# ATTITUDE Comprehensive Message (ACM)

## General

Comprehensive attitude information may be exchanged between two participants by sending attitude data/content for one or more epochs using an Attitude Comprehensive Message (ACM). The ACM aggregates and extends ADM and AEM content in a single hybrid message. The ACM simultaneously emphasizes flexibility and message conciseness by offering extensive optional standardized content while minimizing mandatory content.

The ACM shall be a plain text file consisting of attitude data for a single space object, or in the case of a parent/child satellite deployment scenario, a single parent object. It shall be easily readable by both humans and computers.

The ACM file-naming scheme should be agreed to on a case-by-case basis between the exchange partners, and should be documented in an ICD. The method of exchanging ACMs should be decided on a case-by-case basis by the exchange partners and documented in an ICD.

Attitude information may be exchanged between two participants by sending an attitude ephemeris in the form of one or more time series of attitude states using an Atittude Comprehensive Message (ACM). If attitude states are desired at arbitrary time(s) contained within the span of the attitude ephemeris, the message recipient is encouraged to use a suitable interpolation or propagation method. For times outside of supplied attitude state time spans or if the step size between attitude states is too large to support interpolation or propagation, optional dynamic parameters should be included with this message and the recipient must have a suitably-compatible attitude dynamics propagator.

NOTE – Detailed syntax rules for the ACM are specified in section TBD.

## ACM content/STRUCTURE

### General

The ACM shall be represented as a combination of the following as shown in Table 5-1. The ordering of these sections is mandatory. The order of occurrence of the ACM sections shall be fixed as shown in table 5-1.

1. a single mandatory header;
2. a single mandatory metadata section (data about data);
3. optional data section(s), comprised of one or more data constituent types:
	1. a single, optional space object physical characteristics section
	2. a single, optional estimator description section
	3. a single, optional sensor description section
	4. optional maneuver data section(s)
	5. optional attitude state time histories
	6. optional sensor data time histories
	7. optional covariance time histories
	8. optional actuator/torque description and data section
	9. a single, optional, user-defined data and supplemental comments (explanatory information).

Table 5‑1 : ACM File Layout and Ordering Specification

|  |  |
| --- | --- |
| **Section** | **Content** |
| Mandatory Header | Header of message |
| Mandatory Metadata | Metadata(Informational comments recommended but not required.) |
| Optional Space Object Physical Description | Optional space object physical characteristics, if known. |
| Optional Estimator Description Section | Type of estimator used in attitude determination, states estimated, sensors used in estimation |
| Optional Sensor Description Section | Sensor Types on the spacecraft, calibration, alignment parameters for each sensor listed |
| Optional Maneuver Section(s) | Optional maneuver specifications  |
| Optional Attitude Section(s) | Optional: attitude state time histories (each consisting of one or more attitude states), each time history corresponds to the estimator specified in the Estimator Description Section |
| Optional SEnsor Data Section(s) | Optional: One or more sensor data history sections, each block containing data from a single sensor type, sensor descriptions are as provided in the Sensor Description Section |
| Optional Covariance Data Section(s) | Optional: covariance time histories, each time history corresponds to the estimator specified in the Estimator Description Section |
| Optional Actuator/Torque Section(s) | Optional: Actuators, external torques. NOT YET INCLUDED. |
| Optional User Defined Data | User-defined |

### ACM Header

Table 5-2 specifies the keywords for each header item.

Only those keywords shown in table 5-2 shall be used in an ACM header.

The order of occurrence of these ACM header keywords shall be fixed as shown in table 5-2.

Table 5-2 : ACM Header

|  |  |  |  |
| --- | --- | --- | --- |
| **Keyword** | **Description** | **Examples of Values** | **Mandatory** |
| CCSDS\_ACM\_VERS | Format version in the form of ‘x.y’, where ‘y’ is incremented for corrections and minor changes, and ‘x’ is incremented for major changes. | 1.0 | **Yes** |
| COMMENT | Comments (allowed in the ACM Header only immediately after the ACM version number).  | COMMENT This is a comment | No |
| CREATION\_DATE | File creation date/time in UTC. (For format specification, see 7.5.9.) | 2001-11-06T11:17:332002-204T15:56:23Z | **Yes** |
| ORIGINATOR | Creating agency. The value for the “ORIGINATOR” keyword “should” come from the SANA registry.  | CNES, ESOC, GSFC, GSOC, JPL, JAXA, Other Agency | **Yes** |
| MESSAGE\_ID | ID that uniquely identifies a message from a given originator. The format and content of the message identifier value are at the discretion of the originator. | 201113719185ABC-12\_34 | **No** |

### ACM Metadata

Table 5-3 specifies the metadata keywords. Only those keywords shown in table 5-3 shall be used in ACM metadata.

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The “ACM Metadata” section is mandatory; “mandatory” in the context of Table 5-3 denotes those keywords which must be included in this section.

Only one ACM Metadata section (data block) shall appear in an ACM.

