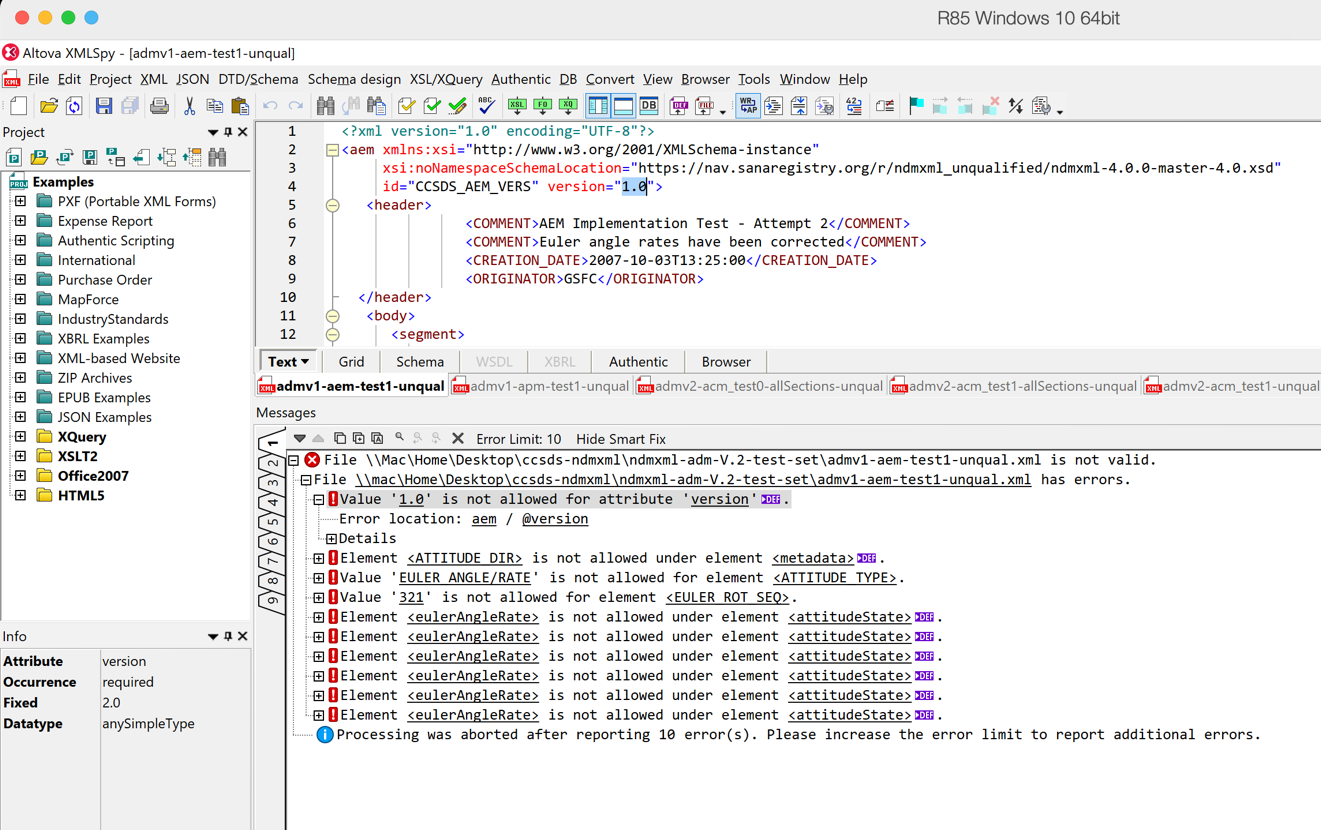
| **Message File Name** | **Source** | **Expected Result** | **Actual Result** | **Comments** |
| --- | --- | --- | --- | --- |
| admv1-aem-test1-unqual.xml | ADM Version 1 testing | Not Valid | Not Valid | Test of an AEM version 1 message that should fail validation |
| admv1-apm-test1-unqual.xml | ADM Version 1 testing | Not Valid | Not Valid | Test of an AEM version 1 message that should fail validation |
| admv2-acm-test1-qual.xml | Schema Developer | Valid | Valid | Test message used in schema development |
| admv2-acm\_test0-allSections-unqual.xml | Schema Developer | Valid | Valid | Test message used in schema development |
| admv2-acm\_test1-allSections-unqual.xml | Schema Developer | Valid | Valid | Test message used in schema development |
| admv2-acm\_test1-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Converted from ADM V.2 KVN Test Case |
| admv2-acm\_test2-allSections-unqual.xml | Schema Developer | Valid | Valid | Test message used in schema development |
| admv2-acm\_test2-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Converted from ADM V.2 KVN Test Case |
| admv2-acm\_test3-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Converted from ADM V.2 KVN Test Case |
| admv2-acm\_test4-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Converted from ADM V.2 KVN Test Case |
| admv2-acm\_test5v3-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Converted from ADM V.2 KVN Test Case |
| admv2-acm\_test6v2-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Converted from ADM V.2 KVN Test Case |
| admv2-acm\_test7v2-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Converted from ADM V.2 KVN Test Case |
| admv2-aem-allEphemerisTypes-unqual.xml | Schema Developer | Valid | Valid | Test message used in schema development |
| admv2-aem-test1-qual.xml | ADM Co-Editor/Tester | Valid | Valid | Test message used in schema development |
| admv2-aem\_test1-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Converted from ADM V.2 KVN Test Case |
| admv2-aem\_test2-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Converted from ADM V.2 KVN Test Case |
| admv2-apm-test1-qual.xml | Schema Developer | Valid | Valid | Test message used in schema development |
| admv2-apm-test1a-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Test message used in schema development |
| admv2-apm-test2a-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Test message used in schema development |
| admv2-apm-test3a-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Test message used in schema development |
| admv2-apm-test4a-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Test message used in schema development |
| admv2-apm\_test1-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Converted from ADM V.2 KVN Test Case |
| admv2-apm\_test2-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Converted from ADM V.2 KVN Test Case |
| admv2-apm\_test3v2-unqual.xml | ADM Co-Editor/Tester | Valid | Valid | Converted from ADM V.2 KVN Test Case |

