



EOS Aqua



Aqua Spacecraft Status Extended Mission

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Topics



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- **2017 Senior Review Proposal – Current Plan**
- **Aqua after the A-Train**
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Aqua Extended Mission Chronology



Changes since 11/17/2016 Project Scientists Teleconference are in blue

- 2016 Lifetime analysis indicates fewer than 5 years left – June 2016
- Briefed Aqua Project Scientist – July/August/September 2016
- Briefed NASA Program Executive – September 2016
- **Constellation MOWG Meeting** – September 2016
- Send options to Aqua Instrument Teams for their feedback – October 6, 2016
- Develop & Perform Analysis on viable mission extension options – October 2016
- Brief updated options to Aqua Instrument Teams for their feedback – November 3, 2016
- **Constellation/A-Train Project Scientist Meeting** – November 17, 2016
- Aqua Science Team Meeting Opportunity – December 11-16, 2016 (at AGU)
- Aqua Instrument Team feedback due – Late December 2016
- **Send Aqua options to Constellation for feedback** – Late December 2016
- Extended Mission Engineering Peer Review – Postponed to 2018
- **Constellation Feedback** – February 2017
- Aqua Extended Mission Senior Review Proposal submitted – March 3, 2017
- **Spring 2017 Inclination Adjustment – March 2017**
- Science Team Meeting at A-Train Science Symposium – April 19-21, 2017
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- **Constellation MOWG Meeting (at GSFC)** – **June 2017**
- **Constellation MOWG Meeting** – **December 5-7, 2017 (location TBD)**
- **Final Decision Deadline – December 2017 (prior to 2018 inclination adjust)**
- **Extended Mission Engineering Peer Review – April 2018**



Aqua Key Facts



Changes since 11/17/2016 Project Scientists Teleconference are in blue

- Aqua has been the Cornerstone mission for the A-Train
- Required to hold sufficient fuel in reserve to:
 - Safely exit the constellation
 - Lower perigee to meet the NASA 25-year reentry requirement
- Required to use the NASA's Debris Assessment Software (DAS) for end-of-mission life analyses (Current Version 2.0.2)
 - Created by NASA's Orbital Debris Office at Johnson Space Center
 - DAS is the Agency standard for end-of-mission life analyses and lifetime estimations
 - DAS Solar Flux model is updated twice per year
- Goal: Maximize mission science objectives with remaining fuel while still meeting the Constellation Exit and NASA's and International 25-year re-entry requirements
 - Current plan is to perform full Inclination adjustments in 2018 thru 2021 time frame
 - Exit Constellation/A-Train in March 2022 (circularly lower orbit by 4+ km)
 - Find a way to operate Aqua out into the 2025-2027 time frame
 - Investigating more fuel-efficient inclination adjust and retrograde maneuvers



Aqua Extended Mission – 2016



- **Summary:**

- During 2016 the ESMO Project undertook analysis of multiple options to extend the Aqua mission, including lowering Aqua out of the A-Train before 2022 in order to save fuel to extend the length of the mission after exiting the A-Train.
- In November 2016, the Aqua science leadership (Aqua Project Scientist, Aqua Deputy Project Scientist, and Aqua science team leaders) concluded, based on all available information and the status of the Aqua instruments and spacecraft bus, that Aqua's current A-Train orbit and tight control on equatorial crossing times should be continued for as long as they can while meeting all Agency requirements, a timeframe determined by ESMO to be until March 2022.
- The science leadership's decision was based on the priority of continuing to collect the high-quality science data sets needed by the climate research community for as long as possible.



Aqua Senior Review Proposal



- **Plans for the Aqua Mission Subsequent to Exiting the A-Train**
 - Aqua remains in excellent health.
 - All spacecraft subsystems are still configured to their primary hardware.
 - No subsystem-specific issues where normal on-orbit degradation is expected to significantly limit the lifetime of any major spacecraft subsystem or component.
 - Aqua is fully redundant in all components needed to continue its mission and meet the future constellation exit and orbit lowering requirements.
 - Based on past performance, planned propellant usage, and expected degradation rates, the Aqua spacecraft bus appears capable of operating into 2025 and perhaps beyond.
 - Four of Aqua's Earth-observing instruments continue to take high quality science data, with three of them (AIRS, CERES, and MODIS) in excellent health.



