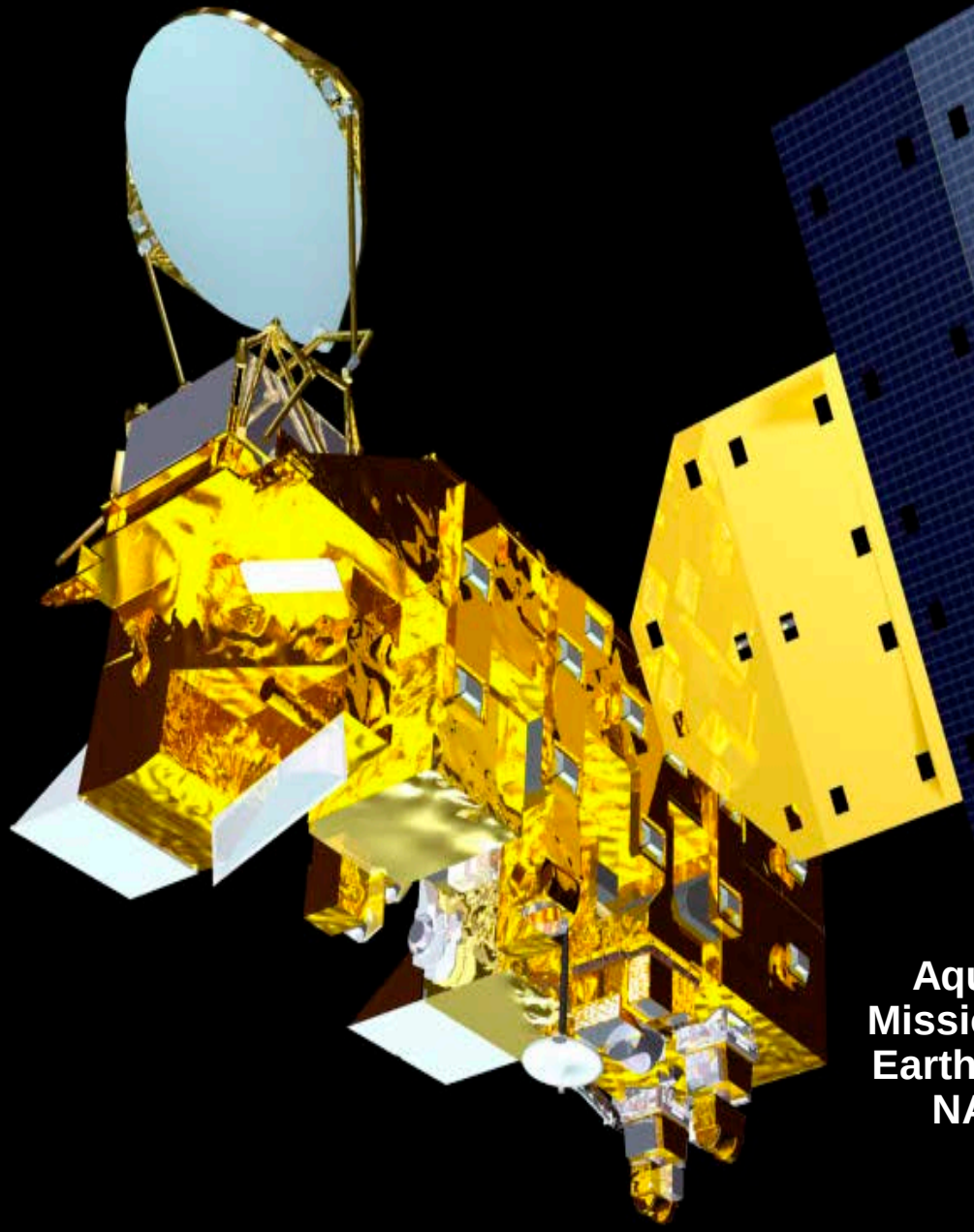
EOS Aqua



Mission Status at the Earth Science Constellation (ESC) Mission Operations Working Group (MOWG) Meeting In Toulouse, France

June 5, 2019

Bill Guit

Aqua Mission Director - Code 584/428
Mission Validation and Operations Branch
Earth Science Mission Operations Project
NASA/Goddard Space Flight Center

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Topics

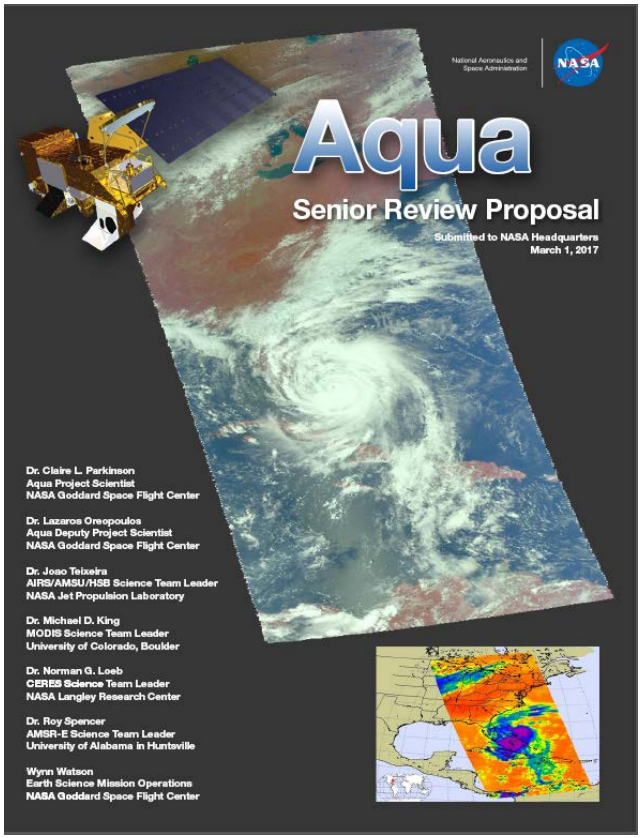
Changes since December 2018 MOWG Meeting are in blue

- **Mission Summary**
- **Spacecraft Subsystems Summary**
- **Recent and Planned Activities & Process Improvements**
- **Inclination Adjust Maneuvers**
  - Spring 2020 Calendar – **Slide 11 (DRAFT – Version 1)**
  - Long-Term Plan – **Minor CHANGES** (see Flight Dynamics Presentations)
- **Propellant Usage & Lifetime Estimate**
- **After-the-A-Train Extended Mission**
- **End of Mission Plan & Orbital Decay**
- **Mission Summary**
- **Additional Slides:**
  - Orbit Maintenance Maneuvers
  - Conjunction Assessment High Interest Events
  - Ground Track Error & Mean Local Time History
  - Spacecraft Orbital Parameters Trends & Predictions

EOS Aqua Mission Summary

Changes since December 2018 MOWG Meeting in blue

- **05/04/2002: Launch (6-Year Design Life)**
- **12/02/2008: End of Prime Mission Review**
- **12/08/2015: End of AMSR-E Operations**
- **11/17/2016: A-Train PS Teleconference**
  - Maintain tight Mean Local Time (MLT)
- **03/03/2017: Senior Review Proposal #6**
  - Reliability Estimates thru 2025
  - Consumables through 2022
  - Potential After the A-Train Extended Mission
- **06/22/2017: NASA Earth Science Senior Review Subcommittee Report – 2017**
  - Continue as baselined through at least FY23
- **12/21/2017: Received HQ Guidance**
- **03/30/2018: Updated Aqua Phase F Plan**
- **05/04/2018: Aqua 16-Year Anniversary**
- **10/02/2018: Aqua Decommissioning Review**
- **04/02/2019: ESMO Annual Review #12**



Aqua Spacecraft Subsystems

All subsystems configured to primary hardware

Changes since December 2018 MOWG Meeting in blue

- **Command & Data Handling (CDH) – Nominal (Solid State Recorder (SSR) holds ~2 orbits of data)**
  - *SSR Ops Error Anomaly (12/2/2007) – fully recovered 1/28/2009*
- **Communications (COMM) – Nominal**
- **Electrical Power System (EPS) – Nominal (Numerous power drops and current fluctuations)**
  - *Array Regulator Electronics (ARE) 4A: 8/13/2004 – self-recovered – stable for 5+ years*
    - » *Re-occurred 1/11/2010 and 7/17/2013 (3 strings)*
  - *ARE-6C: 9/3/2010 numerous – most recent 5/29/2018 (4 strings), ARE-6A: 7/19/2012 (1 string)*
  - *ARE-1C: 11/7/2010 (1 string) and ARE-1A: 6/28/2011 (1 string)*
  - *ARE-3A: 2/15/2012 (1 string) and **ARE-3C: 4/29/2019 (1-2 strings – TBC)***
  - *ARE-4C: 4/26/2015 – Reoccurrences in 2016, 2017: 7/17 & 12/2, 2018: 2/22 & 5/19 (2 strings)*
  - *ARE-5C: 5/3/2016 – Partial recovery on 6/17/2016 (1 string), ARE-5A: 12/26/2017 (1 string)*
  - ***Summary: Estimated that Aqua has lost up to 18 strings (TBC) of solar cells out of a total of 132 strings***
    - » ***Aqua continues to have significant power margin where the life limiting item is fuel***
  - *Battery Cell Anomaly (9/2/2005)*
  - *Solar Array (SA) Panel #8 Thermistor #6 Failure (8/3/2009)*
  - *Solar Array (SA) Offset (Reported 11/17/09, Corrected 6/29/2010)*
- **Flight Software (FSW) – Nominal**
- **Guidance, Navigation & Control (GN&C) – Nominal**
- **Propulsion (PROP) – Nominal**
  - *Dual Thruster Module (DTM-2) Heater Anomaly (9/8/2007)*
- **Thermal Control System (TCS) – Nominal**

Recent Spacecraft Activities

(December 2018 – 5/30/2019)

- **4 CARA High Interest Orbital Debris Events (HIEs):** see charts 25 & 26
  - 3 RMM/DAMs PLANNED – 3 SELF-MITIGATED – **0 EXECUTED**
  - 1 Maneuvers cancelled and/or re-planned due to orbital debris concerns (3/28 IAM)
- **2 Spacecraft Bus Anomalies: Ongoing solar array (SA) strings**
  - 02/18/2019: Body Rate Alarm Anomaly – Single Event Upset (SEU)
  - 04/29/2019: ARE-3C Current Drop (1-2 strings) – Latest observed on Aqua
- **1 Instrument Anomalies:**
  - 03/20/2019: CERES FORE (CEF) Safe Event – IOT Operations Error
- **9 Spacecraft Maneuvers:**
  - 5 Routine Drag Make-Up Maneuvers (DMUMs) – Last DMUM #138 on 05/23/2019
  - 0 Debris Avoidance Maneuvers (DAMs) – Last DAM 07/12/2018
  - 4 Inclination Adjust Maneuvers (IAMs) – March/April 2019
- **6 Instrument Calibration Maneuvers:**
  - Monthly MODIS Lunar Calibrations

