CCSDS Concept Paper

Launch Data Message

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## ABSTRACT

The Launch Data Message serves to improve all data exchange, coordination and inter-organizational aspects of both domestic and international launches, thereby reducing operations costs, increasing overall efficiency and minimizing operational risk.

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# Introduction

Extensive coordination activities and analyses are required to prepare for and conduct successful spacecraft launch and early orbit sequences. The owners, operators and analysts of the launchers, upper stages, and deployed satellites often span a diverse international and organizational space community. Space lift providers commonly launch and deploy many satellites in a single launch. This is especially driven by nanosatellite and CubeSat programs, with upcoming launches anticipated to deploy as many as 50 multi-national spacecraft. Each entity may have different methods for coordination, launch data content, spacecraft commissioning and operation. This can yield a lack of coordination between pertinent space organizations, extensive workload in converting non-standard launch data formats, and the potential for data misinterpretation and operational errors.

The Launch Data Message serves to improve all data exchange, coordination and inter-organizational aspects of both domestic and international launches, thereby reducing operations costs, increasing overall efficiency and minimizing operational risk.

The aforementioned information can to a large extent be better covered by OEMs [2], AEMs [3] and CDMs [4].

Standardisation is needed because:

* no current standard covers the exchange of points-of-contact (phonebook), launch-relevant agency information, launch sequencing and trajectory information, tracking requirements, collision avoidance/laser clearinghouse/search and acquisition needs etc.
* standardising the data exchange would make launch-relevant easier to access, exchange and use by the interested entities (data acquisition, analysis, operations)
* standardising the data exchange would encourage more entities to easily and consistently share such information because the standard would promote best practices of what should be exchanged
* promotes interoperability of systems and the re-use of software and processes

# Launch data

A prototype Launch Data Message is shown in the attached appendix. Types of launch data include:

Definition of Launch Support Package format

* Launch Information
* Launch site Information: Name, Geodetic Latitude (WGS 84 Ellipsoid), Longitude, Altitude, Launch Azimuth at Liftoff, Applicable References and metadata.
* Launching agency: Name/Designators, Launch Points of Contact, Operations Points of Contact
* Earliest Launch Times (Window Open): Tabular by date and time (Julian/UTC)
* Latest Launch Times (Window Close): Tabular by date and time (Julian/UTC)
	+ Number and Names of Objects to be Launched
* Payload(s) to achieve orbit. Duration, Mass at Launch, Power, Dimensions, Antenna Information, Solar Array Area and Dimensions, Maximum Downlink Rate, Spacecraft Command Center Information, Nominal Operational Lifetime
* Rocket bodies to achieve orbit
* Other objects to achieve orbit, include debris and debris clusters, clouds, bolts, and so forth.
* Launch booster and sustainer combinations. If augmenting strap-on motors are used, state the number
	+ Tracking requirements
* EODET (Early Orbit Determination) and SOI (Space Object Identification) requirements: Include points of contact for EODET and SOI
* Tracking and observation support requests: direct transmission of tracking data to EODET, transmission vectors and/or element sets, RA (reentry assessment) support, contingency support; and so forth.
	+ Data to support Collision Avoidance for launch and early orbit: COLA screening windows, probability of collision thresholds for conjunction with resident objects on orbit, agencies responsible for COLA, points of contact to be informed, screening volume geometry and dimensions.
	+ Orbital parameter information for all objects (objects 1 square meter or larger in size, or any object that will survive reentry regardless of size) achieving orbit. (Provide information for all orbits up to and including final orbit.) Include seven significant figures for orbit parameters.
	+ Burn out vectors for each piece of the launch achieving an altitude of more than 100 km. Vectors should be epoched to burnout. Also, include time from launch.
	+ Sequence of events from liftoff to final injection. Time from lift-off; times for events such as separation of booster(s), engine ignition(s) and cut-off(s), jettison of pieces, maneuvers, separation of intermediate stages, and reorientations, deorbits and ejection of special packages or other experiments (unclassified missions), and so forth.
	+ Schedule of events during the active life of all packages on the satellite payload. Give schedule for events: such as ejection of experiments, maneuvering (unclassified missions), jettison of parts, extension of antenna and solar arrays, venting, spinning or despinning attitude changes, reorientation, or anything which may affect the orbital characteristics,
	+ Missions with brief narratives.
	+ Transmitting frequency and power of all devices (including continuous radio transmissions) and power and or schedule of lights (if any) throughout the operational life. State if an emission is scheduled by fixed program, command, or transponder tracking signal.
	+ Cataloguing instructions and remarks from requirements derived from previous requirements.
	+ Points of contact for clarification information.

# Recommendation

The proposed work fits in with the work performed in the Navigation Working Group in the MOIMS area. If this Concept Paper is approved by the CMC/CESG and if necessary, the Navigation WG charter can and should be expanded to cover this work.