 ACM Metadata data block

The order of occurrence of these ACM metadata keywords shall be fixed as shown in table 5-3, with the exception that comments may be interspersed throughout the metadata section as required.

The TIME\_SYSTEM value must remain fixed within an ACM.

Any spacecraft physical characteristics, maneuver, attitude states, covariance values, sensor and/or actuator values in the ACM data which require time-tagging shall be time-tagged by a relative time value measured with respect to the epoch time specified via the EPOCH\_TZERO keyword.

The ACM shall only contain a single metadata section in the entire scope of the message.

NOTE – For some keywords (OBJECT\_NAME, OBJECT\_ID) there are no definitive lists of authorized values maintained by a control authority; the references listed in 0 are the best known sources for authorized values to date.

NOTE 2 – While specification of OBJECT\_DESIGNATOR, OBJECT\_NAME and INTL\_DESIGNATOR are each in and of themselves optional, one of these keywords must be supplied.

NOTE 3 – The only metadata fields which are relied upon by the subsequent optional ACM message subtypes (e.g. maneuver data,

**Table 5-3: ACM Metadata**

| **Keyword** | **Description** | **Examples of Values** | **Mandatory** | **Any ACM sections relying upon this field ?** |
| --- | --- | --- | --- | --- |
| COMMENT | Comments (allowed at any point(s) throughout the ACM Metadata section).  | COMMENT This is a comment | No |  No |
| ORIGINATOR \_POC | Free text field containing Programmatic or Technical Point-of-Contact (PoC) for ACM | Ms. Rodgers | No | no |
| ORIGINATOR \_PHONE | Free text field containing PoC phone number |  +49615130312 | No | no |
| ORIGINATOR \_POSITION | Free text field containing contact position of the PoC | GNC EngineerACS Design Lead | No | no |
| ORIGINATOR\_ADDRESS | Free text field containing Technical PoC information for ACM creator (suggest email, website, or physical address, etc.) | JANE.DOE@ SOMEWHERE.NET | No | no |
| OBJECT\_NAME | Spacecraft name of the object corresponding to the attitude data to be given. There is no CCSDS-based restriction on the value for this keyword, but it is recommended to use international designators from the UN Office of Outer Space Affairs | SPOT, ENVISAT, IRIDIUM, INTELSAT | Yes | no |
| OBJECT\_ID | Spacecraft identifier of the object corresponding to the attitude data to be given. Wile there is no CCSDS-based restriction on the value for this keyword, it is recommended to use names from the UN Office of Outer Space Affairs  | 2000-052A | Yes | no |
| CENTER\_NAME | Origin of reference frame, which may be a natural solar system body (planets, asteroids, comets, and natural satellites), including any planet barycenter or the solar system barycenter, or another spacecraft (in this the value for ‘CENTER\_NAME’ is subject to the same rules as ‘OBJECT\_NAME’). There is no CCSDS-based restriction on the value for this keyword, but for natural bodies it is recommended to use names from the NASA/JPL Solar System Dynamics Group (reference [TBD]) | EARTHEARTH BARYCENTERMOON | No | no |
| TIME\_SYSTEM | Time system used for attitude data (see also table TBD). The full set of allowed values is enumerated in annex B, wich an excerpt provided in the ‘Normative Values/Examples’ column. Explanations of these time systems can be found in *Navigation Definitions and Conventions* (reference [TBD]).  | UTCTAI | Yes | no |
| EPOCH\_TZERO | Epoch from which all ACM relative times are referenced. (For format specification, see 7.5.9.). The time scale EPOCH\_TZERO is the one specified by "TIME\_SYSTEM" keyword in the metadata section. | 2001-11-06T00:00:00 | Yes | MNVR, STATES, COVARSTM, EC |
| INCL\_DATA\_BLOCKS | Comma-delimited list of data blocks included in this message. | MAN, ATT, COV, AD, PHYS, SENSOR | No | no |
| START\_TIME | Relative time of the earliest of all time tags corresponding to maneuver, attitude state, covariance, sensor and/or actuator data. The epoch is specified in timing system “TIME\_SYSTEM”(For format specification, see **Error! Reference source not found.** for absolute time format; relative time is measured in seconds from EPOCH\_TZERO) | 100.0 | No | no |
| STOP\_TIME | Relative time of the end of TOTAL time span covered by ALL maneuver, attitude state, covariance, sensor and/or actuator data contained in this message. (For format specification, see **Error! Reference source not found.** for absolute time format; relative time is measured in seconds from EPOCH\_TZERO) | 1500.0 | No | no |
| TAIMUTC\_TZERO | Difference (TAI – UTC) in seconds (i.e. total # leap seconds elapsed since 1958) as modeled by the message originator at epoch “EPOCH\_TZERO”. | 37 [s] | No | no |
| TIME\_SYSTEM\_ABS | Timing system used for the absolute time contained in EPOCH\_TZERO. **Omission of this non-mandatory field defaults to “UTC”** | UTC | No | MNVR, STATES, COVARSTM, EC |
| TIME\_SYSTEM\_REL | Timing system used for all relative time specifications relative to EPOCH\_TZERO. **Omission of this non-mandatory field defaults to “UTC”** | UTCTAI | No | MNVR, STATES, COVARSTM, EC |

### ACM DATA: Space Object Physical Characteristics

Table 5-4 gives an overview of the ACM space object physical characteristics section. Only those keywords shown in table 5-4 shall be used in ACM space object physical characteristics data.