Ongoing Process Improvements

- **Aqua/Aura Maneuver Working Group: Reestablished in May 2016**
  - Develop retrograde maneuver capability for use during operational mission
  - Develop more fuel-efficient propulsive maneuvers
    - » Constellation exit retrograde maneuvers using reaction wheels and thrusters
    - » IAMs using reaction wheels (RWs) for spacecraft attitude reorientation
    - » **11/30/2018: Aura Test Maneuver (-76 degrees and back on RWs)**
    - » **03/06/2019 – 04/10/2019: Aura IAMs on RWs (4) – Aqua IAMs in 2020**
  - **Additional details in Aura Mission Status presentation**
- **EOS Automation (EA): Multi-year/Multi-phase development**
  - Version 3.1: Automated Nominal Commanding → OPS 9/10/2018
  - Version 3.2: S/C SSR Commanding & Contact Execution → OPS 2/8/2019
  - Version 3.3: Enhancements ongoing → OPS in summer 2019
- **Collision Risk Management System (CRMS) – Initiated in 2015**
  - Summary on next slide
  - **"CARA Devolution" details in Dimitrios Mantziaras presentation**

Collision Risk Management System (CRMS)

- **ESMO has developed the Collision Risk Management System (CRMS) and Flight Dynamics System (FDS) capabilities to automatically generate and deliver Risk Mitigation Maneuver (RMM) ephemeris files for Debris Avoidance Maneuver (DAM) planning – FDS AutoRMM Operational May 2018**

- **Developed in response to an increased number of predicted close approaches with orbital debris and operational satellites (slides 25 & 26)**
  - Increased number of High Interest Events (HIEs) has led to increased efforts to plan mitigation maneuvers
  - Concern that the new US Air Force Space Fence will significantly increase the size of the Space Catalog

- **Key CRMS capabilities include:**
  - User-defined collision risk thresholds – when to plan, what to mitigate to
  - Maneuver optimization to address conjunctions with multiple secondary objects and repeating conjunctions
  - Unconstrained and user-defined constrained maneuver options

- **ESMO is currently operating with CRMS Release 7.0 (ORR: April 25, 2019)**

CARA Devolution/ESMO Pilot

- **CARA Devolution is a spreading of Conjunction Assessment (CA) operations responsibilities to mission FOTs**
  - Permits efficiencies in handling the increased workload caused by Space Fence and large constellations
  - Missions given more flexibility in choosing specific approach to CA requirements that resonates best with their particular needs
  - CARA retains Agency oversight through an established NASA Standard (e.g. training and tool certification)
  - CARA retains subject matter expertise (SME) for Agency support
- **Memorandum of Understanding (MOU) between the NASA Earth Science Mission Operations (ESMO) Project and the NASA Conjunction Assessment Risk Analysis (CARA) program for the ESMO Mission Operations Conjunction Assessment (MOCA) Devolution Pilot Program**
  - Documents an arrangement for conducting a Pilot Program by the ESMO Project of Mission Operations Conjunction Assessment (MOCA) operations for the Aqua, Aura, Terra, and GPM spacecraft. The contents, governing parameters, logistical arrangements, and completion criteria for this pilot program are defined in a series of documents.
  - **ESMO Pilot Program Parallel Operations began 3/26/2019**

Planned Activities
(2019 thru early 2020)

- **June 5-7, 2019: ESC/A-Train MOWG Meeting in Toulouse, France**
  - **PRELIMINARY DRAFT** 2020 Inclination Adjust Maneuver Schedule
- **July 2019: DRAFT 2019 Aqua Decommissioning & Lifetime Analysis**
  - DRAFT 2020 Inclination Adjust Maneuver Schedule
- **Oct 2019: FINAL 2019 Aqua Decommissioning & Lifetime Analysis**
- **Fall 2019: Complete CARA Devolution ESMO Pilot Program**
- **Fall 2019: ESC/A-Train MOWG Meeting (Date/Location TBD)**
  - Update propellant budget and decommissioning analysis
  - FINAL 2020 Inclination Adjust Maneuver Schedule
- **Late 2019: Updated End of Mission Plan for 2020 Senior Review**
- **Late 2019: After the A-Train Extended Mission Plan (2022 – 2026)**
- **January 2020: ESMO Annual Review #13**
- **March 2020: Next Senior Review Proposal cycle**
- **Spring 2020: Aqua IAMs on Reaction Wheels and Thrusters**

Planned Activities

(Mid-to-Long-Term)

Changes since December 2018 MOWG Meeting are in blue

- **Aqua/Aura Retrograde Maneuver Working Group – also working Aqua/Aura IAMs on combination of reaction wheels and thrusters**
  - Adopt experience and lessons learned on Aura for Aqua
  - Retrograde maneuver capability to be fully simulated in 2019
  - **Targeting Aqua 2020 IAMs** for using reaction wheels to perform the spacecraft attitude reorientation necessary to align the spacecraft thrusters to perform the inclination adjust
  - **On-orbit retrograde capability by Aura A-Train exit if early exit in 2021**
- **EOS Automation (EA) – automation of routine operations**
  - **EA Release 3.3 (Enhancements) – ORR summer 2019**
- **Continue to improve DAM planning and execution process**
  - Full automation end-to-end, identification-to-approval 24x7x365
  - **CRMS Release 8.0 Targeted to be operational by late 2019 (TBC)**
  - Unclear how **CARA CA Devolution** will impact CRMS 8.0 development
- **Possible Re-fueling Mission – Unlikely – but not giving up hope**

Spring 2020 DRAFT Aqua/Aura Inclination Adjust Plan

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
16 Feb	17	18	19	20	21	22
23	24	25	26 Aura IAM #63	27 Aqua IAM #66	28	29
1 Mar	2	3	4 Aura IAM #64	5 Aqua IAM #67	6	7
8	9	10	11 Aura IAM #65	12 Aura IAM #68	13	14
15	16	17	18 Aura IAM #66	19 Aqua IAM #69	20 Equinox EPS State of Health Test	21
22	23	24	25 Aura IAM #67	26 Aqua IAM #70	27	28
29	30	31	1 APR Aura IAM #68	2 Aqua IAM #71	3	4
5	6	7	8 Aura Back-up	9 Aqua Back-up	10	11
12 Easter	13	14	15	16	17	18
19	Golden Week in Japan (April 28 – May 6, 2020)					

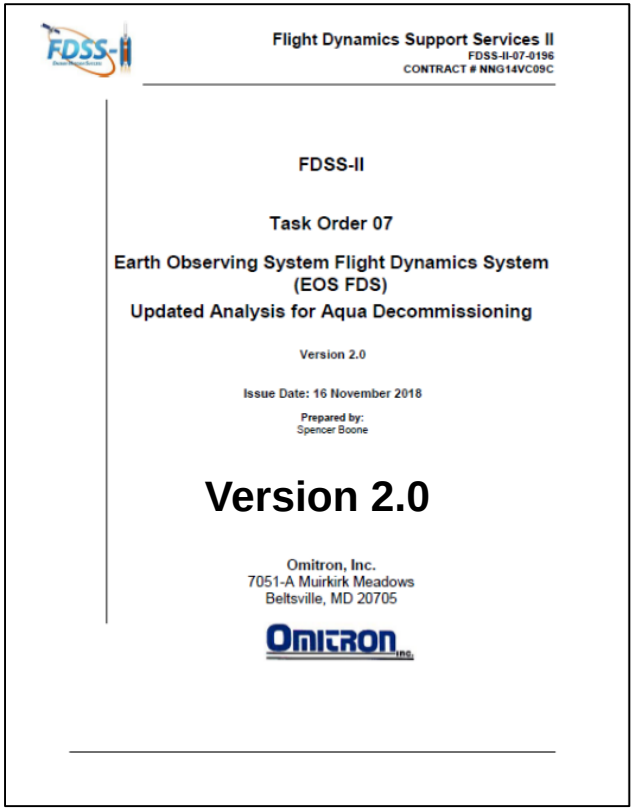
PRELIMINARY DRAFT 2020 Aqua/Aura IAM Calendar (V1)

Aqua Propellant Usage

(November 2018)

KEY: Updates since last MOWG Meeting in blue – NONE

- **2006: Initial Aqua lifetime fuel analysis**
- **2008: Detailed Aqua & Aura lifetime analyses**
  - Presented to A-Train MOWG and at Aqua EOPM Review
- **September 2012: Initial Aqua Decommissioning Plan**
  - Updated Lifetime Estimates
- **August 29, 2013: Updated Decommissioning Plan**
  - Updated Constellation Exit Plan
- **September 30, 2014: Updated Decommissioning Plan**
  - Updated definitive fuel usage and predicted solar flux levels
  - Updated propellant trends for IAMs & DMUMs
- **September 2015 Delayed to allow additional time to evaluate long-term plan and decommissioning maneuvers**
- **Summer 2016: Investigated more fuel efficient inclination adjust and retrograde maneuver options and various options for extending operations into mid-2020ies**
- **December 16, 2016: Updated Decommissioning Plan (V1.1)**
- **November 13, 2017: Updated Decommissioning Plan (V1.1)**
  - Updated definitive fuel usage & predicted solar flux levels
- **July 3, 2018: Updated Decommissioning Plan (V1.0)**
  - Updated definitive fuel usage & predicted solar flux levels
  - Updated propellant trends for IAMs and DMUMs
  - 08/02/2018 Summer IAM required update to document and IAM Plans
- **November 16, 2018: Updated Decommissioning Plan (V2.0)**
- **Annual updates will be provided each July (started in 2017)**
  - Final will be produced 60 days before start of decommissioning



Flight Dynamics Support Services II
FDSS-II-07-0196
CONTRACT # NNG14VC09C

FDSS-II

Task Order 07

Earth Observing System Flight Dynamics System (EOS FDS)
Updated Analysis for Aqua Decommissioning