# Conclusion

A CCSDS standard covering authoritative and comprehensive launch data is desirable and of interest. Developing the standard would help ensure a safer and more efficient launch process.

# Abbreviations and acronyms

|  |  |
| --- | --- |
| CCSDS | Consultative Committee for Space Data Systems |
| CESG | CCSDS Engineering Steering Group |
| CMC | CCSDS Management Council |
| LDM | Launch Data Message |
| MOIMS | Mission Operations and Information Management Services |
| SSA | Space Situational Awareness |
| WG | Working Group |

# Appendix 1: Launch Data Message Sample Content

(Note: Focus on the content rather than the format. The format would be modified as appropriate to reflect CCSDS message requirements)

SUBJECT: LDM for Prometheus VII / Cassandra

ITEM 1: Launch site

Eastern Range Launch Complex 29 (WGS 84 reference ellipsoid)1

Launch Stand Geodetic Latitude 28.56224379° N

Launch Stand Longitude 279.4227448° E

Launch Stand Altitude -21.43 meters relative to reference ellipsoid

 (6.92 meters above mean sea level)

Launch Azimuth at Liftoff 98.6 Degrees2

References (1) Geodetic Coordinates Manual, 15 January 2015.

 (2) Launch Systems Corporation Prometheus VII/Cassandra Mission Design Document, October 2015.

ITEM 1A: Launch date

On or after 19 October 2015 (UTC)

ITEM 1B: Launching agency

Eastern Range, 5th Space Launch Squadron (5 SLS)

 Prometheus VII Flight Commander: Lt Candy Cane, 5 SLS/DEA

 (888) 888-1234 DSN 888-1234

 On Console: (888) 888-1234 DSN 888-1234

1st Range Operations Squadron (1 ROPS)

 Program Support Manager: Mr. Arnold Ziffle

 (888) 888-1234 DSN 888-1234

 On Console: (888) 888-1234 DSN 888-1234

ITEM 2: Earliest launch time (UTC)

The earliest launch times from 19 October 2015 through 28 October 2015 (UTC) are:

| **Launch Window Open (UTC)** | **Launch Window Open (EST)** |
| --- | --- |
|  2015/10/19 21:12:00  |  2015/10/19 16:12:00  |
|  2015/10/20 21:08:00  |  2015/10/20 16:08:00  |
|  2015/10/21 21:04:00  |  2015/10/21 16:04:00  |
|  2015/10/22 21:00:00  |  2015/10/22 16:00:00  |
|  2015/10/23 20:56:00  |  2015/10/23 15:56:00  |
|  2015/10/24 20:52:00  |  2015/10/24 15:52:00  |
|  2015/10/25 20:48:00  |  2015/10/25 15:48:00  |
|  2015/10/26 20:44:00  |  2015/10/26 15:44:00  |
|  2015/10/27 20:40:00  |  2015/10/27 15:40:00  |
|  2015/10/28 20:36:00  |  2015/10/28 15:36:00  |

ITEM 2A: Latest launch time (UTC)

The latest launch times from 19 October 2015 through 28 October 2015 (UTC) are:

| **Launch Window Close (UTC)** | **Launch Window Close (EST)** |
| --- | --- |
|  2015/10/19 22:12:00  |  2015/10/19 17:12:00  |
|  2015/10/20 22:08:00  |  2015/10/20 17:08:00  |
|  2015/10/21 22:04:00  |  2015/10/21 17:04:00  |
|  2015/10/22 22:00:00  |  2015/10/22 17:00:00  |
|  2015/10/23 21:56:00  |  2015/10/23 16:56:00  |
|  2015/10/24 21:52:00  |  2015/10/24 16:52:00  |
|  2015/10/25 21:48:00  |  2015/10/25 16:48:00  |
|  2015/10/26 21:44:00  |  2015/10/26 16:44:00  |
|  2015/10/27 21:40:00  |  2015/10/27 16:40:00  |
|  2015/10/28 21:36:00  |  2015/10/28 16:36:00  |

ITEM 3: List the number and names of all objects to achieve orbit. Use items 3A, 3B, and 3C to provide the following information for each object to achieve orbit: mass, a physical description of the objects including dimensions, method of stabilization, and spin rate.

ITEM 3A: Payload(s) to achieve orbit. Include the nominal operational life of payload(s)/active package(s).