Aqua after the A-Train



- **Plan going forward:**

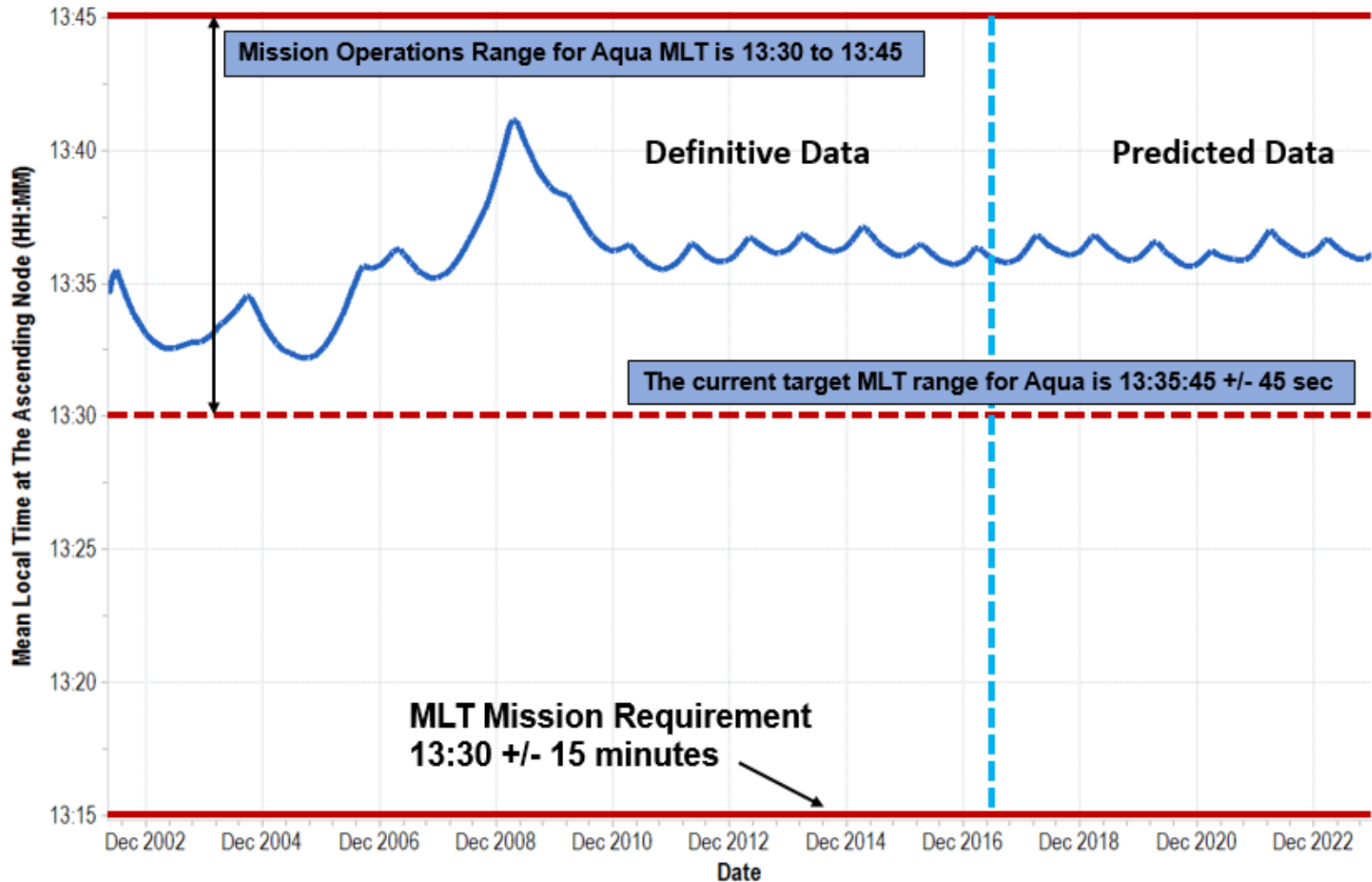
- During 2017 and 2018, the ESMO Project will work with the Aqua science leadership to develop an Extended Mission Operations Plan (EMOP) for operating the mission beyond the A-Train exit now planned for March 2022.
- Aqua scientists will need to determine what changes to make to the current science data processing algorithms to allow the instrument data to be successfully processed at slightly lower orbit altitudes than the current mission requirements and increasing mean local times (MLTs) and solar beta angles.
- The EMOP will contain a list of trigger points that would change the current End-of-Mission Plan (EOMP) if significant changes occur.
- It is envisioned that the EOMP will be re-evaluated with each successive Senior Review Proposal or more frequently if needed.

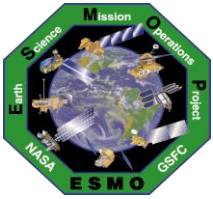


Orbit Predictions



Aqua Mean Local Time (MLT) (Definitive and Predicted at Ascending Node)