Version 2.0

Issue Date: 16 November 2018

Prepared by:
Spencer Boone

Version 2.0

Omitron, Inc.
7051-A Muirkirk Meadows
Beltsville, MD 20705

Next Update July 2019

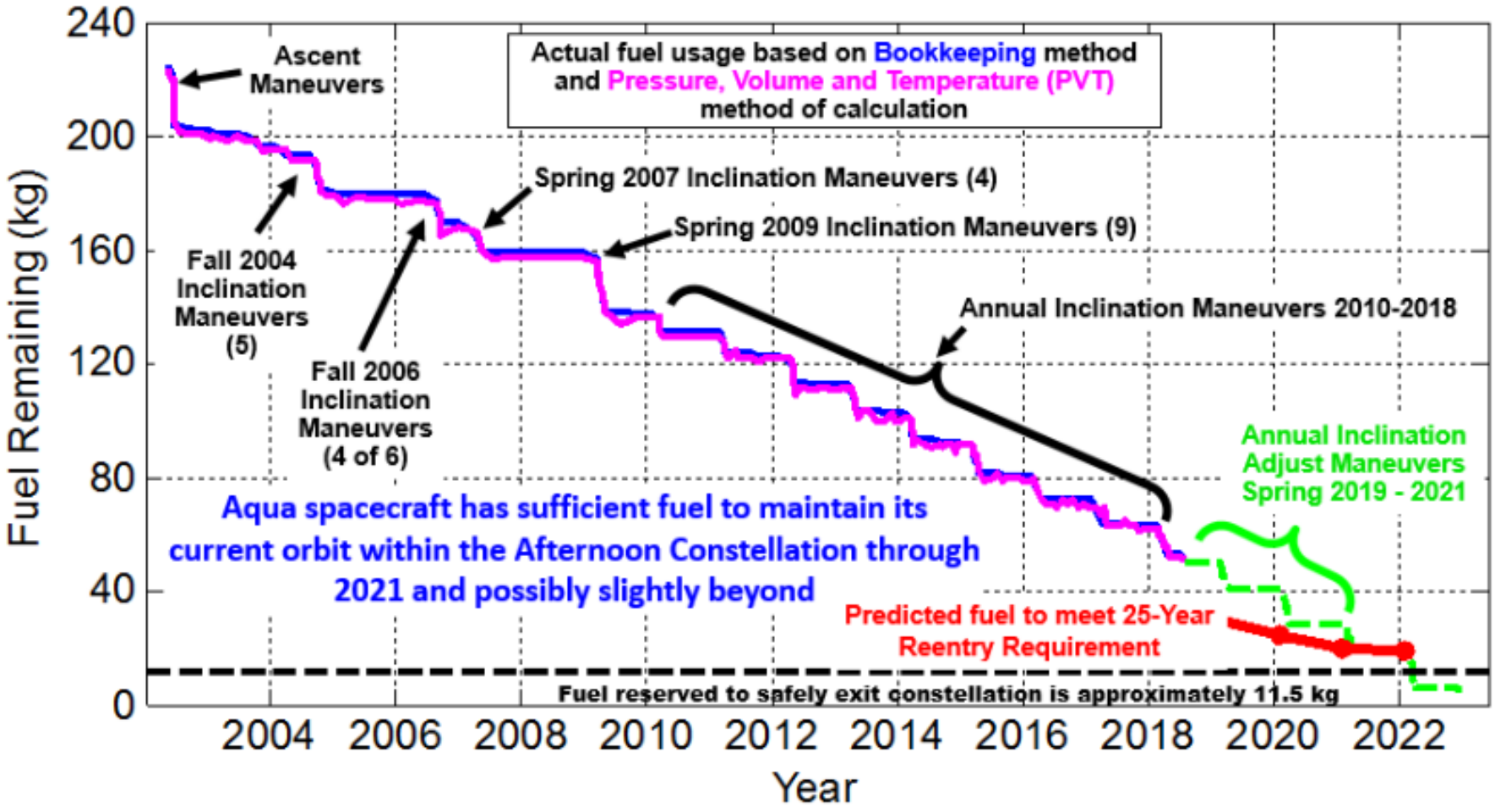
Aqua Remaining Fuel Estimate

(November 2018)

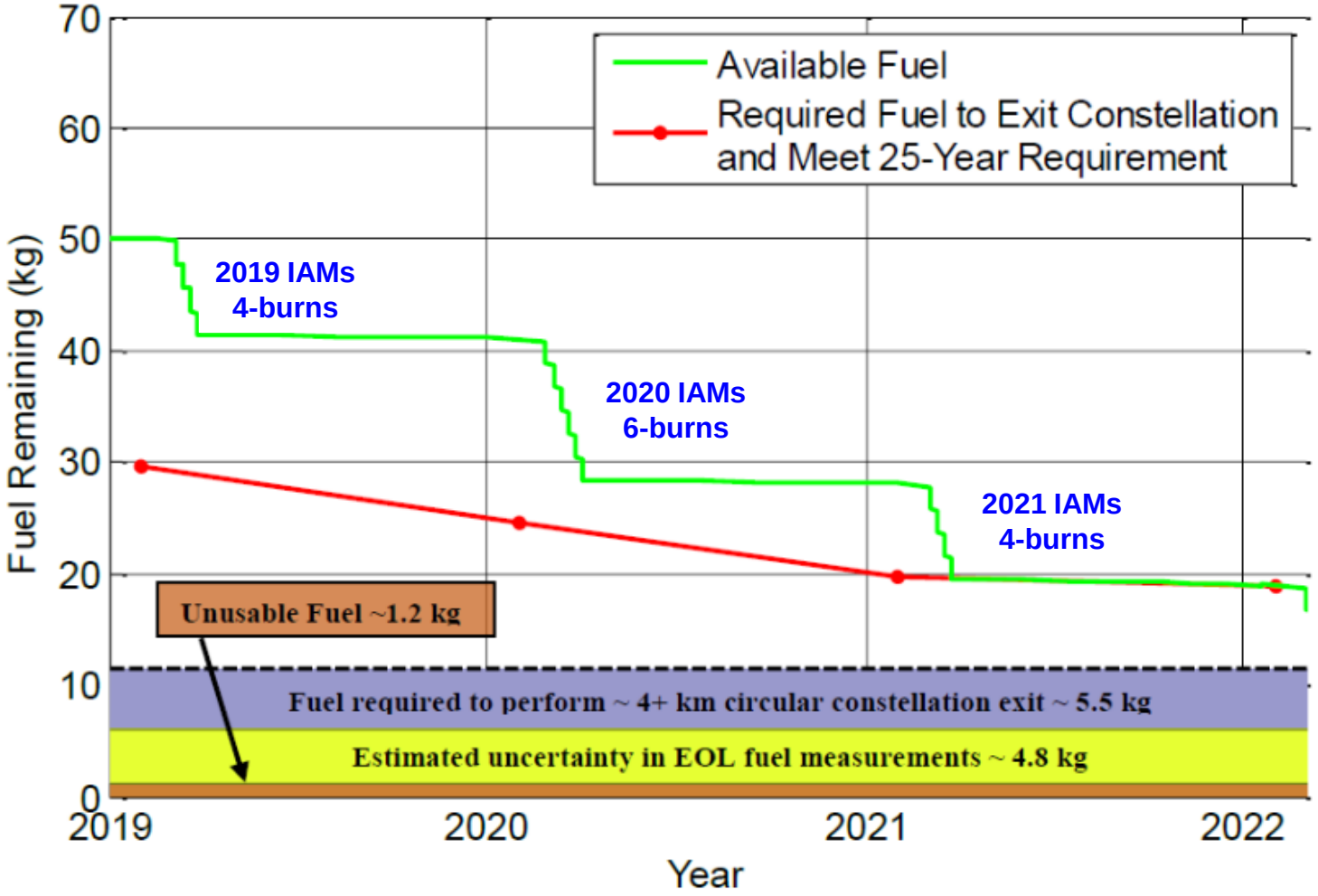
KEY: Updates since last MOWG Meeting in blue – NONE

- **Long-term orbit simulations were run for Aqua through 2026**
  - Used mean nominal Schatten solar flux predictions (**March 2018**)
  - Estimated the frequency of drag make-up maneuvers (DMUMs) to maintain Aqua's WRS-2 ground track requirements
  - Estimated the required number of annual inclination maneuvers (IAMs) for Aqua to maintain it's mean local time (MLT) requirement
  - Did not include potential debris avoidance maneuvers
  - Utilized **FreeFlyer 6.10.0** which incorporated the solid earth tide model allowing greater accuracy for long term predictions of inclination, beta angle, and mean local time
- **Lifetime predictions for Aqua shows that the spacecraft will have sufficient fuel to maintain its current orbit within the Afternoon Constellation through the 2021 inclination adjust series of maneuvers.**
- **Exit from the constellation in early 2022 will be into a new operational orbit, <u>not the decommissioning and passivation orbit</u>, approximately 4.4 km below the current ESC/A-Train operational orbit.**
- **Currently investigating various options to extend the potential Aqua mission life out into the 2026 time frame and possibly beyond.**
- **<u>BOTTOM LINE</u>: Aqua will hold sufficient fuel in reserve after exiting the constellation to lower perigee such that its reentry will meet the NASA 25-year reentry requirement.**

Fuel Usage: Actual & Predicted
(November 2018)

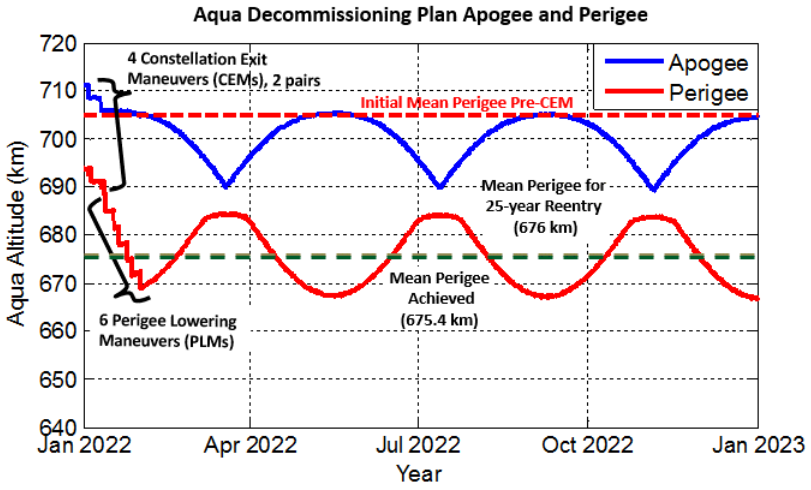


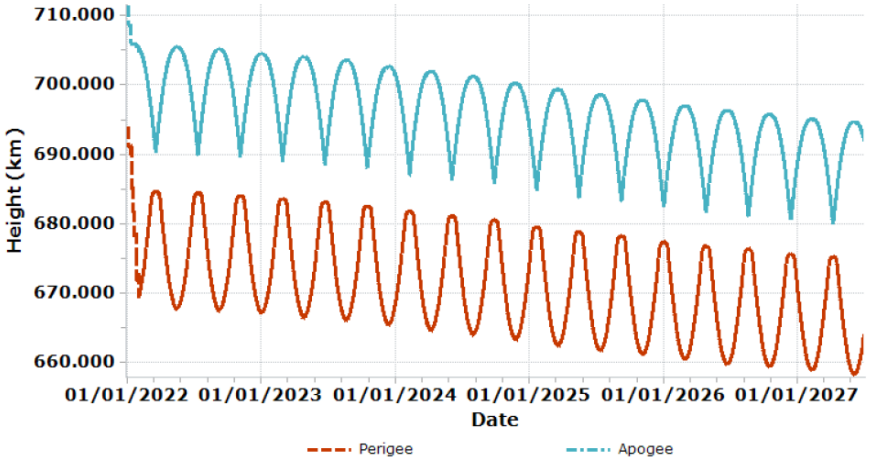
Fuel Usage: Predicted Available & Required (November 2018)