The Cassandra Mission to Saturn is an international venture involving the [National Aeronautics and Space Administration (NASA)](http://www.nasa.gov/home/index.html), the [European Space Agency (ESA)](http://www.esa.int/esaSC/120378_index_0_m.html), the [Italian Space Agency (ASI)](http://www.asi.it/en), and several separate European academic and industrial partners. The mission is managed for NASA by the Jet Propulsion Laboratory in Pasadena, California. The spacecraft will carry a sophisticated complement of scientific sensors, including an Ultraviolet Imaging Spectrograph. [The large spacecraft](http://saturn.jpl.nasa.gov/spacecraft/overview/) will consist of an orbiter and ESA's Pandora probe. The orbiter mass at launch will be 10,000 kg, over half of which is propellant for trajectory control. The mass of the Pandodra probe (5.4 m diameter) is roughly 1200 kg.

Satellite: 3-axis stabilized and fully redundant spacecraft.

Duration: Cassandra has a twelve-year science mission and carries enough fuel to operate for an additional seven years.

Mass: Total mass of the spacecraft at launch is 5,200 kg (11,464 lbm); payload 1,550 kg (3,419 lbm) and fuel 3,650 kg (8,047 lbm).

Power: Total available power is 3,500 Watts (W) from 12.5 m2 of solar arrays

Dimensions: The overall length of the spacecraft along the sun-pointing axis is 7.5 m (24.6 ft), and each side is 3.65m (12.0 ft). The span of the spacecraft with extended solar panels is 12.0 m (39.4 ft).

High-gain Antennas: The high-gain antennas rotate once each orbit to follow Earth.

Solar Array: The solar panels cover an area of 67.5 m2 producing 1,500 W of power.

Maximum Downlink Rate: The spacecraft has a continuous, high-rate science data downlink rate of 700 Megabits per second (Mbps) at a Ka-Band frequency of about 22 GHz.

Spacecraft Command Center: The spacecraft command center will be located at the Huron Space Flight Center.

ITEM 3B: Rocket bodies to achieve orbit. If none achieve orbit, enter “none.”

The separated Prometheus upper stage performs a Collision/Contamination Avoidance Maneuver (CCAM) and a blowdown of residual propellant resulting in a highly elliptical disposal orbit.

ITEM 3C: All other objects to achieve orbit, include debris and debris clusters, clouds, bolts, and so forth. If none will achieve orbit enter “none.”

None.

ITEM 4: Launch booster and sustainer combinations. If augmenting strap-on motors are used, state the number.

The Prometheus 1200 launch vehicle consists of a Prometheus VII booster with three Endyne J-50 engines, twelve strap-on solid rocket motors (SRMs), a Prometheus upper stage with a single BJ-40 engine, and a 17-m extremely large payload fairing (ELPF). The Prometheus core is 15.5 ft. (4.7 m) in diameter by 305.6 ft. (93.1 m) long and uses 1,102,311 lbm (500,000 kg) of liquid oxygen and PL-7 propellants.

The Prometheus cryogenic upper stage is powered by a single Ryan Hydron turbopump-fed engine, burning liquid oxygen and liquid hydrogen. The Ryan RT-17 engine provides a thrust of 50,000 lbf (222.4 kN). The Logi-Core inertial navigation unit (INU) provides guidance and navigation. The Cassandra engines are capable of multiple in-space starts. The Prometheus upper stage is 88.2 feet (26.9 m) in length and 20 feet (6.10 m) in diameter.

ITEM 5A: EODET (Early Orbit Determination) and SOI (Space Object Identification) requirements.

a. EODET. If used, include the name and phone number of the points of contact.

EODET is not required.

b. SOI.

SOI is not required.

c. Special instructions and special spacecraft support required.

None.

ITEM 5B: State all space surveillance support requests: such as direct transmission of tracking data from the sensors to AFSCN and/or GSFC, transmission of SCC vectors and/or element sets, RA (reentry assessment) support, contingency support; and so forth. Note: Provide office symbol and routing indicator.

See above ITEM 5A, paragraph c for coordination of tracking data, and transmission of SCC vectors and/or element sets. RA support is not required. Contingency support is required as per coordination. Routing indicators will be provided as per coordination.

All requests for post-launch information will be coordinated through Mr. Luke Warm, Space Control Center, (888) 888-1234.

ITEM 5C: Provide all of the following data to support Collision Avoidance for launch and early orbit.

ITEM 5C(1) COLA Screen

ITEM 5C(1)a: Screen duration (default 100 min)

COLA screen is for launch at any time between open and close of the launch window, with launch planned to occur on the whole minute. The launch time dispersion is from +0 to +3 seconds from the planned launch time, and thus, the launch window close times may be exceeded by up to 3 seconds.

Reported probability of collision threshold will be 1x10-7.

COLA screen is in two parts and results will be combined into a single report:

(i) COLA Screen part (i) is for the Cassandra spacecraft, and should be performed from liftoff until 100 minutes past spacecraft separation. Screen shall be against all objects, including manned objects, active and inactive satellites, and debris.