Keyword values shall be provided in the units specified in column three of Table 5-4.

The order of occurrence of these ACM Space Objects Physical Characteristics keywords shall be fixed as shown in table 5-4, with the exception that comments may be interspersed throughout the this section as required.

The “ACM Data: Space Object Physical Characteristics” section is optional; “mandatory” in the context of table 5-4 denotes those keywords which must be included in this section if this section is included.

Only one space object physical characteristics section shall appear in an ACM.

The space object physical characteristics data section in the ACM shall be indicated by two keywords: PHYS\_START and PHYS\_STOP.

Further definition of Space Object Physical Characteristics parameters is provided in ANNEX X.

Table 5-4 : ACM Data: Space Object Physical Characteristics

| **Keyword** | **Description** | **Units** | **Examples of Values** | **Mandatory** |
| --- | --- | --- | --- | --- |
| COMMENT | Comments (allowed at any point(s) throughout the ACM Space Object Physical Characteristics).  | n/a | COMMENT This is a comment | No |
| PHYS\_START | Start of a Space Object Physical Characteristics specification | n/a |  | Yes |
| MASS | S/C Mass at the reference epoch “EPOCH\_TZERO” | kg | 500 | No |
| IXX | Moment of Inertia about the X-axis of the spacecraft’s primary body frame (e.g. SC\_Body\_1) | kg\*m\*\*2 | 1000.0 | No |
| IYY | Moment of Inertia about the Y-axis | kg\*m\*\*2 | 800.0 | No |
| IZZ | Moment of Inertia about the Z-axis | kg\*m\*\*2 | 400.0 | No |
| IXY | Inertia Cross Product of the X & Y axes | kg\*m\*\*2 | 20.0 | No |
| IXZ | Inertia Cross Product of the X & Z axes | kg\*m\*\*2 | 40.0 | No |
| IYZ | Inertia Cross Product of the Y & Z axes | kg\*m\*\*2 | 60.0 | No |
| Cp  | Location of spacecraft center of pressure for determining solar pressure torque  | m |  | No |
| CD | Drag coefficient |  |  |  |
| CM | Center of mass | m | 0.5, 0.35, 1.1 |  |
| FUEL | Fuel mass | kg | 750 |  |
| OTHERS? |  |  |  |  |
| PHYS\_STOP | End of a Space Object Physical Characteristics specification | n/a |  | Yes |

### ACM Data: ESTIMATOR DEscription section

Table 5-5 provides an overview of the ACM Estimator Description section. Only those keywords shown in table 5-5 shall be used in ACM Estimator Description.

Keyword values shall be provided in the units specified in column three of table 5-5.

The order of occurrence of these ACM Estimator Description keywords shall be fixed as shown in table 5-5, with the exception that comments may be interspersed throughout the this section as required.

The ACM Estimator Description section is optional; “mandatory” in the context of table 5-5 denotes those keywords which must be included in this section if this section is included.

The ACM Esimator Description section shall be delineated by two keywords: EST\_START and EST\_STOP.

Table 5-5 : ACM Data: Estimator Description

| **Keyword** | **Description** | **Units** | **Examples of Values** | **Mandatory** |
| --- | --- | --- | --- | --- |
| COMMENT | Comments (allowed at any point(s) throughout the ACM Perturbations Specification Data).  | n/a | COMMENT This is a comment | No |
| EST\_START | Start of Estimator Description  |  |  |  |
| TYPE\_OF\_ESTIMATOR | Type of estimator used | n/a | EKF, TRIAD, QUEST, BATCH, SPIN,Q METHOD, FILTER SMOOTHER | No |
| ATTITUDE\_SOURCE | Source of attitude estimate, whether from a ground based estimator or onboard estimator | n/a | GND,OBC |  |
| NUMBER\_STATES | Number of states if EKF or BATCH is specified | n/a | 3, 6 | No |
| ATTITUDE\_STATES | Type of attitude state included in the estimator |  | QUATERNIONEULER ANGLES… | No |
| REF\_FRAME\_A | Name of the reference frame that defines the starting point of the transformation described by the attitude state in the estimator. |  | J2000 |  |
| REF\_FRAME\_B | Name of the reference frame that defines the ending point of the transformation described by the attitude state in the estimator. |  | SC\_BODY |  |
| RATE\_STATES | Type of rate state included in the estimator  | rad/s | ANG\_VELGYRO\_BIAS | No |
| OTHER\_STATES | Additional calibration states included in the estimator |   | GYRO\_ALIGNMENTGYRO\_SCALE… | No |
| NUMBER\_SENSORS\_USED | Number of sensors used to provide estimator measurements | n/a |  2, 3 | No |
| SENSORS\_USED\_i | Types of sensors used in estimation, i = 1 to NUMBER\_SENSORS\_USED |  | AST, DSS, IMU |  |
| NUMBER\_SENSOR\_NOISE\_COVARIANCE\_i | Number of noise elements for sensor i. For example, noise along x, y, and z axes of sensor. |  | 2,3 |  |
| SENSOR\_NOISE\_COVARIANCE\_i | Noise covariance matrix for sensor i, if estimator type is EKF or BATCH |   |  | No |
| SIGMA\_U | Rate random walk if RATE\_STATES=GYRO\_BIAS | rad/sec\*\*1.5 |  | No |
| SIGMA\_V | Angle random walk if RATE\_STATES=GYRO\_BIAS | rad/sec\*\*0.5 |  | No |
| SENSOR\_FREQUENCY\_i | Frequency of sensor i data |  Hz |  | No |
| OTHERS TBD | e.g. Process noise elements (if gyro is not used but rate is estimated) |  |  |  |
| EST\_STOP | End of the estimator description | n/a |  | Yes |