Aqua A-Train Exit Scenario

NEW Slide for the ESC MOWG Meeting



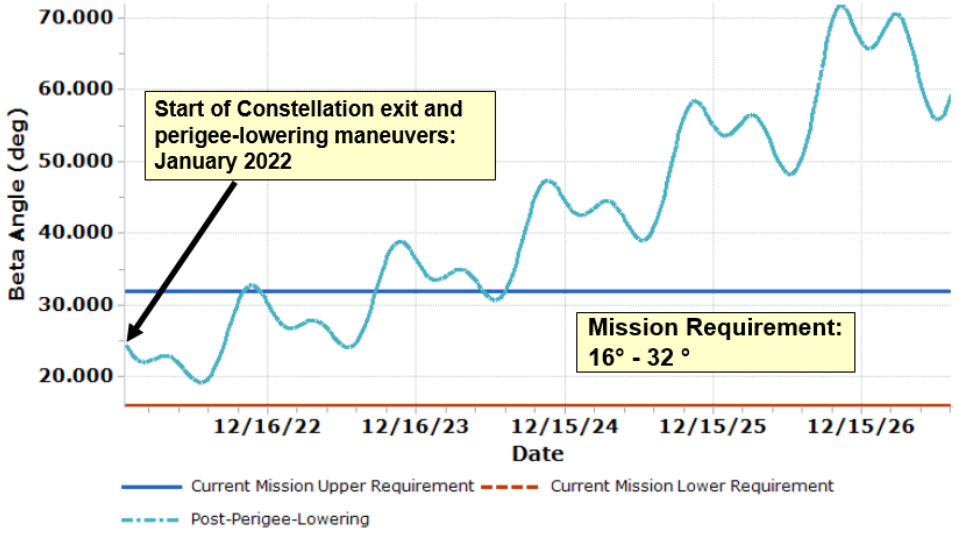


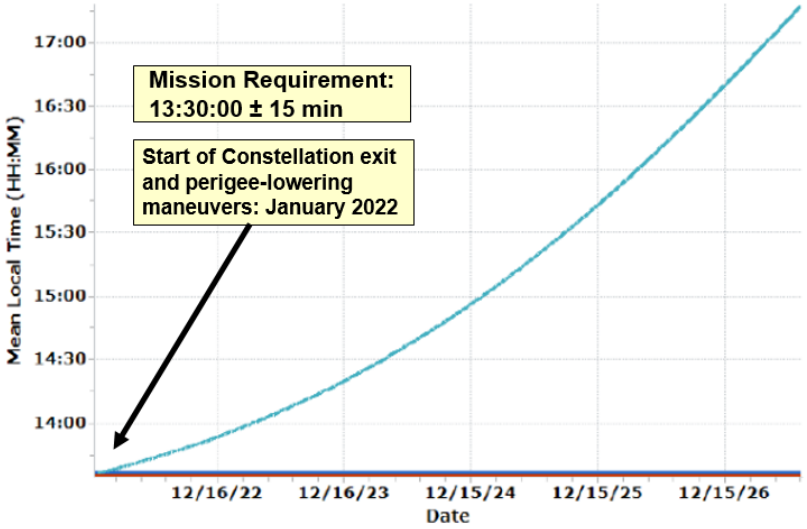
Man. #	Maneuver Type	Maneuver Date	Perigee Height (km)	Apogee Height (km)	Tank Mass (kg)	Delta-V (m/s)
1	Perigee Burn	Jan 04 2022 12:39:25.250	693.897	711.137	19.040	0.679
2	Apogee Burn	Jan 05 2022 14:11:50.500	693.897	708.538	17.950	0.677
3	Perigee Burn	Jan 11 2022 12:40:15.750	690.966	708.538	16.862	0.675
4	Apogee Burn	Jan 12 2022 14:11:41.000	690.966	705.911	15.776	0.907

- **Constellation Exit Review – Late 2021 at ESC MOWG Meeting (Nov/Dec?)**
- **Perform 4 Constellation Exit Maneuvers (CEMs)**
- **Perform 6 Perigee Lowering Maneuvers (PLMs)**

Aqua "After-the-A-Train"

NEW Slide for the ESC MOWG Meeting





Decommissioning Plan	A-Train Exit Year	Perigee Lower Year	# of Lowering Burns*	Apogee at Depletion (km)	Perigee at Depletion (km)	End of Mission (EOM)	EOM to Reentry (years)	Reentry Date
Baseline	2022	2022	4	697.4	675.4	2026	25	2047

After the A-Train Science Operations Plan Overview:

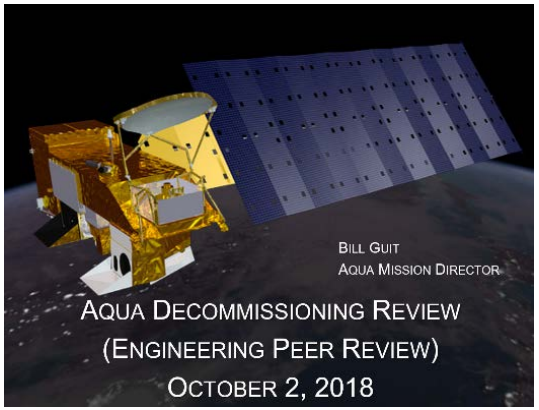
1. **Exit Constellation and lower orbit perigee to reenter within 25-years**
2. **Drift until Science no longer good or budget is projected to runs out**
3. **Decommission the mission – passivate and dispose of spacecraft (2026?)**

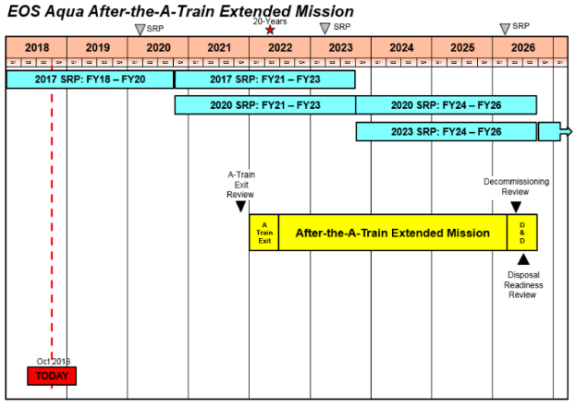
Aqua Decommissioning Review

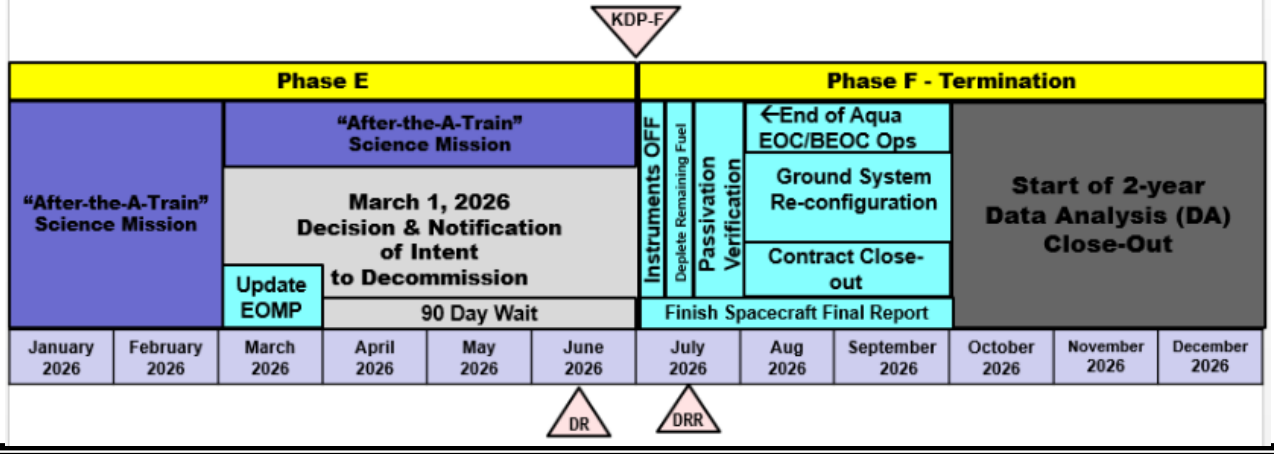
(October 2, 2018)

NEW Slide for the ESC MOWG Meeting

- **Request from ESMO Management – "DRAFT" Decommissioning Review**
  - **Document Phase F spacecraft activities, any new products to be developed for Spacecraft and/or Instrument calibrations, any proposed Engineering Tests, and the final Passivation and Disposal Sequence**



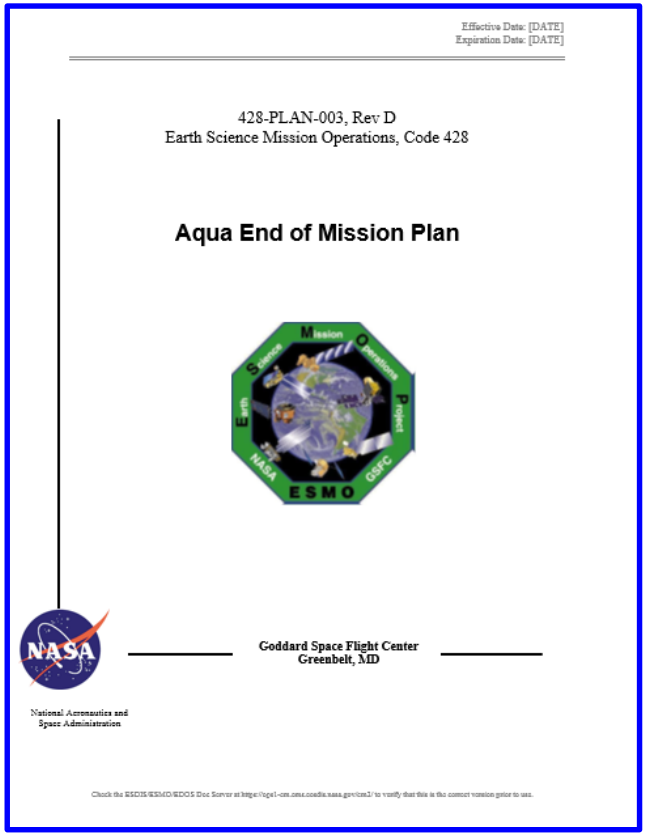




Aqua End of Mission Plan

KEY: Updates since last MOWG Meeting in blue

- **Initial draft February 2009**
- **"Interim" End of Mission Plan: May 2011**
  - Approved by NASA HQ July 2011
- **End of Mission Plan (Rev A): February 2013**
  - Updated Lifetime Estimates (09/2012)
  - Added Small Object Collision Assessment
- **End of Mission Plan (Rev B): June 2015**
  - Safely exit the A-Train Constellation (19 km)
  - Passivate to the extent possible for uncontrolled reentry
  - Aqua has five (5) approved waivers for passivation
    - » Pressurant Passivation
    - » Large Object Collision Probability
    - » Small Object Collision Probability
    - » Orbital Lifetime (30-Year)
    - » Re-entry Risk (Un-controlled)
  - **Waivers were approved in May 2013**
- **End of Mission Plan (Rev C): August 2017**
  - Includes ~4.4 km exit from A-Train in early 2022
- **End of Mission Plan (Rev D): January 2019**
  - Latest Annual Lifetime Estimate (November 2018)
  - Retrograde maneuver slews on reaction wheels
  - Currently in final review
- **Final produced 60 days before End of Mission**