1. COLA Screen part (ii) is for the Prometheus VII upper stage, and should be performed from the time of spacecraft separation until Prometheus VII End of Mission (SVSEP + 6000 sec). Screen shall be against all objects, including manned objects, active and inactive satellites, and debris.

ITEM 5C(1)b: COLA runs.

COLA runs are required prior to launch on the delivery schedule and to the recipients specified in ITEM 5C(2).

Expert Systems Corporation Lead for Conjunction Assessment Program Launch Support:

 Houston, TX

 Mr. Coupe DeVille (888) 888-1234 FAX (888) 888-1234

 coupe.deville@anywhere.org Page (888) 888-1234

Expert Systems Corporation Conjunction Assessment Program Points of Contact:

 Expert Systems Corporation, San Diego, CA

 Primary Analyst: Mr. Larry Fine Home (888) 888-1234

 (888) 888-1234 FAX (888) 888-1234

 larry.fine@anywhere.org

 Backup Analyst: Mr. Roger Dodger CELL (888) 888-1234

 (888) 888-1234 FAX (888) 888-1234

 roger.dodger@anywhere.org

Expert Systems Corporation Launch Systems Point of Contact:

 San Diego, CA

 Mr. Bartles N. James (888) 888-1234 FAX (888) 888-1234

 bartles.n.james@anywhere.org

 Mr. Johnny Cash (888) 888-1234 FAX (888) 888-1234

 johnny.cash@anywhere.org

Eastern Range 45th Space Wing Point of Contact (POC):

 Patrick Air Force Base, FL

 45SW/SELF (888) 888-1234 DSN 888-1234 FAX 888-1234

 Mr. Ward Cleaver ward.cleaver@anywhere.af.mil

 Ms. Dot Matrix dorothy.matrix@anywhere.af.mil

Eastern Range 5th Space Launch Squadron (SLS) Point of Contact (POC):

 Cape Canaveral Air Force Station, FL

 Lt Sophie Tucker (888) 888-1234 DSN 888-1234 FAX (888) 888-1234

 sophie.tucker@anywhere.af.mil

JFCC Space/J95 USV Contingency Points of Contact (POC):

 First Choice: Day Staff (Mr. Luke Warm, 888-888-1234, DSN 888-1234)

 Second Choice: Day Staff (Lt. Carmine Dioxide, 888-888-1234, DSN 888-1234)

 If Necessary: On-Duty Space Battle Manager (SBM)

 Joint Space Operations Center (JSpOC)

 888-888-1234, DSN 888-1234)

 UNCLASS FAX 888-888-1234, 888-1234)

NASA Kennedy Space Center COLA Points of Contact (POC):

 Mr. Bucky Beaver, KSC Flight Dynamics Branch Chief

 (888) 888-1234 FAX (888) 888-1234

 bucky.beaver@nasa.gov CELL (888) 888-1234

 Mr. Rocky Rhodes, KSC Flight Design Lead

 (888) 888-1234

 rocky.rhodes@nasa.gov CELL (888) 888-1234

 Mr. Omar Khayyam, KSC Flight Launch Manager

 (888) 888-1234 Console

 omar.khayyam@nasa.gov CELL (888) 888-1234

ITEM 5C(1)c: Screen dimensions.

COLA runs should identify all conjunctions between the Cassandra spacecraft, the Prometheus VII upper stage, and all orbital objects. Conjunctions with manned objects should be identified within a spherical radius (close approach) of 200 km.

ITEM 5C(2) Distribution of COLA results.

Note (1): COLA runs are required three times prior to launch, to be distributed at L-2 days, at L-1 day, and at L-2 hours.

Note (2): COLA runs are UNCLASSIFIED.

COLA runs are required three times prior to launch to the recipients specified in 5C(2). COLA runs are required at L-2 days, L-1 day, and L-2 hours for each launch/recycle attempt. Every attempt will be made to deliver the COLA results for the L-2 days and L-1 day runs during regular duty hours at the launch base. For launch delays up to 48 hours, only the L-1 day and L-2 hr COLA runs shall be repeated. For launch delays of more than 48 hours, L-2 days, L-1 day and L-2 hr COLA runs shall be repeated.