### ACM Data: sensor DEscription section

Table 5-6 provides an overview of the ACM Sensor Description section. Only those keywords shown in table 5-6 shall be used in ACM Sensor Description.

Keyword values shall be provided in the units specified in column three of table 5-6.

The order of occurrence of these ACM Sensor Description keywords shall be fixed as shown in table 5-6, with the exception that comments may be interspersed throughout the this section as required.

The ACM Sensor Description section is optional; “mandatory” in the context of Table 5-6 denotes those keywords which must be included in this section if this section is included.

The ACM Sensor Description section shall be delineated by two keywords: SENSOR\_START and SENSOR\_STOP.

Table 5-6 : ACM Data: Sensor Description

| **Keyword** | **Description** | **Units** | **Examples of Values** | **Mandatory** |
| --- | --- | --- | --- | --- |
| COMMENT | Comments (allowed at any point(s) throughout the ACM Perturbations Specification Data). (See 2.7 for formatting rules.) | n/a | COMMENT This is a comment | No |
| SENSOR\_START | Start of sensor description |  |  |  |
| NUMBER\_OF\_ SENSORS | Number of sensors on the spacecraft | n/a |  2, 3 | No |
| SENSOR\_TYPE\_i | Type of sensor i, where i = 1 to NUMBER\_OF\_SENSORS | n/a | AST, CSS, DSS, IMU |  |
| NUMBER\_ELEMENTS\_i | Number of data points for SENSOR\_TYPE\_i | n/a | 1, 2, 3, 4 |  |
| UNITS\_i | Units for SENSOR\_TYPE\_i data | mG, rad  |   | No |
| MEASUREMENT\_FRAME\_i | Frame of measurement for SENSOR\_TYPE\_i | n/a | AST\_i, SC\_BODY | No |
| DATA\_ADJUSTMENT\_i | Calibration or transformation parameters includes | n/a | Yes, No | No |
| NUMBER\_ADJUSTMENTS\_i | Number of adjustements included for SENSOR\_TYPE\_i | n/a  | 2 | No |
| ADJUSTMENT\_TYPE\_i | What calibration or transformation is included | n/a | ALIGNMENT, BIAS, etc | No |
| ALIGNMENT\_i\_FRAME\_A | Name of the reference frame that defines the starting point of the sensor alignment | n/a | SC\_BODY | No |
| ALIGNMENT\_i\_FRAME\_B | Name of the reference frame that defined the endo of the sensor alignment |  n/a | AST\_i | No |
| ALIGNMENT\_QUAT\_i | Quaternion representing the alignment from ALIGNMENT\_i\_FRAME\_A to ALIGNMENT\_i\_FRAME\_B |  | 0,0,0,1 |  |
| BIAS\_i | Bias for SENSOR\_TYPE\_i, must be in the same frame as MEASUREMENT\_FRAME\_i | rad/sec, mG | Gyro bias, magnetometer bias | No |
| Others TBD (USER DEFINED?) |  |   |  | No |
| SENSOR\_STOP | End of the sensor specification | n/a |  | Yes |

###  ACM Data: Maneuver specification

Table 5-7 provides an overview of the ACM maneuver specification section. Only those keywords shown in table 5-7 shall be used in the ACM maneuver specification.

Keyword values shall be provided in the units specified in column three of Table 5-7.

The order of occurrence of these ACM Maneuver Specification keywords shall be fixed as shown in table 5-7, with the exception that comments may be interspersed throughout the this section as required.

The “ACM Data: Maneuver Specification” section is optional; “mandatory” in the context of Table 5-7 denotes those keywords which must be included in this section if this section is included.

One or more ACM Maneuver Specification sections may appear in an ACM.

Maneuver data in the ACM shall be indicated by two keywords: MAN\_START and MAN\_STOP.