Effective Date: [DATE]
Expiration Date: [DATE]

428-PLAN-003, Rev D
Earth Science Mission Operations, Code 428

Aqua End of Mission Plan

Goddard Space Flight Center
Greenbelt, MD

National Aeronautics and Space Administration

Next Update targeted for Late 2019 (Rev E)

Debris Assessment Software

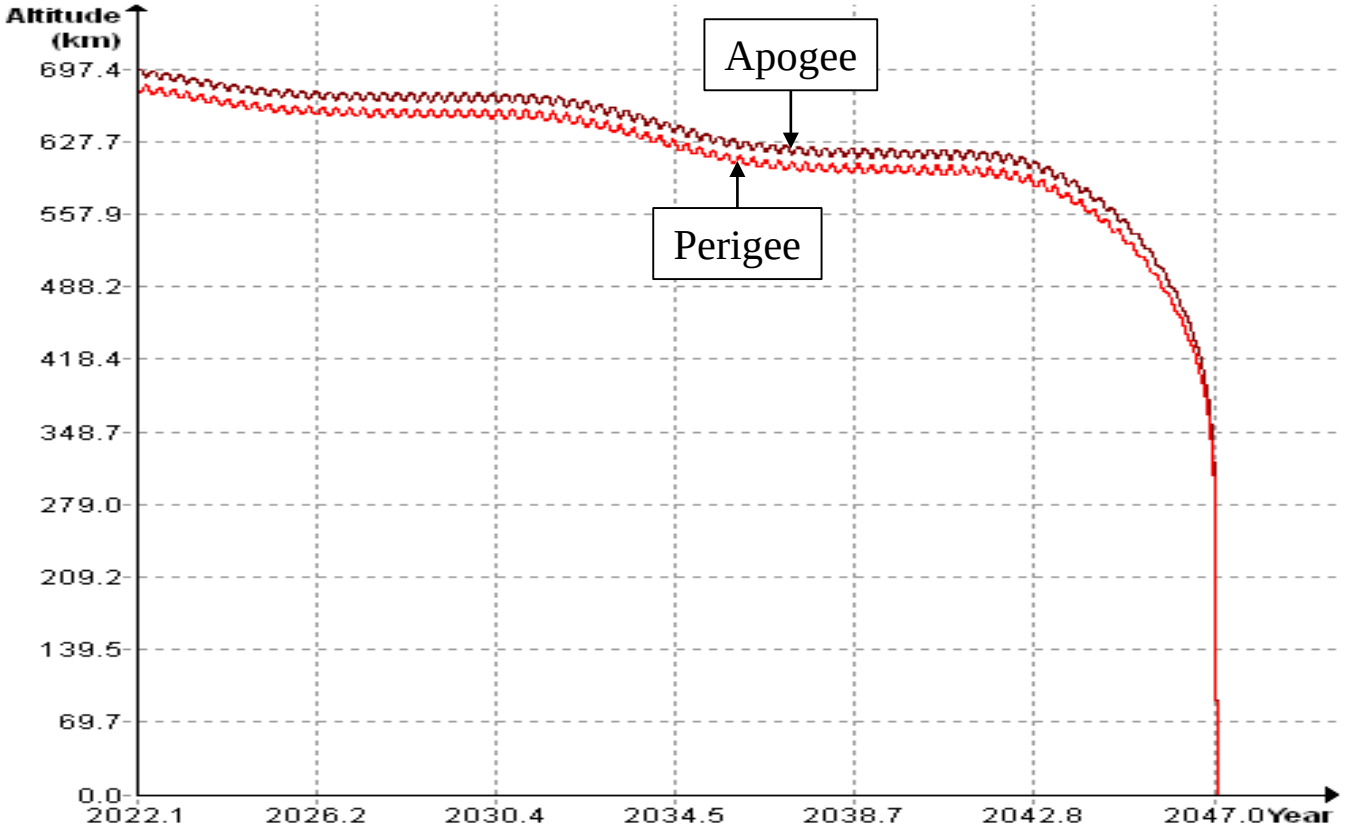
(November 2018)

KEY: Updates since last MOWG Meeting in blue – NONE

- **The Debris Assessment Software (DAS) was created by the Orbital Debris Office in Johnson Space Center and is the Agency standard for end of mission life analyses and lifetime estimations. (Current Version 2.1.1)**
- **DAS requires several inputs describing the spacecraft's mission:**
  - Launch date = 05/04/2002
  - Start inclination = 98.2º
  - Tumbling Area = 47.80 m2 (FDSS-II-07-0084 Aqua Average Area Version 1.0 Dated 28Feb2017)
  - Spacecraft dry mass = 2854.6 kg
  - Total end-of-life mass = 2860.6 kg (includes 1.2 kg of unusable fuel and 4.8 kg of uncertainty)
  - Area to Mass Ratio = 0.01671 m2/kg = Tumbling Area/(Dry Mass + unusable + uncertainty)
  - Final Apogee (Average Height) of orbit after constellation exit (early 2022) = **697.4 km**
  - Final Perigee of orbit after final perigee lowering burn (early 2022) = **675.4 km**
- **DAS outputs:**
  - If the mission is compliant with NASA requirements for limiting orbital debris.
  - A recommended apogee and perigee that will allow the spacecraft to reenter within a specific period and satisfy the NASA requirements.
- **Aqua has a waiver to the 30-years from launch requirement.**
- **Holding sufficient fuel in reserve to meet the 25-year reentry requirement.**

Aqua Orbital Decay

With A-Train Exit and perigee lowering in early 2022, Aqua is predicted to reenter within the required 25-year Agency & International requirement.



Summary

KEY: Updates since last MOWG Meeting in blue

- **Spacecraft Status - GREEN**
- **Instrument Status - GREEN**
  - AIRS and MODIS: Nominal Operations
  - AMSU: Nominal Operations except for Channels 1, 2, 4, 5 and 7
  - CERES: Nominal Operations except for CERES-Fore instrument
  - AMSR-E: Powered Down 3/3/2016
  - HSB: Survival Mode since 2/5/2003
- **Data Capture/L0 Processing Status – GREEN**
  - SSR Data Capture April 2019: **100%**
  - SSR Data Capture to 4/30/2019: **99.9800177%**
- **Data Latency – Excellent**
- **Ground Systems – Responding to new security requirements and upgrades to obsolete hardware or COTS systems, as required**
  - EOS Automation (EA) fully operational in summer 2019

Additional Slides

Orbit Maintenance Maneuvers
Conjunction Assessment High Interest Events
Ground Track Error & Mean Local Time History
Spacecraft Orbital Parameters Trends & Predictions

Orbit Maintenance

KEY: Updates since last MOWG Meeting in blue

- **<u>Mission Requirement</u>: Perform Drag Make-Up Maneuvers (DMUMs) to maintain Aqua's ground track error (GTE) with respect to the World Reference System (WRS-2) within +/-10 Km at the Descending Node (A-Train Requirement/Goal)**
  - Changed from +/-20 Km Mission Requirement with DMUM #19 (1/12/05)
  - **137** DMUMs have been performed to date (**Last #137 on 4/24/2019 – Next #138 on 5/23**)
  - Variation in performance from –20.9% (cold) to +24% (hot) #108 was 20.9% COLD
- **<u>Control Box Excursions</u>: Since 2012 there have been 7 Control box Excursions**
  - **4 on +10km front-side:**
    - 11/4/12 to 11/14/12, 10/23/13 to 10/24/13, 3/6/14 to 3/10/14 and 3/16/2015 to 4/2/2015
  - **3 on -10km back-side:** 11/7/13 to 12/14/13 (Emergency DAM on 10/24/13 and DAM on 11/28/13)
    - 4/2/2016 to 5/7/2016 and 7/29/2018 to 8/21/2018 (DAM on 7/12/2018)
- **<u>Mission Requirement</u>: Perform inclination adjust maneuvers (IAMs) to maintain the Mean Local Time (MLT) as measured at the Ascending Node between 1:30 and 1:45 MLT (Mission Goal starting in 2011: 13:35:45 +/- 45 seconds)**
  - **65 Inclination Adjustment Maneuvers (IAMs) performed to date**
    - Fall 2003 (1), Spring 2004 (1), Fall 2004 (5), 2005 (NONE)
    - Fall 2006 (4 of 6 - cancelled final 2 burns), Spring 2007 (4 - interrupted 2-weeks),
    - Spring 2008 – NONE per special request from PARASOL
    - Spring 2009 (9), Spring 2010 (3), Spring 2011 (3), Spring 2012 (4)
    - Spring 2013 (4 with #3 being delayed 1-week), Spring 2014 (4), Spring 2015 (5)
    - Spring 2016 (4 with one having to be re-scheduled), Spring 2017 (4)
    - Spring 2018: (5 with one having to be re-scheduled due to PMCOC), Summer 2018 #61 on 8/2/2018
    - **Spring 2019: (4 planned on: 3/7 (#62), 3/14 (#63), 3/22 → 4/4 (#64), 3/28 → 4/11 (#65)**

Aqua Conjunction Assessment High Interest Events (HIEs) – 2019

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2019	3	1	2	0									6
Tier 1	0	0	1	0									1
Tier 2	2	0	0	0									2
Tier 3	1	1	0	0									2
Tier 4	0	0	1	0									1

2013: 28 CARA HIEs – 9 required significant action
2014: 34 CARA HIEs – 14 required significant action
2015: 26 CARA HIEs – 16 required significant action
2016: 21 CARA HIEs – 4 required significant action
2017: 16 CARA HIEs – 11 required significant action