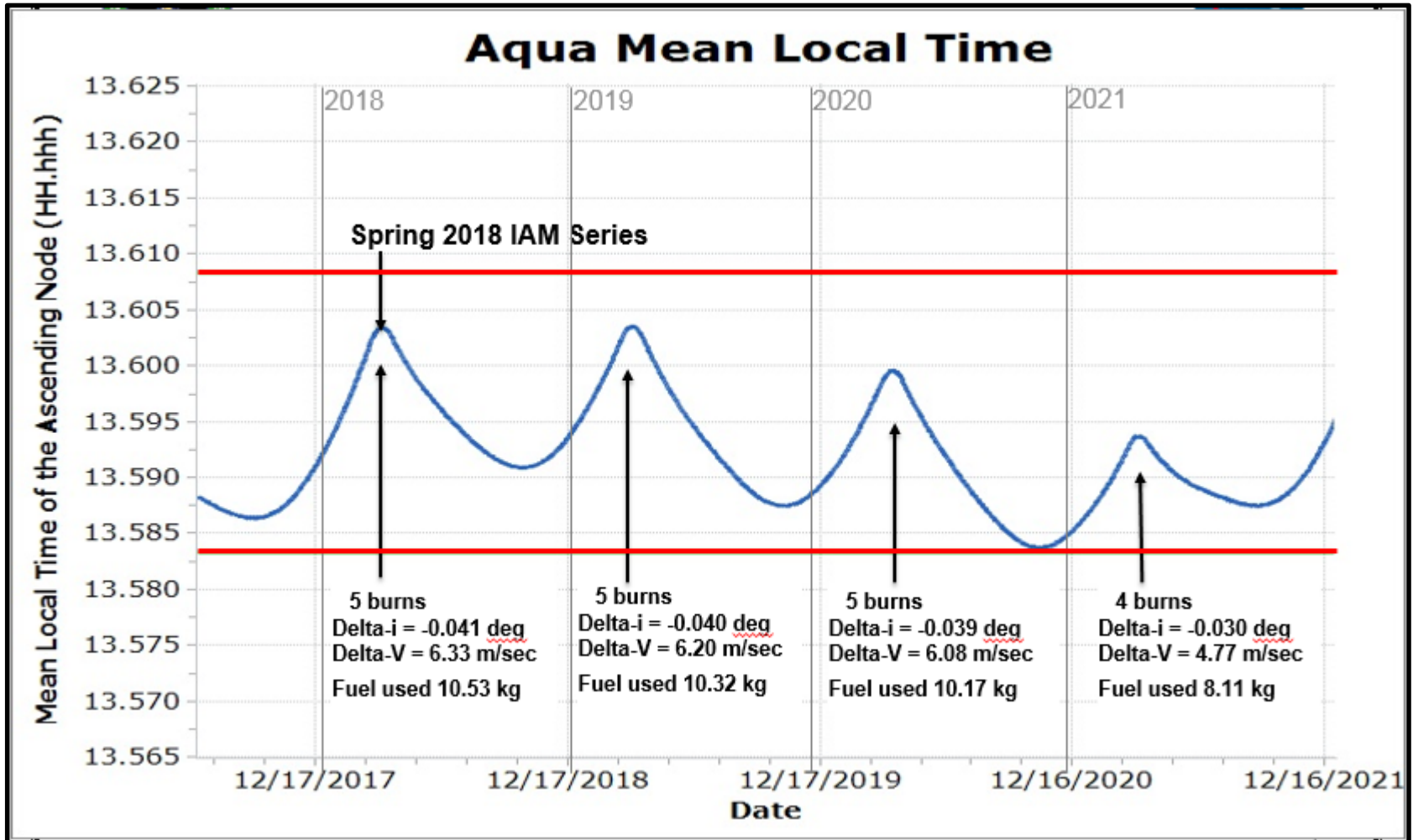




Aqua Predicted MLT

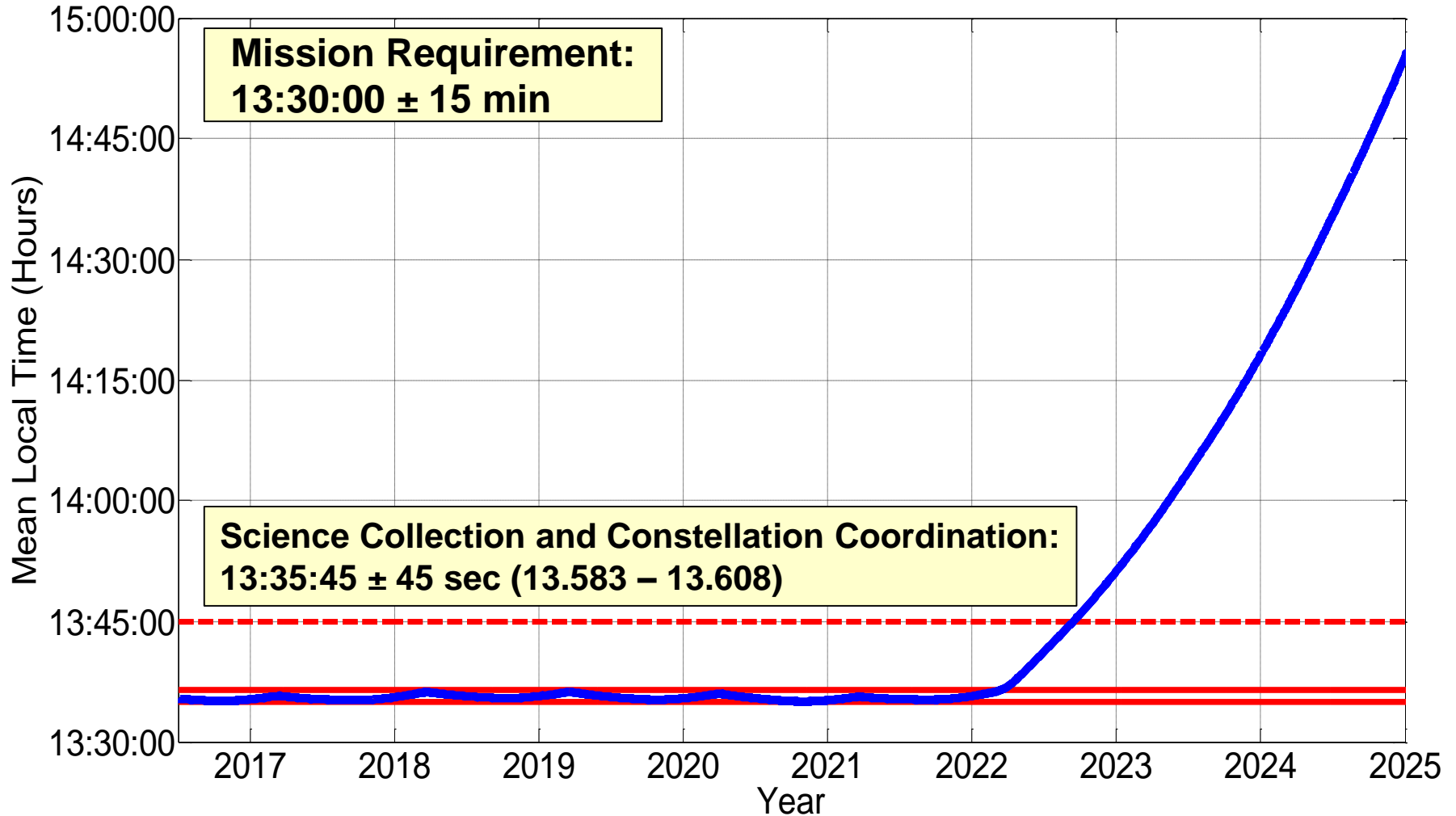


Science Collection and Constellation Coordination:
13:35:45 ± 45 sec (13.583 – 13.608)