The ‘MAN\_TYPE’ keyword must appear before the first line of any maneuver time history data.

Attitude maneuver data in the ACM data shall be time-tagged by a relative time value measured with respect to the epoch time specified via the EPOCH\_TZERO keyword.

**Table 5-7** **: ACM Data: Maneuver Specification**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Keyword** | **Description** | **Units** | **Examples of Values** | **Mandatory** |
| COMMENT | Comments (allowed at any point(s) throughout the ACM Maneuver Specification section).  | n/a | COMMENT This is a comment | No |
| MAN\_START | Start of a maneuver data interval specification | n/a |  | Yes |
| MAN\_ID | Optional identification number for this maneuver | n/a |   | No |
| MAN\_PURPOSE | The user can specify the intention(s) of the maneuver. Multiple maneuver purposes can be provided as a comma-delimited list. While there is no CCSDS-based restriction on the value for this keyword, it is suggested to use:  Attitude adjust (ATT\_ADJUST) Momentum desaturation (MOM\_DESAT) Pointing Request Message (PRM\_ID\_xxxx) Science objective (SCI\_OBJ) Spin rate adjust (SPIN\_RATE\_ADJUST)  | n/a | ATT\_ADJUST | No |
| MAN\_WIN\_START | Identifies the start of maneuver window that may be different than the maneuver execution start time. This may identify the time at which the satellite is placed into a special maneuver attitude control mode, for example  | n/a | 2001-11-06T11:17:332002-204T15:56:23Z | No |
| MAN\_WIN\_STOP | Identifies the end of the maneuver window that may be different than the maneuver execution end time. This may identify the end time of any special maneuver attitude control mode, for example  | n/a | 2001-11-06T11:17:332002-204T15:56:23Z | No |
| MAN\_EXEC\_START | Start time of actual maneuver |  |  |  |
| MAN\_EXEC\_STOP | End time of actual maneuver |  |  |  |
| MAN\_DURATION | Length of maneuver, should only specify MAN\_EXEC\_STOP or MAN\_DURATION, not both | s | 100 |  |
| ACTUATOR\_USED | Specifies the type of actuator used for the maneuver | n/a | THR, RWA | No |
| TARGET\_MOMENTUM | If MAN\_PURPOSE=MOM\_DESAT, TARGET\_MOMENTUM in SC\_BODY | N-m-s |   | No |
| TARGET\_ATTITUDE | If MAN\_PURPOSE-ATT\_ADJUST, target quaternion |  |  | No |
| TBD |  |  |  | No |
|  |  |  |  | No |
|   |  |  |  | Yes |
| MAN\_STOP | End maneuver data interval specification | n/a |  | Yes |

### ACM Data: ATTITUDE State Time History

Table 5-8 provides an overview of the ACM attitude state time history section. Only those keywords shown in table 5-8 shall be used in ACM attitude state time history data specification.

Keyword values shall be provided in the units specified in column three of table 5-8.

The order of occurrence of these ACM Attitude State Time History keywords shall be fixed as shown in table 5-8, with the exception that comments may be interspersed throughout this section as required.

The “ACM Data: Attitude State Time History” section is optional; “mandatory” in the context of table 5-8 denotes those keywords which must be included in this section if this section is included.

One or more ACM Attitude State Time History sections may appear in an ACM. Each ACM Attitude State Time History shall be paired with an Estimator Description block.

Attitude state time history data intervals in the ACM shall be indicated by two keywords: ATT\_START and ATT\_STOP.

The states and reference frames included shall be specfied in in the estimator description, as described in Table 5-8.

The ATT\_STOP keyword must appear after the last line of attitude state data and metadata. Each of these keywords shall appear on a line by itself.

All orbit state values in the ACM data shall be time-tagged by a relative time value measured with respect to the epoch time specified via the EPOCH\_TZERO keyword.

Each attitude state time history shall be time-ordered to be monotonically increasing, with the exception that the message creator may indicate a change in state over which interpolation or propagation should not be performed by providing exactly two consecutive lines containing a duplicate timestamp (e.g. following application of a maneuver or spacecraft or orbit event). In the case of such a duplicate timestamp, interpolation or propagation prior to the duplicate timestamp shall use the first of the two duplicate timestamp attitude states, and interpolation or propagation after the duplicate timestamp shall use the second of the two.

If the user includes attitude states at key mission event times, it is recommended that those mission event states be annotated as such by a preceding descriptive comment line.

Time tags of consecutive attitude states within the ordered sequence may be separated by uniform or non-uniform step size(s).

Attitude state time tags may or may not match those of maneuver, covariance and/or sensor time histories.

Each set of attitude data, including the time tag, must be provided on a single line. The order in which data items are given shall be fixed: **T\_Relative** followed by the attitude state as defined in the attitude state identified in .

At least one space character must be used to separate the items in each attitude data line.