**In all test cases, the "Expected Result" and the "Actual Result" were the same**.

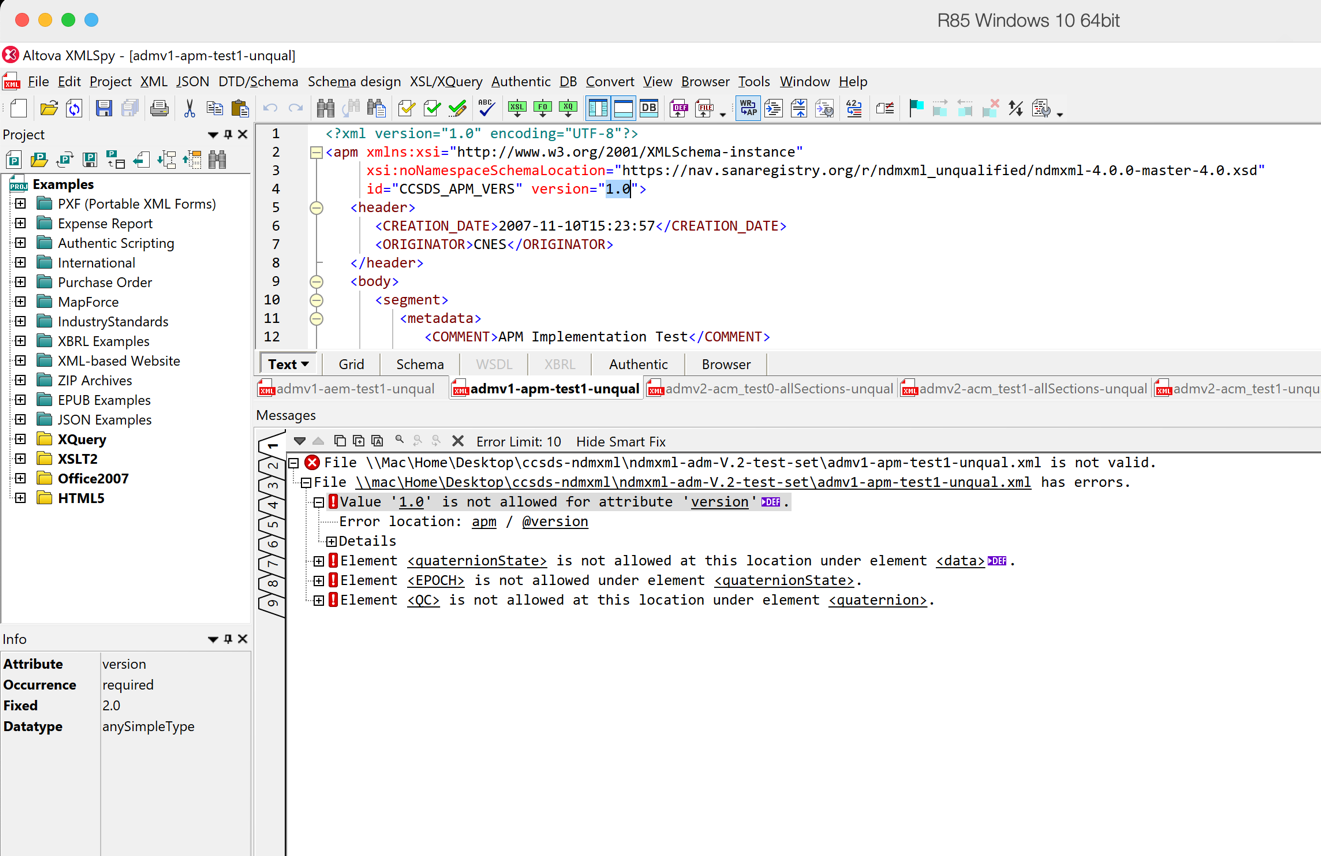
Figures 1 through 3 below are screen shots of the output from the XMLSpy Schema Validator. First is a screen shot of all 25 tests showing the general result: valid or invalid. The next 2 screen shots are included to confirm that the tests were not rigged and that the validator could detect an invalid message. Two Version 1 messages were included (one AEM, one APM); these show that messages for which CCSDS\_APM\_VERS=1.0 and CCSDS\_AEM\_VERS=1.0, i.e., that do not conform to the revised standard, fail as expected.



**Figure 1: XML Testing of Updated ADM Messages**



**Figure 2: AEM Version 1 Message Failure Detail**



**Figure 3: APM Version 1 Failure Detail**

### Tests performed by entity 2 (ESA/GMV)

All KVN files have been converted to XML to check the consistency between the 2 formats.

Here are the comments that were raised during the final testing stages.

**APM**

APM#1: When following the procedure for the conversion, we found a small discrepancy in the example in page F-5. In section F5.3, just after the table, is it possible that the value of Q2 should be -0.0334 instead of 0.0334?

APM#2: No issues or suggestions.

APM#3: Regarding the modifications in apm\_test3v3.txt with respect to v2, the mass should be indeed negative, and it has been detected that the units for the nutation have been corrected. This error with the units was not detected before on our side as our libraries do not read the unit and set the standard one when writing, so this is an aspect that we could improve.

However more modifications were added in the file sent by email that did not seem correct: START\_TIME and STOP\_TIME have ‘SC\_BODY’ as value instead of a time, and REF\_FRAME\_A and REF\_FRAME\_B should not be included in the metadata. We generated an XML including the erroneous fields, and when validating against schema an error is raised, as expected, so it was useful for schema validation.

**AEM**

All AEM converted to XML and back and validated against latest schema. No issues found with that.