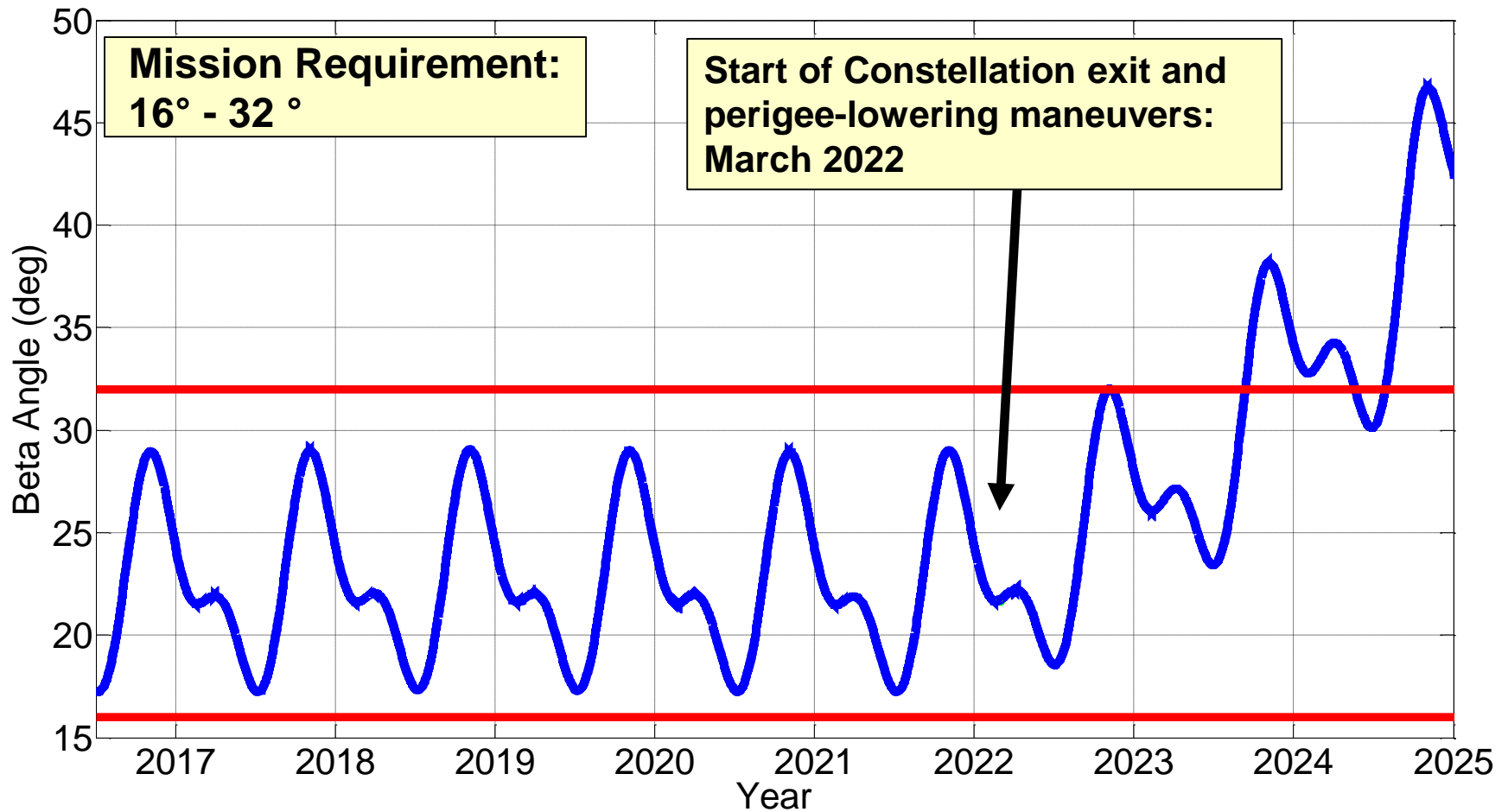


Aqua Predicted MLT with A-Train exit in March 2022



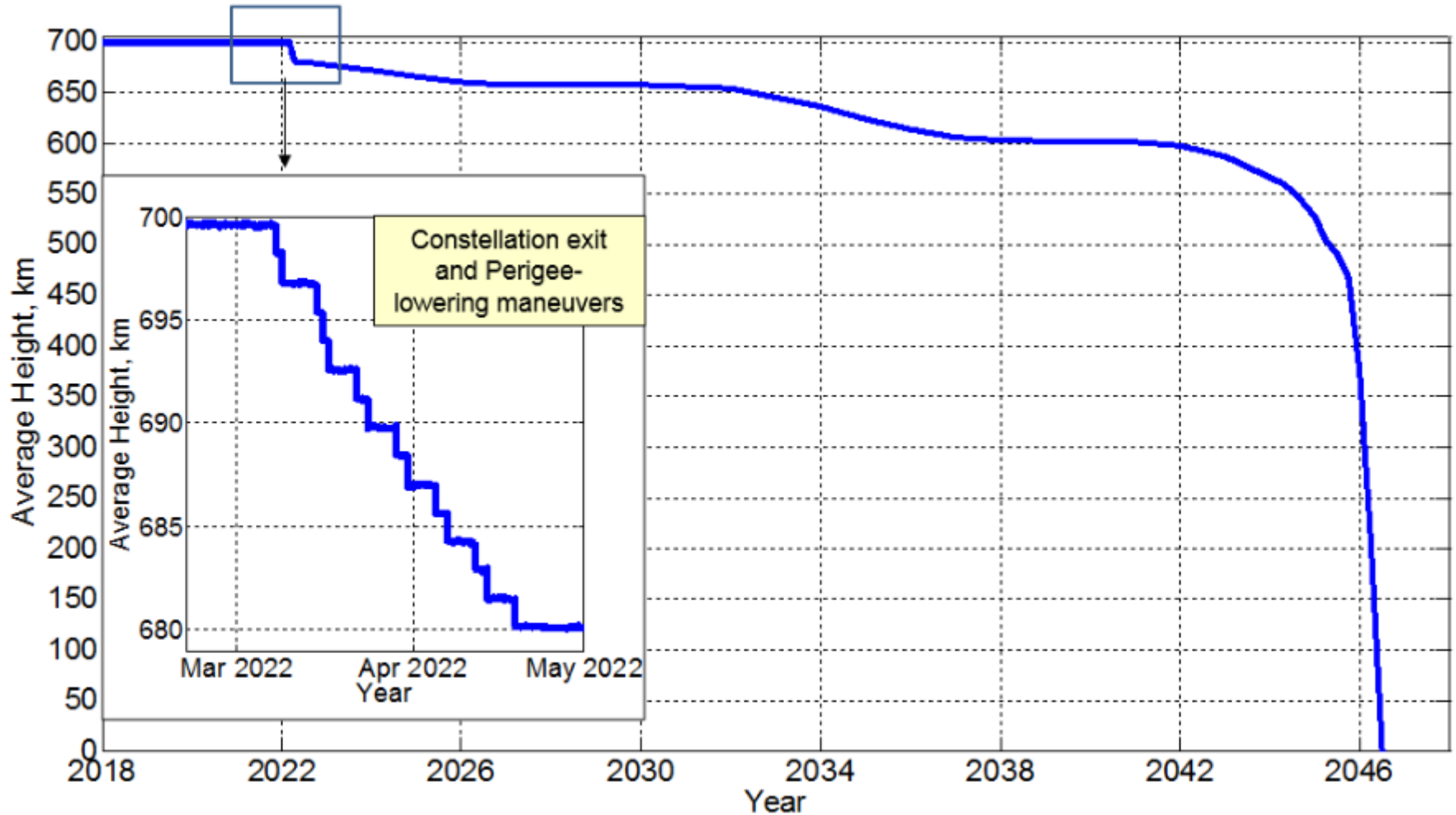


Aqua Predicted Beta Angle with A-Train exit in March 2022





Aqua Orbital Decay with A-Train exit in March 2022





Backup Slides



Summary of Changes

(Presented at September 2016 MOWG Meeting)



- **Constellation Exit:**
 - **Adopted the 4+ km exit as its new baseline exit (about 5.5 kg of fuel)**
 - Based on approval of the 2015 Operations Coordination Plan
 - Based on lessons learned from Terra and Landsat-8 (and also PARASOL)
- **Fuel Analysis:**
 - **Expanded fuel usage plots to include multiple measuring methods**
 - Bookkeeping (B-K) - what's been shown in the past
 - Pressure, Volume and Temperature (PVT) – most conservative
 - **Now including estimated uncertainty in the fuel measurements (4.8 kg)**
 - **Now including unusable fuel trapped in lines and tank (1.2 kg)**
- **Extended Mission Analysis:**
 - **Currently investigating more fuel efficient methods of performing inclination adjust and retrograde maneuvers**
 - **Currently investigating various methods for extending the Aqua operational science mission lifetime with sufficient fuel to exit constellation and meet the 25 year re-entry requirement**