Table 5-8 : ACM Data: Attitude State Time History

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Keyword** | **Description** | **Units** | **Examples of Values** | **Mandatory** |
| COMMENT | Comments (allowed at any point(s) throughout the ACM Attitude State Time History section). (See 7.7 for formatting rules.) | n/a | COMMENT This is a comment | No |
| ATT\_ID | Optional identification number for this orbit state time history block | n/a | ATT\_20160402\_XYZ | No |
| ATT\_START | Start of an attitude state vector or time history section | n/a | n/a | Yes |
| ATT\_N | Number of state vector components contained in the set. | n/a | 7 | No |
|  … < Insert attitude lines here> |  |  |  | Yes |
| ATT\_STOP | End of an attitude state vector or time history section | n/a | n/a | Yes |

### ACM Data: SENSOR Data

Table 5-9 provides an overview of the ACM sensor data section. Only those keywords shown in table 5-9 shall be used in ACM attitude determination data specification.

Keyword values shall be provided in the units specified in column three of table 5-9.

The order of occurrence of these ACM Sensor Data keywords shall be fixed as shown in table 5-9, with the exception that comments may be interspersed throughout the this section as required.

The ACM Data: Sensor Data section is optional; “mandatory” in the context of table 5-9 denotes those keywords which must be included in this section if this section is included.

A Sensor Data section can be included for any number of sensor types or sensor residuals. Each Sensor Data section shall be paired with a Sensor Description block.

Sensor data shall be indicated by two keywords: DATA\_START and DATA\_STOP.

All sensor data event times shall be specified in DAYS relative to the epoch time specified via the EPOCH\_TZERO keyword.

**Table 5-9** **: ACM Data: Sensor Data**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Keyword** | **Description** | **Units** | **Examples of Values** | **Mandatory** |
| COMMENT | Comments (allowed at any point(s) throughout the ACM Attitude Determination Data section).  | n/a | COMMENT This is a comment | No |
| AD\_ID | Optional identification number for this attitude determination data block | n/a | aD\_20160402 | No |
| DATA\_START | Start of a sensor data section | n/a | n/a | Yes |
| DATA\_TYPE | Sensor data included or residual data | n/a | SENSOR, RESIDUAL | Yes |
| DATA\_NUMBER | Number of elements included in the DATA\_TYPE | n/a | 3 | No |
| SENSOR\_TYPE | The type of sensor or sensor residual included | n/a | AST, DSS, IMU | No |
| SENSORS\_UNITS | Units of sensor data or sensor residual |   | rad, mG  | No |
| <insert sensor data lines here> |   |  |  | No |
| DATA\_STOP |   |  |  | No |

### ACM Data: ATtitude State Covariance Time History

Table 5-10 provides an overview of the ACM covariance time history section. Only those keywords shown in table 5-10 shall be used in ACM covariance time history data specification.

Keyword values shall be provided in the units specified in column three of table 5-10.

The order of occurrence of these ACM Attitude State Covariance Time History keywords shall be fixed as shown in table 5-10, with the exception that comments may be interspersed throughout the this section as required.

The “ACM Data: Attitude State Covariance Time History” section is optional; “mandatory” in the context of table 5-10 denotes those keywords which must be included in this section if this section is included.

One or more ACM covariance time history sections may appear in an ACM. Each ACM Attitude State Covariance Time History shall be paired with an Estimator Description Block.

Covariance time history data intervals in the ACM shall be indicated by means of two keywords: COV\_START and COV\_STOP. The COV\_START keyword must appear before the first line of any covariance metadata. The COV\_STOP keyword must appear after the last line of covariance data and metadata. Each of these keywords shall appear on a line by itself.

All covariance matrices in the ACM data shall be time-tagged by a relative time value measured with respect to the epoch time specified via the EPOCH\_TZERO keyword.

Each covariance time history shall be time-ordered to be monotonically increasing, with the exception that the message creator may indicate a change in state over which interpolation or propagation should not be performed by providing exactly two consecutive covariance data blocks containing a duplicate timestamp (e.g. following application of an impulsive maneuver or spacecraft or orbit event). In the case of such a duplicate timestamp, interpolation or propagation prior to the duplicate timestamp shall use the first of the two duplicate timestamp covariance matrices, and interpolation or propagation after the duplicate timestamp shall use the second of the two.

If the user includes covariances at key mission event times, it is recommended that those mission event covariances be annotated as such by a preceding descriptive comment line.

 Time tags of consecutive covariance information within the ordered sequence may be separated by uniform or non-uniform step size(s).

 Covariance time tags may or may not match those of maneuver, attitude state and/or sensor data time histories.