Explanation of XML structure for the AEM seems clear enough.

No issues found processing results of Luc’s tests for the conversion in AEM#1 and AEM#3. It was already tested that the numerical results were consistent.

**ACM**

All ACM converted to XML and back, and validated against latest schema with no major issues, only some comments below:

ACM#5:

Modified our libraries to adapt to the new convention for the sensors. We think it is indeed much clearer this way, and consistency between KVN and XML is an advantage.

We have a small comment regarding the field SENSOR\_USED. In the test file, that’s the used keyword; but when generating an XML file and validating against the latest schema, we got an error stating that the expected keyword should be SENSOR**S**\_USED. We guess it is a small issue in the schema, as the keyword included the ‘S’ before the modification.

The attached XML file currently includes SENSORS\_DATA as tag so that it could be validated, but we understand it is not correct regarding to the standard.

ACM#6: When validating against schema, some errors are obtained in the USER\_DEFINED\_X fields. Apparently, the schema only expects ‘COMMENT’ and ‘USER\_DEFINED’ tags, while USER\_DEFINED\_[…] should be valid.

ACM#7: Same comments of ACM#5 and ACM#6. No additional issues found when processing all the different blocks together in just one file.

In this case we have used the keyword SENSOR\_USED inside the file, and an error is raised when validating.

Analysis of the comments:

APM#1: there was no anomaly after verification of the value.

APM#3: the file that was sent included unexpected keywords. A correct file was sent again. The delta\_mass sign in the test files was incorrect, and that was corrected as well.

ACM#5: the sensor structure has been modified due to difficulties related to XML schemas. The standard was not immediately updated hence difficulty with the testing. In the end everything has been corrected.

ACM#6: This was due to an anomaly in the schemas. This anomaly has been fixed.

**In conclusion, the anomalies that were raised were somehow minor and have been successfully fixed**.

### Tests performed by entity 3 (Orekit team)

Here are some issues that were detected during the testing. The text come directly from email exchanges. Analyses of the reported anomalies are also shown.

Step 1:

Up to now, I have found two problems in the test files and in the ADM V2 document.

The first problem, very minor, lies in the apm\_test3v2.txt file. The NUTATION entry has units set to deg/s whereas they should be deg.

⇒Disposition : Corrected in test file

The second problem is only slightly more serious. In both some test files and in examples in the pink book, a local frame is specified as SC\_BODY or SC\_BODY1. However, I think it should be SC\_BODY\_1 to match the naming conventions in SANA registry. I have added some logic in my code to handle all these cases, but think the document should really match registry.

⇒Disposition : Example in standard corrected.

Step 2:

I have encountered one discrepancy that I found troublesome, despite it is not serious. In the latest version of OCM I got (pink book DLO V18 for agency review), the new CLASSIFICATION keyword that did appear in OCM metadata was generalized to OPM, OMM and OEM and moved up from the metadata to the header of the message. This CLASSIFICATION keyword also seems to appear in the header of a pink book for CDM. In the last version of ADM, the CLASSIFICATION is only in the ACM metadata. Could it be generalized to all messages and moved up to the header for consistency with other navigation messages?

⇒Disposition : CLASSIFICATION keyword added in header (as in ODM)

During my tests, I also used the example from section F5.4 for spin/nutation/momentum. This example uses a momentum with α=0°, δ=90°.

This leads to a singularity, as when declination is 90°, right ascension is undetermined. It works well when going from angular to Cartesian coordinates, but when doing round-trip validation, the right ascension may end up with arbitrary values. So the example works, but could perhaps be changed to something non-singular to help implementors.

⇒Disposition : Example in standard has been updated

Last point concerns section J. I suggest to add an entry pointing out that in APM, epoch is now outside of quaternion block since this block is now optional. This is a change in the structure of the message so it is an important one.

⇒Disposition : Decided not to change the standard as the notion of “blocks” did not exist in version 1.