Aqua 2022 A-Train Exit and Orbit Lowering



Mission Date (-)	Maneuver Type (-)	Fuel Used (kg)*	Fuel Remaining (kg)**	Perigee (km)**	Apogee (km)**
3/7/2022	Pre-Exit Orbit	-	24.45	693.91	710.90
3/8/2022	Constellation Exit	1.31	23.14	693.90	708.13
3/9/2022	Constellation Exit	1.30	21.84	691.04	708.14
3/15/2022	Constellation Exit	1.30	20.54	690.99	705.42
3/16/2022	Constellation Exit	1.30	19.24	688.14	705.43
3/17/2022	Orbit-Lowering #1	1.29	17.95	685.42	705.37
3/22/2022	Orbit-Lowering #2	1.29	16.66	682.67	705.42
3/24/2022	Orbit-Lowering #3	1.29	15.37	679.94	705.36
3/29/2022	Orbit-Lowering #4	1.28	14.09	677.54	705.23
3/31/2022	Orbit-Lowering #5	1.28	12.81	675.04	705.15
4/5/2022	Orbit-Lowering #6	1.28	11.53	673.15	704.76
4/7/2022	Orbit-Lowering #7	1.27	10.26	670.96	704.56
4/12/2022	Orbit-Lowering #8	1.27	8.98	669.66	703.88
4/14/2022	Orbit-Lowering #9	1.27	7.72	667.67	703.52
4/19/2022	Orbit-Lowering #10	1.27	6.45	667.02	702.43

Apogee burn, lowers Aqua's perigee

Perigee burn, lowers Aqua's Apogee

*Decreasing fuel used is a result of decreasing pressure in the tank with each retrograde maneuver performed. Aqua is performing a 550 sec retrograde maneuver and assuming fixed duty cycle values obtained from maneuver simulations conducted in August 2016.