Tier 1 – Notify (email/phone), Tier 2 – Conduct Briefing,
Tier 3 – Plan Maneuver, Tier 4 – Execute Maneuver
Tier 4 – Postponed and/or replanned Maneuver

2018: 19 CARA HIEs – 13 required significant action (T3 & T4), 18 DAMs Planned, 1 DAM Executed, 1 Maneuver (IAM #60) postponed/replanned

2019 thru 4/30/2019: (6 CARA HIEs – 3 that required significant action (Tiers 3 & 4)

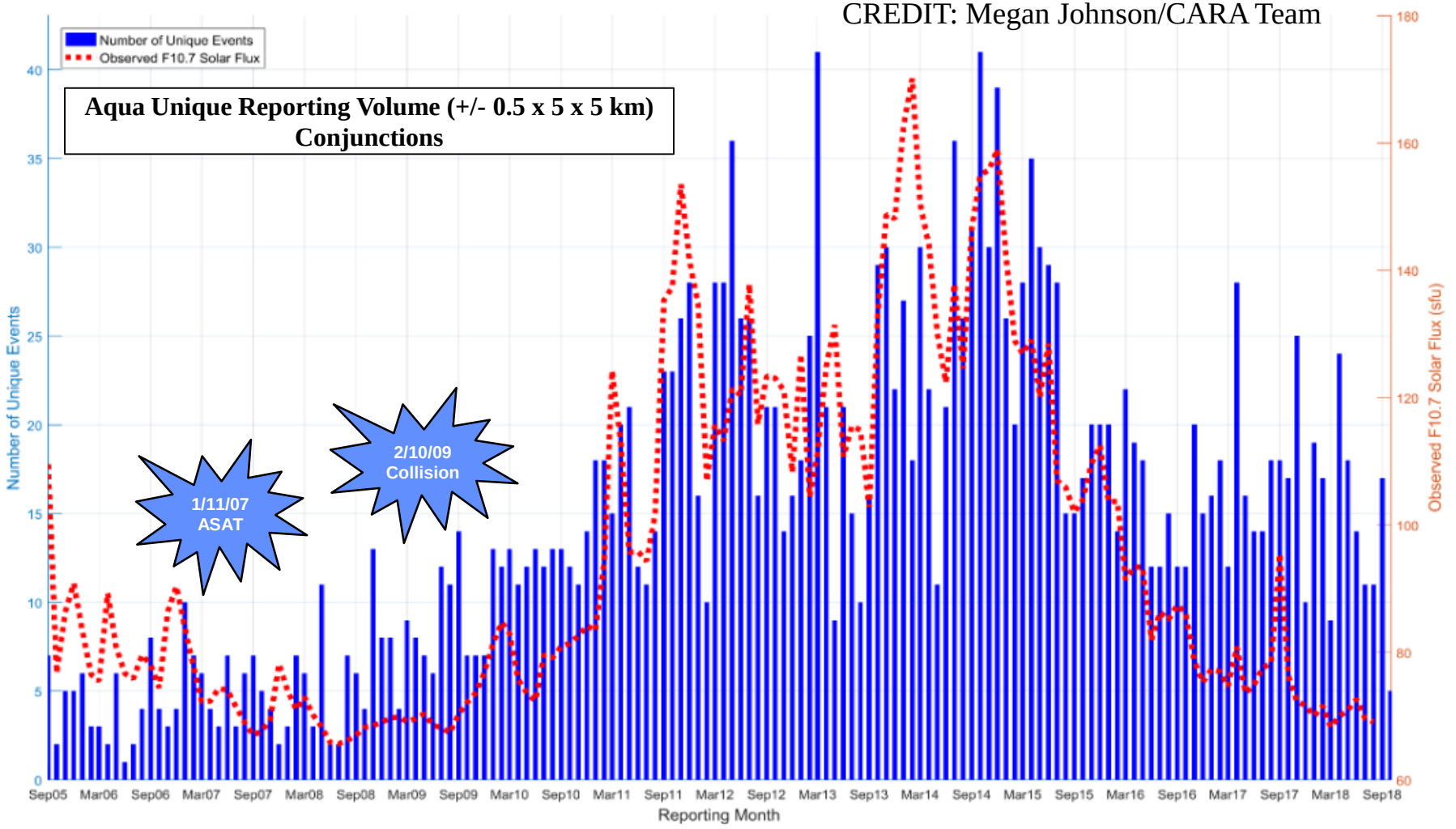
1. 01/28/2019: CA vs. 43345 at 01:48:46 GMT – DAMs planned, self-mitigated (T3)
2. 02/22/2019: CA vs. 35624 at 11:03:44 GMT – DAMs planned, Self-mitigated (T3)
3. 03/28/2019: CA vs. 41533 at 23:34:46 GMT – Post-Maneuver Conjunction of Concern (PMCOC) – Tier 4
4. No HIEs for Aqua in April

2019 Aqua Summary: 2 DAMs Planned, 0 DAM Executed, 2 DAMs that self-mitigated
1 Routine maneuver (IAM #64) was postponed/replanned and/or rescheduled (Tier 4)

Aqua Conjunction Assessment Statistics

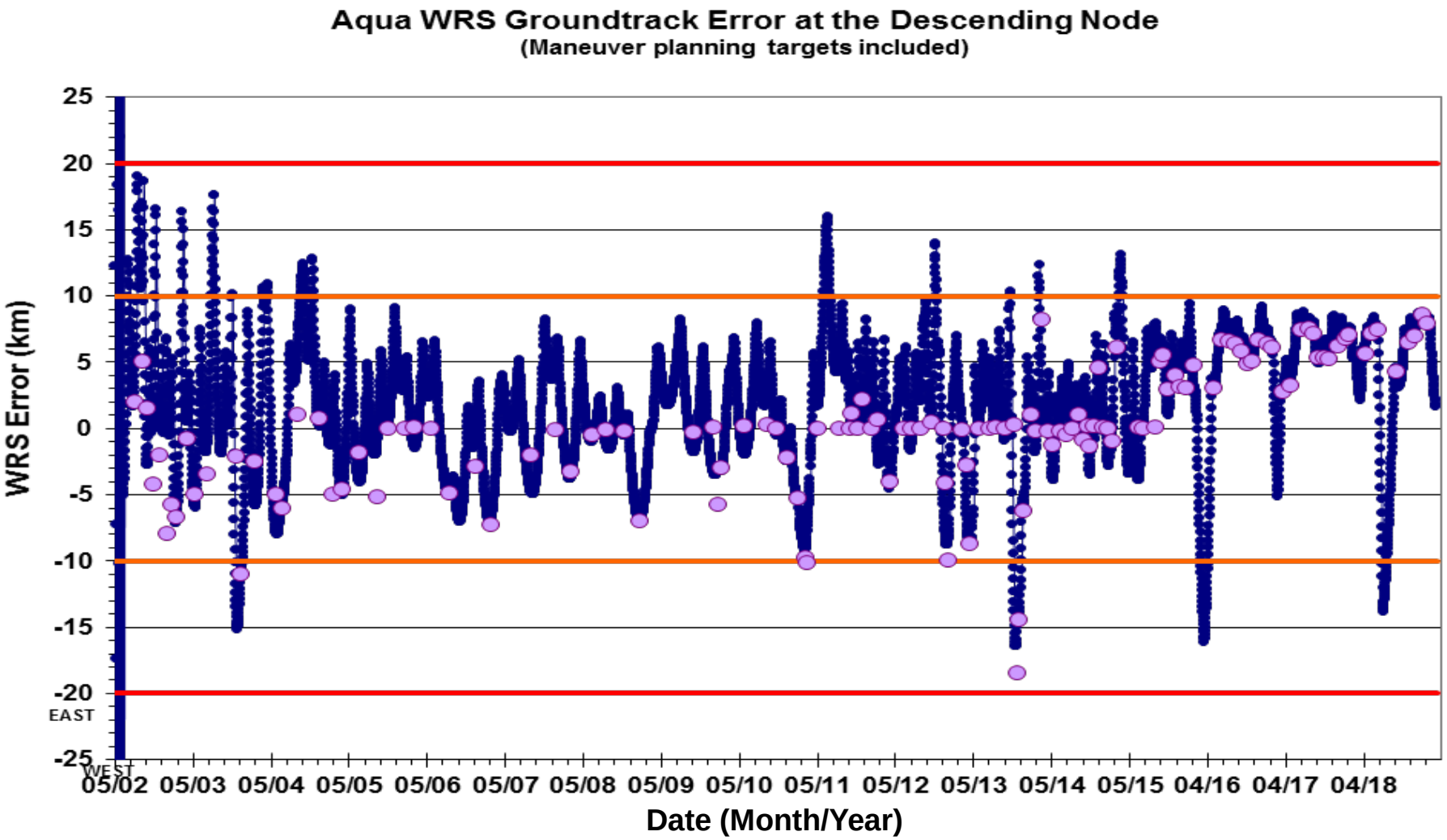
(Monthly Average – September 2005 thru September 2018)