**Col. Forest Greene, Mission Director, DOC MDC, Cape Canaveral Air Force Station, FL**

 **Instruction: For Immediate Dissemination to Addressee**

 UNCLASS Phone: (888) 888-1234

 UNCLASS FAX: (888) 888-1234

**Maj. Jason Time, Launch Director, DOC MDC, Cape Canaveral Air Force Station, FL**

 **Instruction: Immediate Dissemination to Addressee**

 UNCLASS Phone: (888) 888-1234

 UNCLASS FAX: (888) 888-1234

**Mr. Don Tryit, Expert Launch Systems OI MDC, Cape Canaveral Air Force Station, FL**

 **Instruction: Immediate Dissemination to Addressee**

 UNCLASS Phone: (888) 888-1234

 UNCLASS FAX: (888) 888-1234

**Mr. Chip Munk, S/C Launch Director, DOC MDC, Cape Canaveral Air Force Station, FL**

 **Instruction: For Immediate Dissemination to Addressee**

 UNCLASS Phone: (888) 888-1234

 UNCLASS FAX: (888) 888-1234

**Ms. Olive Branch, NASA Launch Manager, HAE MDC, Cape Canaveral Air Force Station, FL**

 **Instruction: For Immediate Dissemination to Addressee**

 UNCLASS Phone: (888) 888-1234

 UNCLASS FAX: (888) 888-1234

**Ms. Paige Turner, Launch Conductor, Prometheus DOC/LCC, Cape Canaveral Air Force Station, FL**

 **Instruction: For Immediate Dissemination to Addressee**

 UNCLASS Phone: (888) 888-1234

 UNCLASS FAX: (888) 888-1234

**Mr. Warren Peace, LVLSC, Cape Canaveral Air Force Station, FL**

 **Instruction: For Your Information**

 UNCLASS Phone: (888) 888-1234

 UNCLASS FAX: (888) 888-1234

**Mr. Angus MacCoatup, Range Safety, 45 SW/SELF, Cape Canaveral Air Force Station, FL**

 **Instruction: For Your Information**

 UNCLASS Phone: (888) 888-1234

 UNCLASS FAX: (888) 888-1234

**Mr. Marty Graw, Eastern Range, L3 Comm ROCC, Cape Canaveral Air Force Station, FL**

 **Instruction: For Your Information**

 UNCLASS Phone: (888) 888-1234

 UNCLASS FAX: (888) 888-1234

**DoD Track, Eastern Range ROCC, Cape Canaveral Air Force Station, FL**

 **Instruction: For Your Information**

 UNCLASS Phone: (888) 888-1234

 UNCLASS FAX: (888) 888-1234

**Mr. Rush Inuit, 1 ROPS/DOUF, Cape Canaveral Air Force Station, FL**

 **Instruction: For Your Information**

 UNCLASS Phone: (888) 888-1234

 UNCLASS FAX: (888) 888-1234

**Mr. Perry Winkle, Expert Systems Corporation, San Diego, CA**

 **Instruction: For Your Information**

 UNCLASS Phone: (888) 888-1234

 UNCLASS FAX: (888) 888-1234

If the COLA results are not planned to be issued at the scheduled times, please notify the following personnel:

 Mr. Don Tryit, Launch Systems Corporation (888) 888-1234

 Ms. Constance Noring, Expert Systems Corporation, (888) 888-1234

ITEM 6: Orbital parameter information for all objects (objects 1 square meter or larger in size, or any object that will survive reentry regardless of size) achieving orbit. (Provide information for all orbits up to and including final orbit.) Include seven significant figures for orbit parameters.

Note (3): Trajectory data in this document is derived from the Launch Systems Corporation Mission Assurance Collision Avoidance Data for the Prometheus VII / Cassandra Mission.

Note (4): Elements computed using World Geodetic System 1984 (WGS 84) Earth model.

Classical elements at **Prometheus Main Engine Cutoff 1 + Decay (MECO1)**:

Note (5): Lift-off time is assumed to be 10/19/2015 21:12:00.0 (UTC).

Note (6): The event Main Engine Cutoff 1 + Decay (MECO1) corresponds to the state of the Prometheus second stage plus payload at the end of thrust decay following completion of the park orbit insertion burn.

6A(1) (MECO1) Epoch time used to calculate parameters (UTC) 10/19/2015 21:26:01.021

6B(1) (MECO1) Nominal Keplerian period (minutes) 88.1954319

6C(1) (MECO1) Inclination (DEG and decimal DEG) 28.5002465

6D(1) (MECO1) Eccentricity 0.0000107

6E(1) (MECO1) Argument of perigee (DEG and decimal DEG) 7.7134246

6F(1) (MECO1) Right ascension of ascending node (DEG and dec. DEG) 46.2891341

6G(1) (MECO1) Mean anomaly (DEG and decimal DEG) 125.0473468

6H(1) (MECO1) Start time of orbit (HH:MM:SS after launch) 00:14:01

6I(1) (MECO1) End time of orbit (HH:MM:SS after launch) 00:42:06

6J(1) (MECO1) Launch azimuth at liftoff (DEG and decimal DEG) 98.6

6K(1) (MECO1) Inertial azimuth at event (DEG and decimal DEG) 110.2361276

6L(1) (MECO1) For geostationary payloads, indicate final location (DEG east) N/A

6M(1) (MECO1) Semimajor axis (km) 6563.3303169

Classical elements at **Prometheus Main Engine Cutoff 2 + Decay (MECO2)**:

Note (7): Lift-off time is assumed to be 10/19/2015 21:12:00.0 (UTC).