** Post maneuver.

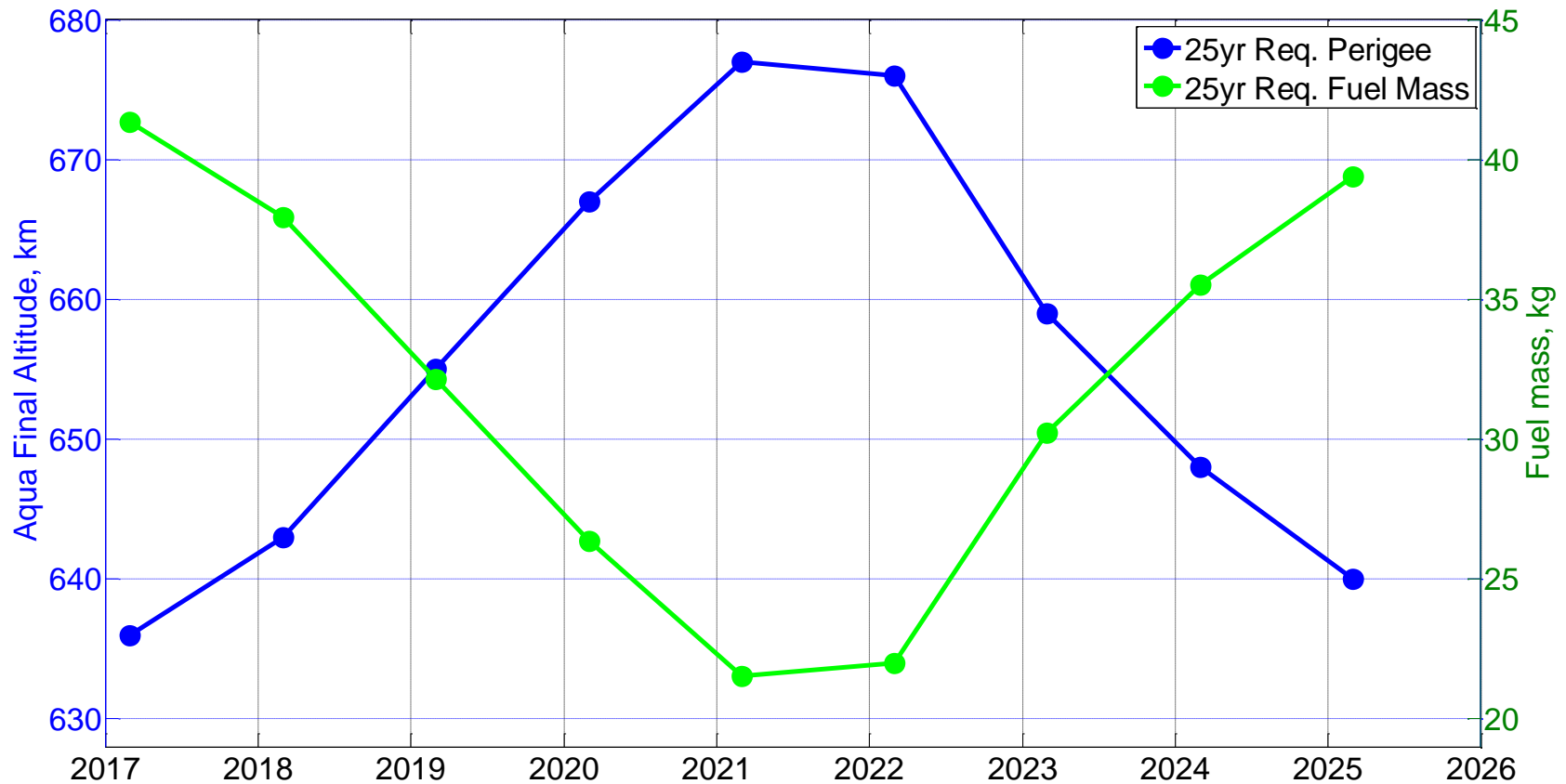


Fuel required to meet DAS required perigee to reenter within 25-years



DAS required perigee to meet 25-year reentry after circular 4+ km exit.

Fuel Required includes 5.5 kg for exit constellation, 1.2 kg unusable, 4.8 kg uncertainty.