CREDIT: Megan Johnson/CARA Team



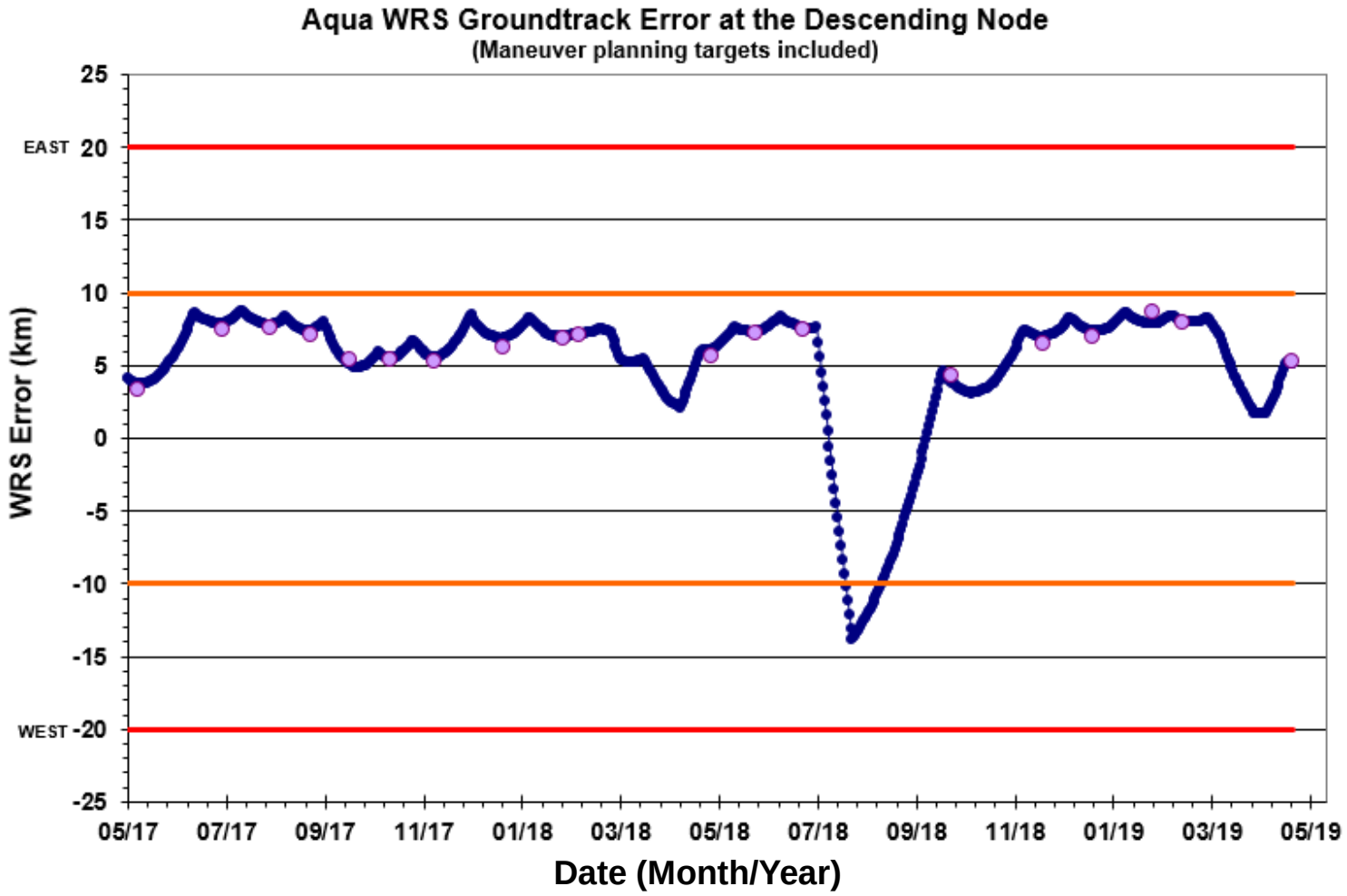
WRS Ground Track Error (GTE)

(As of April 30, 2019)



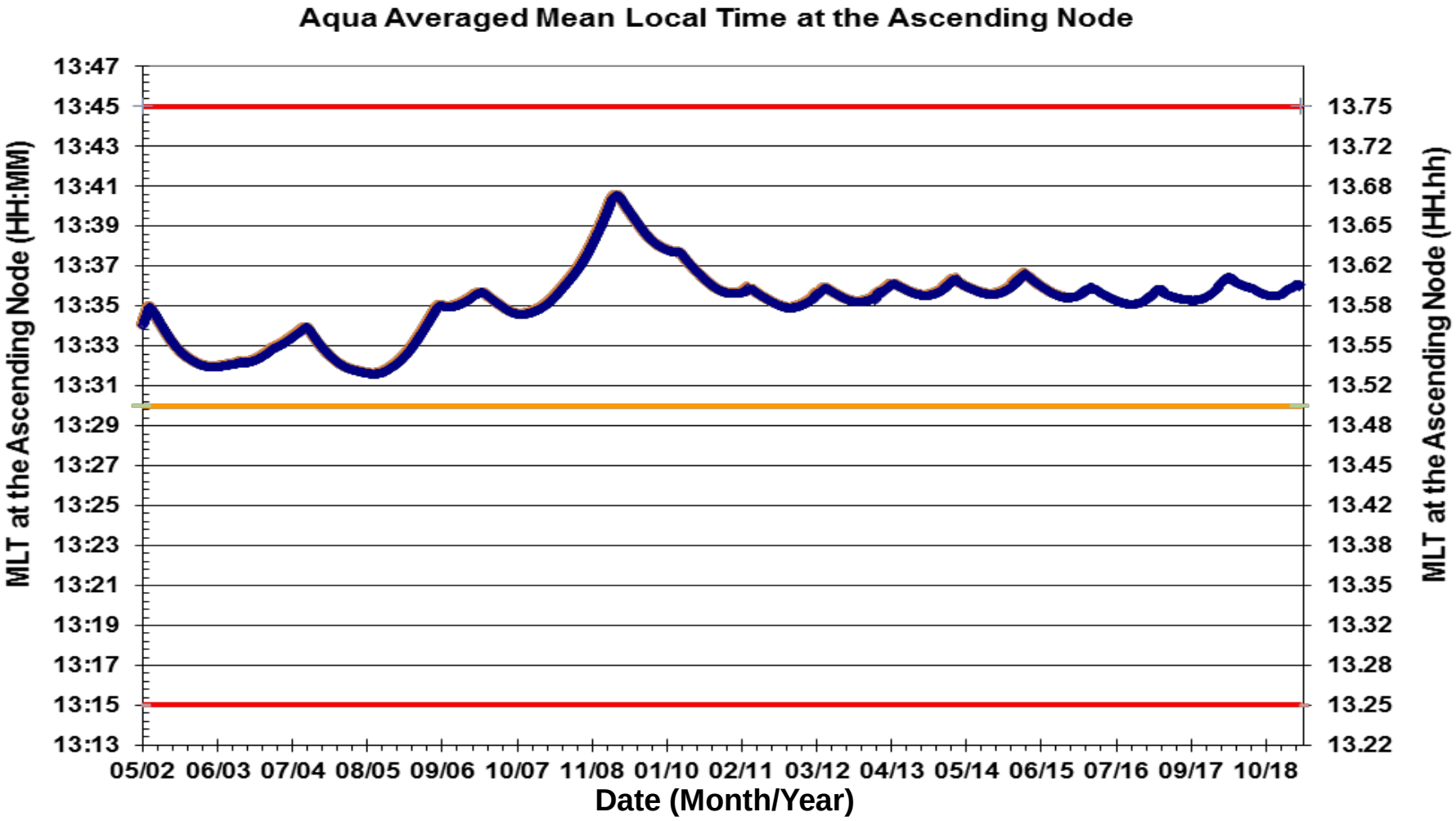
WRS Ground Track Error (GTE)

(Last 2-years as of April 30, 2019)



Aqua Averaged MLT @ Ascending Node

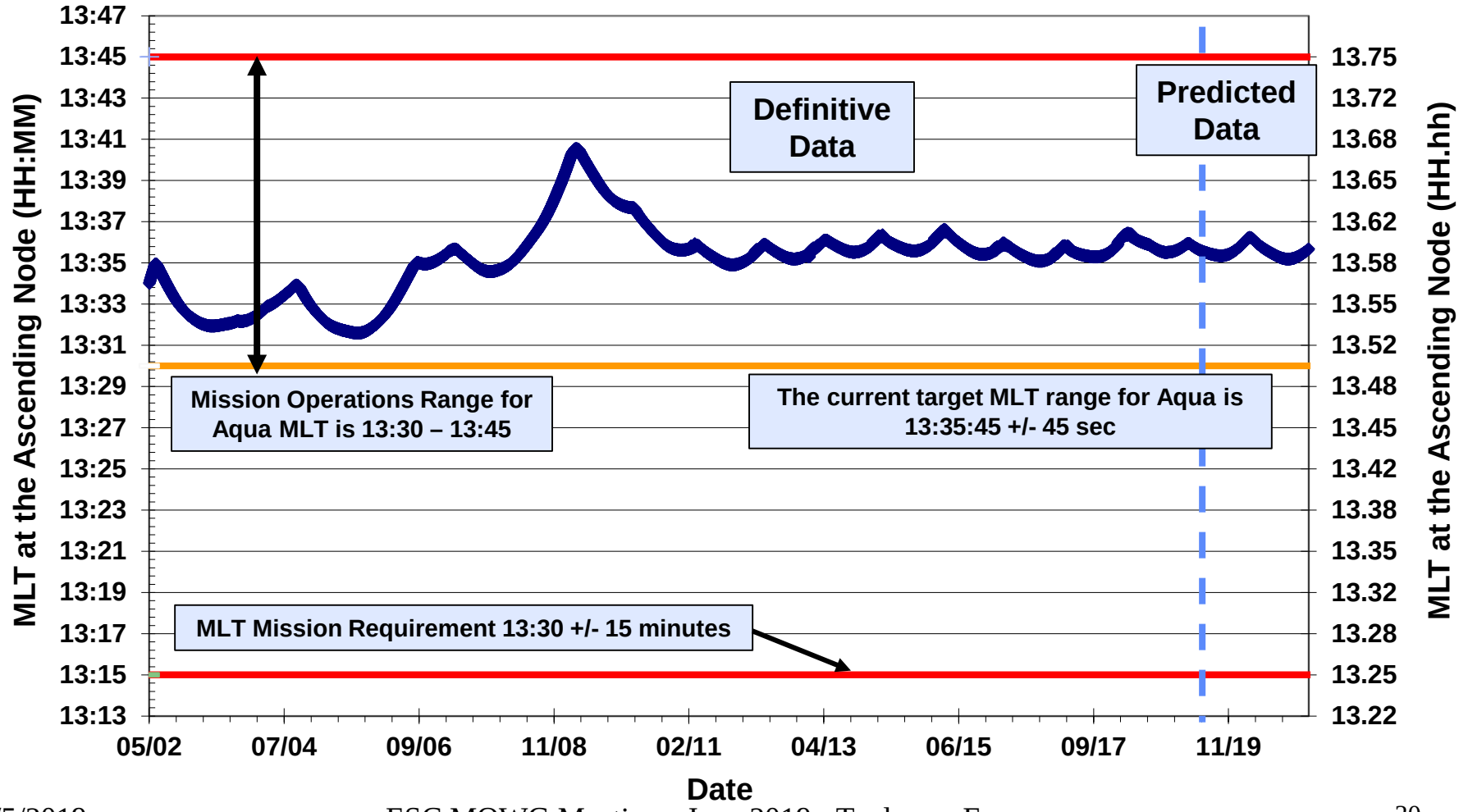
(As of April 30, 2019)



Aqua Definitive and Predictive MLT

@ Ascending Node

(as of April 30, 2019)