 Values in the covariance matrix shall be only main diagonal elements provided on a single line. (Off diagonal could be USER defined block)

**Table 5-10** **: ACM Data: Covariance Time History**

| **Keyword** | **Description** | **Units** | **Examples of Vaes** | **Mandatory** |
| --- | --- | --- | --- | --- |
| COV\_START | Start of a covariance time history section | n/a | n/a | Yes |
| COMMENT | Comments (allowed at any point(s) throughout the ACM Covariance Time History section).  | n/a | COMMENT This is a comment | No |
| ATT\_ID | Optional identification number for this attitude covriance time history block | n/a | ATT\_20160402\_XYZ | No |
| COV\_N | Number of state vector components contained in the set. | n/a | 6 | No |
|  …< Insert covariance data here> |  |  |  | Yes |
| COV\_STOP | End of a covariance time history section | n/a | n/a | Yes |

### ACM DATA: ACTUATOR/TORQUE DESCRIPTION TBD

### ACM Data: User-Defined Parameters

A section of User Defined Parameters may be provided if necessary. In principle, this provides flexibility, but also introduces complexity, non-standardization, potential ambiguity, and potential processing errors. Accordingly, if used, the keywords and their meanings must be described in an ICD. User Defined Parameters, if included in an ACM, should be used as sparingly as possible; their use is not encouraged.

The “ACM Data: User-Defined Parameters” section is optional; “mandatory” in the context of table 5-11 denotes those keywords which must be included in this section if this section is included.

Table 5-11 provides an overview of the ACM user-defined data section. Only those keywords shown in table 5-11 shall be used in ACM user-defined data specification.

Table 5-11 : ACM Data: User-Defined Parameters

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Keyword** | **Description** | **Units** | **Examples of Values** | **Mandatory** |
| COMMENT | Comments (allowed at any point(s) throughout the ACM User-Defined Data section). (See 7.7 for formatting rules.) | n/a | COMMENT This is a comment | No |
| USER\_DEFINED\_x | User defined parameter, where ‘x’ is replaced by a variable length user specified character string. Any number of user defined parameters may be included, if necessary to provide essential information that cannot be conveyed in COMMENT statements. | n/a | OFF\_DIAGONAL\_COV, SENSOR\_TEMPERATURE, SENSOR\_FOV | No |

## ACM Examples

Figures 5-1 through figure 5-5 are examples of Attitude Comprehensive Messages. The first has only a time history of attitude states and constitutes a minimal content ACM. The second includes space object characteristics, the third includes a maneuver with associated attitude history, the fourth contains an example sensor description block followed by sensor data, and the fifth includes a time series of covariance elements.

CCSDS\_ACM\_VERS = X.0

CREATION\_DATE = 1998-11-06T09:23:57

ORIGINATOR = JAXA

OBJECT\_NAME = GODZILLA 5

EPOCH\_TZERO = 1998-12-18T14:28:15.1172

EST\_START

TYPE\_OF\_ESTIMATOR = QUEST

NUMBER\_STATES = 4

ATTITUDE\_STATES= QUATERNION

REF\_FRAME\_A = J2000

REF\_FRAME\_B = SC\_BODY

EST\_STOP

ATT\_START

0.0 0.73566 -0.50547 0.41309 0.180707

0.25 0.73529 -0.50531 0.41375 0.181158

0.50 0.73492 -0.50515 0.41441 0.181610

< additional data records omitted here >

ATT\_STOP

Figure 5‑ : Simple/Succinct ACM File example

CCSDS\_ACM\_VERS = 1.0

CREATION\_DATE = 2017-12-01T00:00:00

ORIGINATOR = NASA

OBJECT\_NAME = SDO

OBJECT\_ID = 2010-005A

EPOCH\_TZERO = 2017-12-26T19:40:00.000

TIME\_SYSTEM = UTC

COMMENT = SDO Onboard Filter

EST\_START =

TYPE\_OF\_ESTIMATOR= EKF

ATTITUDE\_SOURCE = OBC

NUMBER\_OF\_STATES = 7

ATTITUDE\_STATES = QUATERNION

REF\_FRAME\_A = J2000

REF\_FRAME\_B = SC\_BODY

OTHER\_STATES = GYRO\_BIAS

NUMBER\_SENSORS\_USED = 4

SENSORS\_USED\_1 = AST1

SENSORS\_USED\_2 = AST2

SENSORS\_USED\_3 = DSS

SENSORS\_USED\_4 = IMU

EST\_END

COMMENT = Momentum management maneuver

MAN\_START = 2017-07-26T19:40:00.000

MAN\_PURPOSE = MOM\_DESAT

MAN\_DURATION = 450.0

ACUTATOR\_USED = THR

TARGET\_MOMENTUM = 1.30 -16.400 -11.350

MAN\_STOP

COMMENT = OBC Attitude and Bias during Delta H maneuver

ATT\_START

ATT\_N = 7

0.000000 0.1153 -0.1424 0.8704 0.4571 2.271e-06 -4.405e-06 -3.785e-06

2.000000 0.1153 -0.1424 0.8704 0.4571 2.271e-06 -4.405e-06 -3.785e-06

< intervening data records omitted here >

99.80183 0.1017 -0.1332 0.8806 0.4433 2.587e-06 8.769e-06 5.436e-06

< intervening data records omitted here >

599.80275 0.1152 -0.1423 0.8704 0.4571 2.48e-06 -4.350e-06 -3.779e-06

ATT\_STOP

Figure 5-2: ACM example with Delta H maneuver, Estimator Description, and Attitude State History During Manuever