Note (8): The event Main Engine Cutoff 2 + Decay (MECO2) corresponds to the state of the Prometheus second stage plus payload at the end of thrust decay following completion of the final orbit insertion burn.

6A(2) (MECO2) Epoch time used to calculate parameters (UTC) 10/19/2015 21:54:06.100

6B(2) (MECO2) Nominal Keplerian period (minutes) 12954.4762948

6C(2) (MECO2) Inclination (DEG and decimal DEG) 28.4791306

6D(2) (MECO2) Eccentricity 0.9640223

6E(2) (MECO2) Argument of perigee (DEG and decimal DEG) 238.2851811

6F(2) (MECO2) Right ascension of ascending node (DEG and dec. DEG) 46.3210313

6G(2) (MECO2) Mean anomaly (DEG and decimal DEG) 0.0618409

6H(2) (MECO2) Start time of orbit (HH:MM:SS after launch) 00:42:06

6I(2) (MECO2) End time of orbit (HH:MM:SS after launch) 02:11:22

6J(2) (MECO2) Launch azimuth at liftoff (DEG and decimal DEG) 98.6

6K(2) (MECO2) Inertial azimuth at event (DEG and decimal DEG) 100.0734406

6L(2) (MECO2) For geostationary payloads, indicate final location (DEG east) N/A

6M(2) (MECO2) Semimajor axis (km) 182714.6799341

Classical elements at **Space Vehicle Separation (SVSEP)**:

Note (9): Lift-off time is assumed to be 10/19/2015 21:12:00.0 (UTC).

Note (10): The event Space Vehicle Separation (SVSEP) corresponds to the state of the Cassandra spacecraft at the time of S/V separation.

6A(3) (SVSEP) Epoch time used to calculate parameters (UTC) 10/19/2015 21:56:54.800

6B(3) (SVSEP) Nominal Keplerian period (minutes) 13023.6518725

6C(3) (SVSEP) Inclination (DEG and decimal DEG) 28.4781491

6D(3) (SVSEP) Eccentricity 0.9641500

6E(3) (SVSEP) Argument of perigee (DEG and decimal DEG) 238.2924948

6F(3) (SVSEP) Right ascension of ascending node (DEG and dec. DEG) 46.3131066

6G(3) (SVSEP) Mean anomaly (DEG and decimal DEG) 0.1392288

6H(3) (SVSEP) Start time of orbit (HH:MM:SS after launch) 00:44:55

6I(3) (SVSEP) End time of orbit (HH:MM:SS after launch) 04:14:32

6J(3) (SVSEP) Launch azimuth at liftoff (DEG and decimal DEG) 98.6

6K(3) (SVSEP) Inertial azimuth at event (DEG and decimal DEG) 92.1985311

6L(3) (SVSEP) For geostationary payloads, indicate final location (DEG east) N/A

6M(3) (SVSEP) Semimajor axis (km) 183364.5542076

Classical elements at **Prometheus Hydrazine Depletion (DEPL)**:

Note (11): Lift-off time is assumed to be 10/19/2015 21:12:00.0 (UTC).

Note (12): The event Depletion (DEPL) corresponds to the nominal state of the Prometheus second stage at the time of hydrazine depletion.

6A(4) (DEPL) Epoch time used to calculate parameters (UTC) 10/19/2015 23:23:22.340

6B(4) (DEPL) Nominal Keplerian period (minutes) 12652.4201624

6C(4) (DEPL) Inclination (DEG and decimal DEG) 28.0804579

6D(4) (DEPL) Eccentricity 0.9637005

6E(4) (DEPL) Argument of perigee (DEG and decimal DEG) 237.7991508

6F(4) (DEPL) Right ascension of ascending node (DEG and dec. DEG) 46.4847079

6G(4) (DEPL) Mean anomaly (DEG and decimal DEG) 32.6034442

6H(4) (DEPL) Start time of orbit (HH:MM:SS after launch) 02:11:21

6I(4) (DEPL) End time of orbit (HH:MM:SS after launch) 04:14:32

6J(4) (DEPL) Launch azimuth at liftoff (DEG and decimal DEG) 98.6

6K(4) (DEPL) Inertial azimuth at event (DEG and decimal DEG) 62.0470189

6L(4) (DEPL) For geostationary payloads, indicate final location (DEG east) N/A

6M(4) (DEPL) Semimajor axis (km) 179863.3196743

ITEM 7: Burn out vectors for each piece of the launch achieving an altitude of more than 100 km. (The vectors must be in EFG coordinate system in the IRV (inter-range vector) format, carried out to 11 significant figures for position and 9 significant figures for velocity.) Units must be in km and km/sec. Vectors should be epoched to burnout. Also, include time from launch in seconds.