Step 3:

I have found another issue. In ACM, when ATT\_TYPE is set to EULER\_ANGLES, there is no specification of angles order. I guess a EULER\_ROT\_SEQ keyword should be added to ACM metedata for this.

⇒Disposition : Decided to add EULER\_ROT\_SEQ when necessary.

Step 4:

Looking at the results, we get the expected differences (whitespace, formatting of real numbers, numerical differences at the level of a few ulps, presence or not of units…).

As explained on a previous mail, I put the schema location for XML files using the SANA beta registry, but in fact it does not yet contain the schema for ADMV2, so the files will \*not\* validate against these schemas, this is expected. So when reading the files, either validation should be turned off or the declaration must be removed from the XML files).

Here are some additional comments.

- in the standard, in figure G-7 a key is written NUMBER\_OF\_STATES,

whereas in table 5-4 it is NUMBER\_STATES.

- in the standard, in figure G-9, the closing marker is written

AD\_END whereas it should be AD\_STOP

⇒Disposition : Typos corrected

in figures G-7 we see TARGET\_MOMENTUM without TARGET\_MOM\_FRAME, but I am not sure if it is OK or not. I allowed it in my implementation and indeed the frame is not specified in test acm4, so I guess it is OK. I am just not comfortable with this and would personally prefer that the frame should be specified if the vector is specified. The keys are just specified as conditional in table 5-7, without further explanation.

⇒Disposition : Decided to make TARGET\_MOM\_FRAME mandatory if TARGET\_MOMENTUM is present.

The same occurs with CP and CP\_REF\_FRAME (figure G-8 and table 5-5).

Here again, I would prefer to have the frame specified if the vector is specified.

⇒Disposition : Decided to make CP\_REF\_FRAME mandatory if TARGET\_MOMENTUM is present.

Overall, I think ADM V2 is a great improvement over ADM V1.

Step 5:

I have checked validation against the XSD and found a few problems.

The files I produced are consistent with table 7-5 with the special tags <quaternionAngvel> and <eulerAngleAngvel> whereas the XSD uses <quaternionAngVel> and <eulerAngleAngVel> (i.e. the V for velocity is uppercase. As this uppercase V is more consistent with the other key <angVel>, I guess the XSD are right and table 7-5 should be corrected. I have fixed Orekit implementation accordingly.

⇒Disposition : Typo in standard : corrected.

I noticed that despite CLASSIFICATION now appears in <xsd:complexType name="admHeader">, it also appears in xsd:complexType name="acmMetadata". I guess it should be removed from the metadata type.

⇒Disposition : Fixed

When validating the roundtrip files, it occurred to me that apm\_test3v2.txt had a positive MAN\_DELTA\_MASS but the XML schema check it must be negative, hence the roundtrip XML file produced did not validate. I edited the apm\_test3v2.txt test file to use a negative sign.

⇒Disposition : The test file was erroneous: MAN\_DELTA\_MASS should indeed be negative (fixed).

Also one thing I forgot to mention in my previous mail, and which is still true for the new run of tests. In the AEM test 1 with Euler angles, the values of the angles I produce seem different from the input angles for the last four points out of 10, but indeed do represent the same rotations. This is because different Euler angles may represent the same rotations. For the last four points, my tests output the triplet (angle1-180, 360-angle2, angle3+180) instead of (angle1, angle2, angle3), but it seems acceptable to me.

⇒Disposition : The values are equivalent (nothing to be updated)

Step 6:

You will find attached the roundtrip tests I did with your latest files. For these tests, **I used directly the original files, without any edition, and everything ran smoothly**.