CCSDS\_ACM\_VERS = 1.0

CREATION\_DATE = 1998-11-06T09:23:57

ORIGINATOR = JAXA

TECH\_POC = Ms. Rodgers, (719)555-5555, email@email.XXX

EPOCH\_TZERO = 1998-12-18T14:28:15.1172

OBJECT\_NAME = GODZILLA 5

OBJECT\_ID = 1998-999ZZZ

TIME\_SYSTEM = UTC

TAIMUTC\_TZERO = 36 [s]

COMMENT S/C Physical Characteristics:

PHYS\_START

MASS = 1916 [kg]

IXX = 752 [kg\*m\*\*2]

IYY = 1305 [kg\*m\*\*2]

IZZ = 1490 [kg\*m\*\*2]

IXY = 81.1 [kg\*m\*\*2]

IXZ = -25.7 [kg\*m\*\*2]

IYZ = 74.1 [kg\*m\*\*2]

CM = .04,-0.78,-0.023 [m]

PHYS\_STOP

Figure 5-3: Example Spacecraft Physical Characteristics

CCSDS\_ACM\_VERS = 1.0

CREATION\_DATE = 2017-12-30T10:00:00

ORIGINATOR = NASA

OBJECT\_NAME = LRO

OBJECT\_ID = 2009-031A

EPOCH\_TZERO = 2017-12-17T00:00:00.0

TIME\_SYSTEM = UTC

SENSOR\_START

NUMBER\_OF\_SENSORS = 2

SENSOR\_TYPE\_1 = AST

SENSOR\_TYPE\_2 = AST

NUMBER\_OF\_ELEMENTS\_1 = 4

NUMBER\_OF\_ELEMENTS\_2 = 4

MEASUREMENT\_FRAME\_1 = AST1

MEASUREMENT\_FRAME\_2 = AST2

ALIGNMENT\_1\_FRAME\_A = SC\_BODY

ALIGNMENT\_1\_FRAME\_B = AST1

ALIGNMENT\_2\_FRAME\_A = SC\_BODY

ALIGNMENT\_2\_FRAME\_B = AST2

ALIGNMENT\_QUAT\_1 = -0.1294 0.8365 0.2241 0.4830

ALIGNMENT\_QUAT\_2 = 0 0.9659 0.2588 0

SENSOR\_STOP

DATA\_START

COMMENT Sensor residuals for AST1

DATA\_NUMBER = 3

DATA\_TYPE = RESIDUAL

SENSOR\_TYPE = AST

SENSOR\_UNITS = RAD

1. 6.28e-06 1.09e-04 -1.23e-04

1.09669 -8.38e-05 4.32e-05 -5.86e-05

< intervening data records omitted here >

59.89669 -2.96e-04 -4.12e-05 -1.07e-05

DATA\_STOP

DATA\_START

COMMENT Sensor residuals for AST2

DATA\_NUMBER = 3

DATA\_TYPE = RESIDUAL

SENSOR\_TYPE = AST

SENSOR\_UNITS = RAD

0.0 1.35e-05 -6.33e-05 2.79e-04

1.09669 1.67e-05 3.03e-05 1.28e-04

< intervening data records omitted here >

59.89669 5.05e-05 6.60e-05 6.93e-06

DATA\_STOP

Figure 5-4: Sensor Data Description and Sensor Data

CCSDS\_ACM\_VERS = 1.0

CREATION\_DATE = 2017-12-30T00:00:00

ORIGINATOR = NASA

OBJECT\_NAME = LRO

OBJECT\_ID = 2009-031A

EPOCH\_TZERO = 2017-12-30T00:00:00.0

TIME\_SYSTEM = UTC

COMMENT LRO Onboard Filter

EST\_START

TYPE\_OF\_ESTIMATOR = EKF

ATTITUDE\_SOURCE = OBC

NUMBER\_OF\_STATES = 7

ATTITUDE\_STATES = QUATERNION

REF\_FRAME\_A = EME2000

REF\_FRAME\_B = SC\_BODY

OTHER\_STATES = GYRO\_BIAS

NUMBER\_SENSORS\_USED = 3

SENSORS\_USED\_1 = AST1

SENSORS\_USED\_2 = AST2

SENSORS\_USED\_3 = IMU

EST\_END

COV\_START

COMMENT Diagonal Covariance for LRO Onboard Kalman Filter

COV\_N = 6

1. 6.74E-11 8.10E-11 9.22E-11 1.11E-15 1.11E-15 1.12E-15

1.096694 6.74E-11 8.10E-11 9.22E-11 1.11E-15 1.11E-15 1.12E-15

< intervening data records omitted here >

59.896697 6.74E-11 8.10E-11 9.22E-11 1.11E-15 1.11E-15 1.12E-15

COV\_STOP

Figure 6-4: ACM example with Covariance Elements