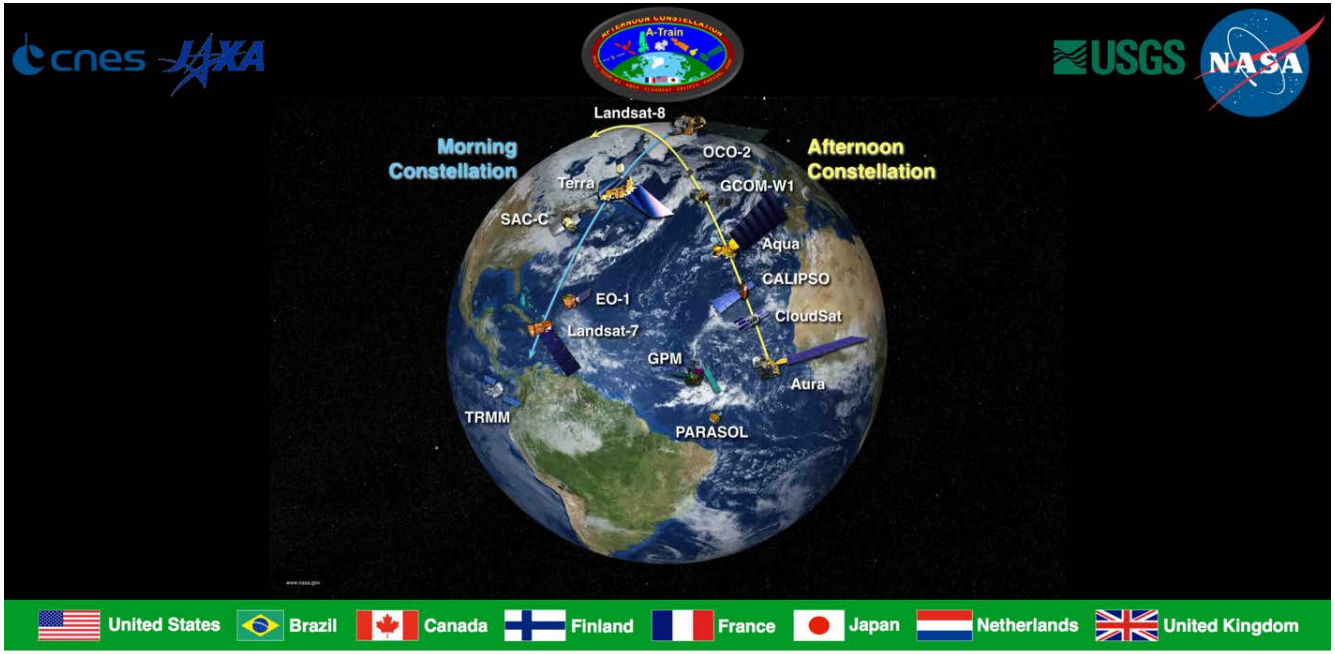
Inclination/MLT Maintenance

(April 2019)

KEY: Updates since last MOWG Meeting in blue

- **EOS Flight Dynamics has analyzed and updated the nominal inclination schedule that ensures Aqua's mean local time of the ascending node (MLTAN) remains within the current target range.**
  - The current target MLTAN range for Aqua is 13:35:45 +/- 45 sec.
  - Aqua's current mission MLTAN requirements are {13:30:00 - 13:45:00}
  - Aqua's performance for the 2019 inclination series was **-0.33% (COLD)**
- **Proposed long-term inclination adjust plan is predicted to keep Aqua within the target MLTAN range.**
  - Nominal case schedules Aqua inclination maneuvers that are not on weeks starting with Easter. **DRAFT** schedule for 2020 has maneuvers centered around the ideal dates with no breaks to optimize overall performance.
  - **Plan is to execute 2020 IAMs on reaction wheels and thrusters.**
- **Will re-visit/re-validate the long-term plan after each series of annual inclination adjust maneuvers.**
- **See EOS Flight Dynamics Presentation for long-term plan.**

Inclination/MLT Maintenance
(Long-Term Plan)



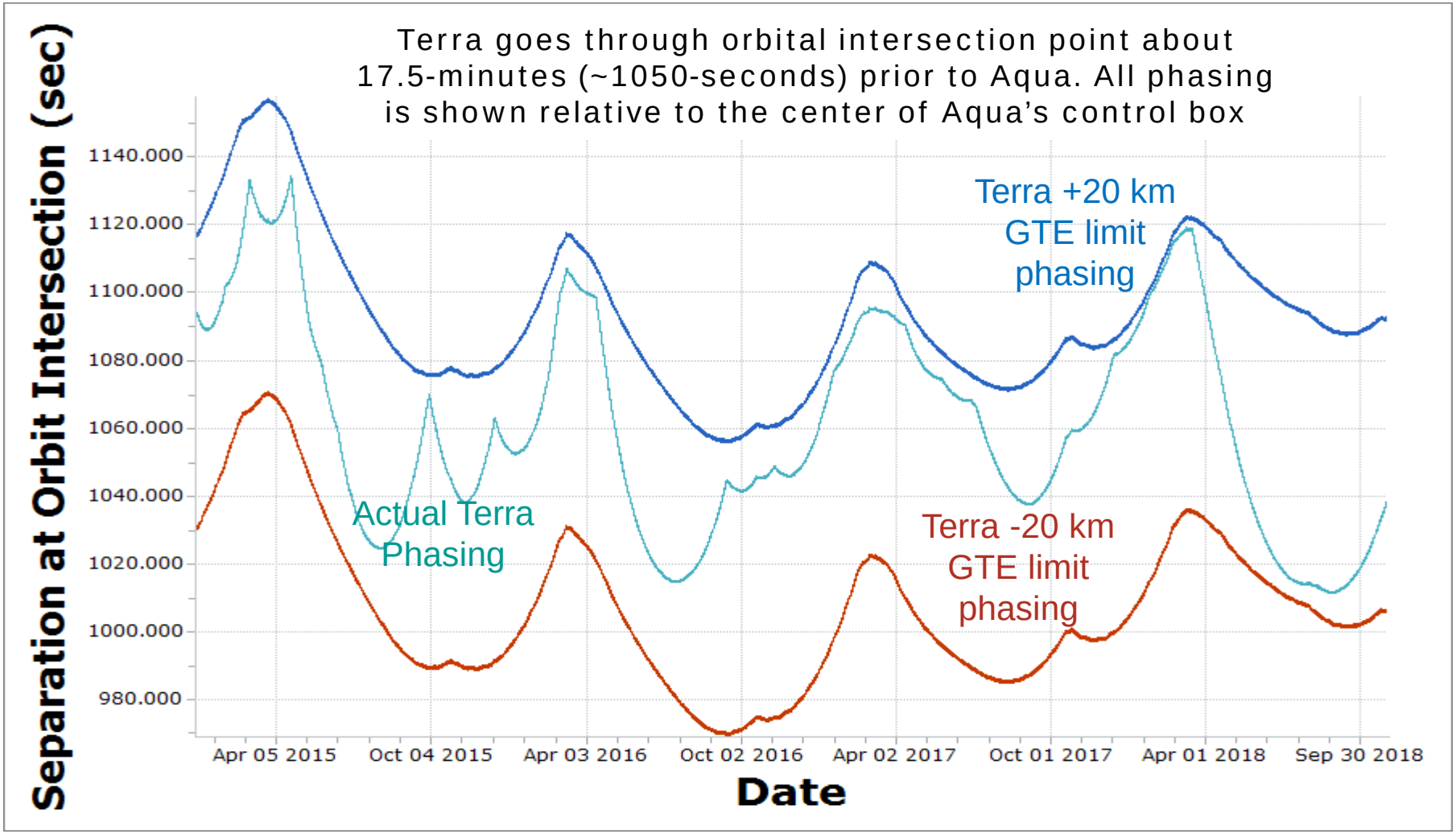
International Earth Science Constellation
Mission Operations Working Group (MOWG)
June 5-7, 2019

Aqua Spring 2019 IAM Series Results

Shawn Hoffman, Omitron, Inc.
EOS FDS, esmo-eos-fds@lists.nasa.gov, +1.301.614.5050

Terra to Aqua Phasing

(as of November 01, 2018)



A-Train/Aqua on Monday June 4, 2019 at 1:30pm EDT (CVT)

Abbreviations / Acronyms List

AIRS –	Atmospheric Infrared Sounder
AMSR-E –	Advanced Microwave Scanning Radiometer for EOS
AMSU –	Advanced Microwave Sounding Unit
ARE –	Array Regulator Electronics
ASAT –	Anti-satellite Weapon
BEOC –	Backup EOC
CA –	Conjunction Assessment
CARA –	Conjunction Assessment Risk Analysis
CDH –	Command & Data Handling
CEF –	CERES Fore
CEM –	Constellation Exit Maneuver
CERES –	Clouds and the Earth's Radiant Energy System
COTS –	Commercial Off the Shelf
CNES –	Centre National d'Etudes Spatiales
CRMS –	Collision Risk Management System
CVT –	Constellation Visualization Tool
DA –	Data Analysis
DAM –	Debris Avoidance Maneuver
DAS –	Debris Assessment Software
DMUM –	Drag Make-up Maneuver
DTM –	Dual Thruster Module
EA –	EOS Automation
EDT –	Eastern Daylight Time
EOC –	EOS Operations Center
EOL –	End of Life
EOM –	End of Mission
EOMP –	End of Mission Plan
EOPM –	End of Prime Mission
EOS –	Earth Observing System
EPS –	Electrical Power System
ESC –	Earth Science Constellation
ESMO –	Earth Science Mission Operations
FDS –	Flight Dynamics System
FDSS-II –	Flight Dynamics Support Services II contract
FOT –	Flight Operations Team
FSW –	Flight Software
FY –	Fiscal Year
GCOM-W1 –	Global Change Observation Mission for Water (1)
GMT –	Greenwich Mean Time
GN&C –	Guidance Navigation & Control
GPM –	Global Precipitation Measurement
GTE –	Ground Track Error
HIE –	High Interest Event
HQ –	Headquarters
HSB –	Humidity Sounder for Brazil
IAM –	Inclination Adjustment Maneuver
JAXA –	Japan Aerospace Exploration Agency
kg –	kilogram
km –	kilometer
L0 –	Level-Zero
m –	meter
min –	minute
MLT –	Mean Local Time
MOCA –	Mission Operations Conjunction Assessment
MODIS –	Moderate Resolution Imaging Spectroradiometer
MOU –	Memorandum of Understanding
MOWG –	Mission Operations Working Group
NASA –	National Aeronautics & Space Administration
OCO-2 –	Orbiting Carbon Observatory-2
Ops –	Operations
ORR –	Operational Readiness Review
PARASOL –	Polarization & Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar
PLM –	Perigee Lowering Maneuvers
PMCOC –	Post Maneuver Conjunction of Concern
PROP –	Propulsion
PS –	Project Scientists
PVT –	Pressure, Volume, & Temperature
RMM –	Risk Mitigation Maneuver
RW –	Reaction Wheels
s or sec –	second
SA –	Solar Array
S/C –	Spacecraft
SEU –	Single Event Upset
SME –	Subject Matter Expert
SSR –	Solid State Recorder
TBC –	To Be Confirmed
TBD –	To Be Determined
TCS –	Thermal Control System
US –	United States
USGS –	United States Geological Survey
WRS –	World Reference System