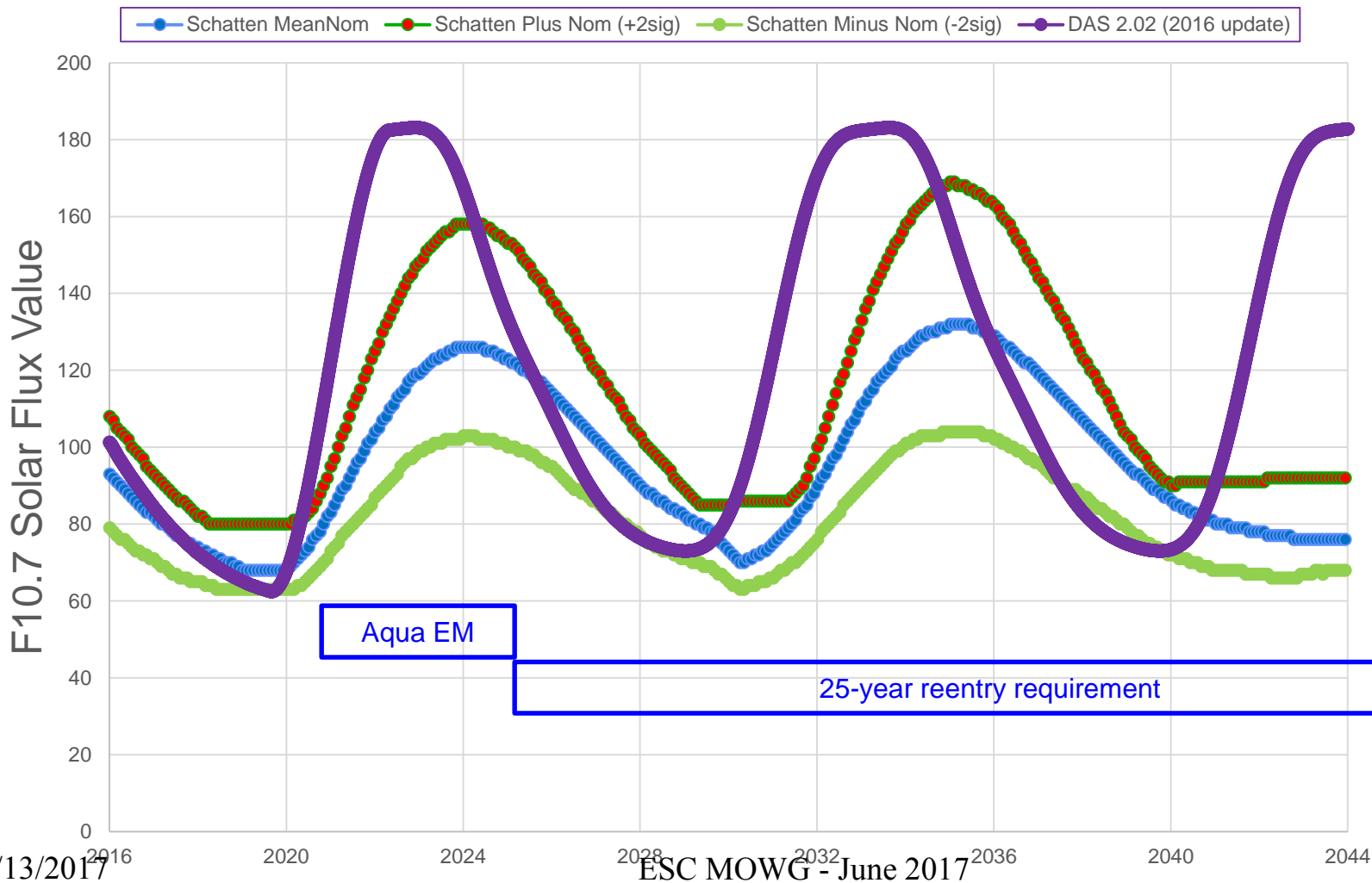


Solar Cycle effects on perigee required to meet 25 year reentry requirement.



Predicted Solar Flux Data

April 2016 Schatten and March 2016 DAS





Abbreviations / Acronyms List



AIRS – Atmospheric Infrared Sounder	ESC – Earth Science Constellation	MODIS – Moderate Resolution Imaging Spectroradiometer
AMSR-E – Advanced Microwave Scanning Radiometer for EOS	ESMO – Earth Science Mission Operations	MOWG – Mission Operations Working Group
AMSU – Advanced Microwave Sounding Unit	FDS – Flight Dynamics System	MTS – Maneuver Trade Space
AN – Ascending Node	FOT – Flight Operations Team	NASA – National Aeronautics & Space Administration
ARE – Array Regulator Electronics	FSW – Flight Software	NGAS – Northrop Grumman Aerospace Systems
ASAT – Anti-satellite Weapon	FY – Fiscal Year	NOAA – National Oceanic and Atmospheric Administration
CA – Conjunction Assessment	GMT – Greenwich Mean Time	NYS – No Yaw Slew
CARA – Conjunction Assessment Risk Analysis	GNC – Guidance Navigation & Control	ORR – Operational Readiness Review
CDH – Command & Data Handling	GSFC – Goddard Space Flight Center	PROP – Propulsion
CERES – Clouds and the Earth’s Radiant Energy System	GTE – Ground Track Error	Pc – Probability of Collision
CRMS – Collision Risk Management System	HIE – High Interest Event	PS – Project Scientists
DAM – Debris Avoidance Maneuver	HK – Housekeeping	RHEL – Red Hat Enterprise Linux
DAS – Debris Assessment Software	HQ – Headquarters	RMM – Risk Mitigation Maneuver
DN – Descending Node	HSB – Humidity Sounder for Brazil	RWA – Reaction Wheel Assembly
DMUM – Drag Make-up Maneuver	IAM – Inclination Adjustment Maneuver	SA – Solar Array
EA – EOS Automation	ID – Ideal Date	SC – Spacecraft
EDOS – EOS Data Operations System	JAXA – Japan Aerospace Exploration Agency	SSR – Solid State Recorder
EOC – EOS Operations Center	Kg – kilogram	TBD – To Be Determined
EOMP – End of Mission Plan	km – kilometer	TCS – Thermal Control System
EOS – Earth Observing System	L0 – Level-Zero	WDE – Wheel Drive Electronics
EPS – Electrical Power System	MLT – Mean Local Time	WRS – World Reference System
	MMOD – Micrometeorite Orbital Debris	
	MMS – Mission Management System	