Note (13): Trajectory data in this document is derived from the Launch Systems Corporation Mission Assurance Collision Avoidance Data for the Prometheus VII / Cassandra Mission.

Note (14): The EFG Coordinate System is a rotating right-handed, Earth-centered, Earth-fixed Cartesian system whose positive G-axis is the north polar axis. The E- and F-axes are in the equatorial plane with the positive E-axis through the prime meridian. The positive F-axis completes the right-handed system.

EFG elements at **Prometheus Main Engine Cutoff 1 + Decay (MECO1)**:

Note (15): Lift-off time is assumed to be 10/19/2015 21:12:00.0 (UTC).

Note (16): The event Main Engine Cutoff 1 + Decay (MECO1) corresponds to the state of the Prometheus second stage plus payload at the end of thrust decay following completion of the park orbit insertion burn.

7A(1) (MECO1) EFG .42699475830E+04 -.44225051890E+04 .22993103984E+04

 Edot,Fdot,Gdot .55937302725E+01 .40880631726E+01 -.25246733191E+01

7B(1) (MECO1) Epoch time (UTC) 10/19/2015 21:26:01.021

7C(1) (MECO1) Time from launch (sec) 841.021

EFG elements at **Prometheus Main Engine Cutoff 2 + Decay (MECO2)**:

Note (17): Lift-off time is assumed to be 10/19/2015 21:12:00.0 (UTC).

Note (18): The event Main Engine Cutoff 2 (MECO2) corresponds to the state of the Prometheus second stage plus payload at the end of thrust decay following completion of the final orbit insertion burn.

7A(2) (MECO2) EFG .30580874444E+04 .50909719080E+04 -.29971591064E+04

 Edot,Fdot,Gdot -.86310136600E+01 .54100261573E+01 -.22103484324E+01

7B(2) (MECO2) Epoch time (UTC) 10/19/2015 21:54:06.100

7C(2) (MECO2) Time from launch (sec) 2526.100

EFG elements at **Space Vehicle Separation (SVSEP)**:

Note (19): Lift-off time is assumed to be 10/19/2015 21:12:00.0 (UTC).

Note (20): The event Space Vehicle Separation (SVSEP) corresponds to the state of the Cassandra spacecraft at the time of S/V separation.

7A(3) (SVSEP) EFG .15649261010E+04 .59225940466E+04 -.33122720790E+04

 Edot,Fdot,Gdot -.90098451451E+01 .44480791252E+01 -.15300214304E+01

7B(3) (SVSEP) Epoch time (UTC) 10/19/2015 21:56:54.800

7C(3) (SVSEP) Time from launch (sec) 2694.800

EFG elements at **Prometheus Hydrazine Depletion (DEPL)**:

Note (21): Lift-off time is assumed to be 10/19/2015 21:12:00.0 (UTC).

Note (22): The event Depletion (DEPL) corresponds to the nominal state of the Prometheus second stage at the time of hydrazine depletion.

7A(4) (DEPL) EFG -.28311750546E+05 .14086531982E+05 .15396190682E+04

 Edot,Fdot,Gdot -.35949492653E+01 .21365067499E+01 .12627079509E+01

7B(4) (DEPL) Epoch time (UTC) 10/19/2015 23:23:22.340

7C(4) (DEPL) Time from launch (sec) 7882.340

ITEM 8: Sequence of events from liftoff to final injection. (Indicate time from liftoff in HH:MM:SS.) Give the times for events such as separation of booster(s), engine ignition(s) and cutoff(s), jettison of pieces, maneuvers, separation of intermediate stages, and reorientations, deorbits and ejection of special packages or other experiments (unclassified missions), and so forth.

Note (23): Times are from the Launch Systems Corporation Cassandra Mission Sequence of Events.

|  |  |  |  |
| --- | --- | --- | --- |
| Event Description | Event | Seconds | HH:MM:SS |
| Mission Elapsed Time (MET) Reference | T-0 | 0.000 | 00:00:00.000 |
| Liftoff |  | 1.077 | 00:00:01.077 |
| Booster Engine Cut Off | BECO | 243.140 | 00:04:03.140 |
| Prometheus VII Stage 1/Stage 2 Separation |  | 246.140 | 00:04:06.140 |
| First Prometheus VII Stage 2 Main Engine Ignition | MES1 | 258.400 | 00:04:18.400 |
| Payload Fairing Jettison | PFJ | 275.420 | 00:04:35.420 |
| First Prometheus VII Stage 2 Main Engine Cutoff | MECO1 | 840.721 | 00:14:00.721 |
| End MECO1 Decay | MECO1+Decay | 841.021 | 00:14:01.021 |
| Second Prometheus VII Stage 2 Main Engine Ignition | MES2 | 2230.320 | 00:37:10.320 |
| Second Prometheus VII Stage 2 Main Engine Cutoff | MECO2 | 2525.801 | 00:42:05.800 |
| End MECO2 Decay | MECO2+Decay | 2526.101 | 00:42:06.101 |
| Cassandra Spacecraft Separation | SVSEP | 2694.801 | 00:44:54.801 |
| Nominal Hydrazine Depletion | DEPL | 7882.340 | 02:11:22.340 |
| End of Mission | EOM | 8694.801 | 02:24:54.801 |