## Summary of remarks / recommendations

|  |  |
| --- | --- |
| **Remark** | **Disposition** |
| Inconsistency between standard and examples (XML) : quaternionAng**v**el / quaternionAng**V**el | Update standard |
| AEM : SPIN/NUTATION\_MOM : not clear which frame the angular momentum vector is given. Reference missing (to APM ?) | Add reference to APM |
| ACM : quaternion order may not be clear enough | Add information in annex B (B6) : Quaternion order is as specified in the APM (Table 3-3). |
| Various typos :   * Table 5-8 - RATES\_STATES : unit should be n/a instead of deg/s * In figure G-7 a key is written NUMBER\_OF\_STATES, whereas in table 5-4 it is NUMBER\_STATES. * In figure G-9, the closing marker is written AD\_END whereas it should be AD\_STOP | Fix typos |
| Name of body frame in some examples: SC\_BODY. Should be SC\_BODY\_1 (for a better consistency with SANA) | Fix the examples. |
| ACM (attitude determination): keyword ordering when « \_I » present in keywords:  Example. Standard says :  SENSORS\_USED\_1, SENSOR\_NOISE\_STDDEV\_1,… SENSORS\_USED\_2, SENSOR\_NOISE\_STDDEV\_2,…   * ordering is changed compared to standard.   Impact on XML as variable keywords are not easy to handle.  Change proposed (KVN) :  SENSOR\_START  SENSOR\_NUMBER = …  SENSOR\_USED = …  NUMBER\_SENSOR\_NOISE\_COVARIANCE = …  SENSOR\_FREQUENCY = …  SENSOR\_NOISE\_STDDEV = …  SENSOR\_STOP  SENSOR\_START  etc… | Update standard. |
| ACM: not completely clear if units are allowed or not.  In OCM there is a specific requirement (also in APM): For OCM keywords that are not used to convey multipartite trajectory state, covariance, or maneuver data lines, units may be included as ASCII text after a value in the OCM for documentation purposes and clarity only. If units are displayed, then… | Update standard: add requirement as in ODM. |
| CLASSIFICATION keyword : in the metadata section of ACM, and not in other ADM messages | Update standard: add CLASSIFICATION keyword in header as in ODM. |
| In example F.4 (“spin/nutation/momentum") : the value of 90 deg for MOMENTUM\_DELTA leads to a singularity. The example works, but could perhaps be changed to something non-singular to help implementors. | Update the example to avoid singularity (change the value to 70 deg) |
| TARGET\_MOM\_FRAME: In figures G-7 we see TARGET\_MOMENTUM without TARGET\_MOM\_FRAME. It is apparently missing. | Update standard: TARGET\_MOM\_FRAME should be present if TARGET\_MOMENTUM is present. |
| Same as above for CP\_REF\_FRAME (figure G-8 and table 5-5) | Update standard: CP\_REF\_FRAME should be present if CP is present. |
| In ACM, when ATT\_TYPE is set to EULER\_ANGLES, there is no specification of angles order. A EULER\_ROT\_SEQ keyword should be added to ACM metadata. | Update standard: add EULER\_ROT\_SEQ keyword. Should be present if ATT\_TYPE (Table 5-4) or ATTITUDE\_STATES (Table 5-8) specifies the use of Euler angles. |

1. ABBREVIATIONS AND ACRONYMS

**(INFORMATIVE)**

ASCII American Standard Code for Information Interchange

CCSDS Consultative Committee for Space Data Systems

CNES Centre National d’Etudes Spatiales

DLR/GSOC Deutsches Zentrum für Luft und Raumfahrt (German Aerospace Center)/German Space Operations Center

ESA/ESOC European Space Agency/European Space Operations Center

ESA/ESAC European Space Agency/European Space Astronomy Center

JAXA Japan Aerospace Exploration Agency

KVN Keyword = Value Notation

NASA/GSFC National Aeronautics and Space Administration/Goddard Space Flight Center

NASA/JPL National Aeronautics and Space Administration/Jet Propulsion Laboratory

NASA/JSC National Aeronautics and Space Administration/Johnson Space Flight Center

NavWG CCSDS Navigation Working Group

OCM Orbit Comprehensive Message

SANA Space Assigned Numbers Authority

XML Extensible Markup Language

XSLT Extensible Stylesheet Language Transformations