ITEM 9: Schedule of events during the active life of all packages on the satellite payload. Give schedule for events: such as ejection of experiments, maneuvering (unclassified missions), jettison of parts, extension of antenna and solar arrays, venting, spinning or despinning attitude changes, reorientation, or anything which may affect the orbital characteristics. Do not include events that have been listed in item 8.

The Cassandra/Pandora spacecraft will perform a series of orbit-raising maneuvers to achieve the required lunar gravity assist trajectory.

ITEM 10: Mission with brief narrative.

The mission utilizes a standard Prometheus VII 1200 ascent profile. At 200,000 ft, the vehicle begins its closed-loop guidance steering. Booster flight continues in this closed loop guidance-steered phase until propellant depletion.

Twelve seconds after booster separation, the Prometheus VII second stage ignites its main engine (MES1). Jettison of the payload fairing nominally occurs at MES1+17 seconds. The Prometheus VII second stage first burn, which is the longer of the two Prometheus VII second stage firings, continues and injects the vehicle into a circular parking orbit.

Following Prometheus VII second stage Main Engine Cut-Off 1 (MECO1), the Prometheus VII second stage and spacecraft enter a coast period. At the guidance-calculated restart time, the Prometheus VII second stage main engine is re-ignited (MES2). The vehicle is then steered by guidance into the desired highly elliptical orbit required by the Cassandra spacecraft. MECO2 is initiated by the guidance command once the pre-flight targeted orbital parameters are achieved.

Following spacecraft separation, a Collision and Contamination Avoidance Maneuver (CCAM) is performed by the Prometheus VII second stage to preclude recontact with the spacecraft while minimizing the possibility of contaminating the spacecraft with Prometheus VII second stage reaction control system exhaust products.

After the Blowdown is completed, the hydrazine depletion phase begins. Finally, the Prometheus VII second stage vent valves will be unlocked to prevent the possibility of subsequent tank rupture and the programmed flight sequence will be terminated.

ITEM 11: Transmitting frequency and power of all devices (including continuous radio transmissions) and power and or schedule of lights (if any) throughout the operational life. State if an emission is scheduled by fixed program, command, or transponder tracking signal.

The Prometheus VII core vehicle transmits two data streams, (1) Enhanced Data Collection System (EDCS) 512 kbps coherent BPSK NRZ-L data on 2288.5 MHz, and (2) Ultra-Wideband Acquisition System (UWASH) 1.96 Mbps PCM/FM NRZ-M data on 2285.5 MHz. Each data stream is relayed through two separate antennas, broadcasting simultaneously. The nominal core transmitter power is 20.0 W.

The Prometheus upper stage vehicle radiates through one of two medium gain antennas, placed 180 degrees apart around the vehicle, driven by a nominal 70-Watt transmitter. The nominal frequency is 2272.5 MHz, PCM/FM convolutionally encoded, at a symbol rate of 1024 ksps. Prometheus upper stage telemetry will be transmitted to ground stations and the Advanced TDRS Satellite System (ATRSS). The radiating antenna is selected by on-board software to optimize coverage for the preferred target at each phase of the mission. That target is generally Advanced TDRS in the Park Orbit and early Transfer Orbit, and fixed ground stations at other times.

The Prometheus VII has a C-band transmitter that receives a pulse-code modulated 5690 MHz signal, and transmits a pulse-code modulated 5765 MHz signal through two circularly polarized antennas, placed 180 degrees apart around the vehicle. The peak power of the C-band transponder is 900 W.

The Cassandra spacecraft instrumentation system consists of a telemetry, command and data subsystem transmitting in the following four channels:

 (1) S-Band - 10 watts using a frequency of 2.3 Ghz

 (2) X-Band - 20 watts using a frequency of 8.6 Ghz

 (3) Ka-Band - 10 watts using a frequency of 32.0 Ghz

 (4) Ku-Band - 6 watts using a frequency of 13.8 Ghz

ITEM 12: Cataloging instructions and remarks from requirements identified in items 6 and 8.

The Cassandra/Pandora spacecraft combination will be placed in a highly elliptical Earth orbit. The Launch Systems Corporation Prometheus VII second stage will be placed into a highly elliptical disposal orbit. These vehicles shall be cataloged as separate objects.

ITEM 13: Points of contact for clarification information.

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