Mission Status at Earth Science Constellation MOWG Meeting @ GSFC June 2, 2015

EOS Aura

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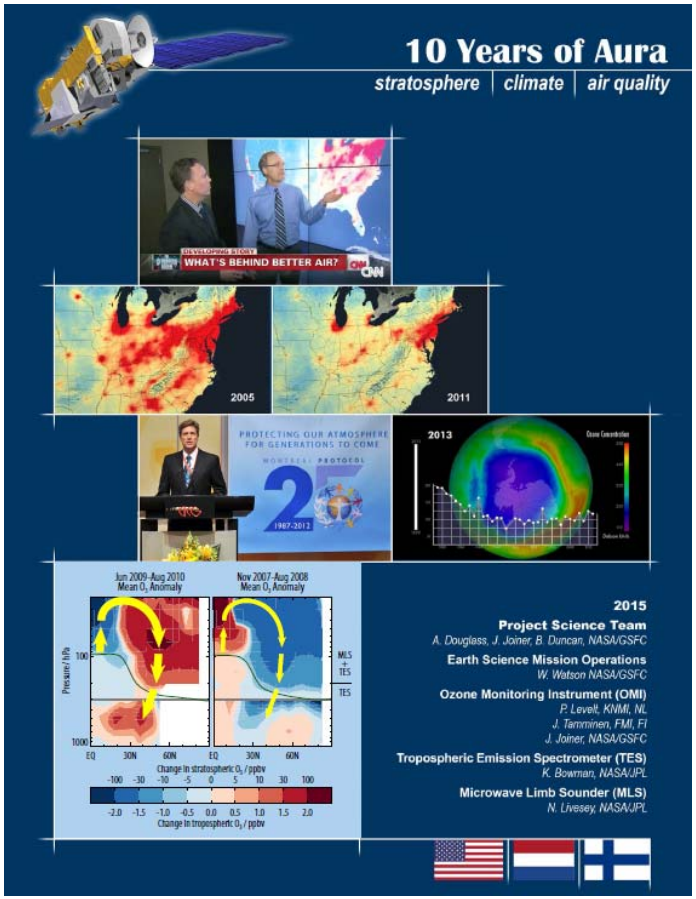
Topics

- **Mission Summary**
- **Spacecraft Subsystems Summary**
- **Recent & Planned Activities**
- **Inclination Adjust Maneuvers**
  - **Spring 2016 Calendar (DRAFT)**
  - **2015 Results & Long-Term Plan (in EOS FD Presentation)**
- **Propellant Usage & Lifetime Estimate**
- **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 Aura Mission Summary

(Updates since October 2014 MOWG at LaRC)

- **07/15/04: Launch**
  - **6-Year Design Life**
- **09/30/10: End of Prime Mission Review**
- **07/10/13: 2013 Mission Extension Senior Review Proposal Panel Report**
  - **#4 Ranked Earth Science Mission**
  - **Mission extension through FY17**
- **07/22/13: Submitted Phase F Study**
- **01/21/15: FOT Annual Review #8**
- **03/03/15: Senior Review Proposal #4**
  - **Reliability Estimates thru 2022**
  - **Consumables through 2023+**
- **07/15/14: 10-Year Anniversary**



Changes since Oct 2014 MOWG at LaRC are in blue

Aura Spacecraft Subsystems

All subsystems configured to primary hardware

- **Command & Data Handling (CDH) – Nominal**
  - ***Solid State Recorder (SSR) Anomaly (December 4-18, 2007)***
    - » ***Returned November 2010 at reduced level – then subsided January 2011***
    - » ***Returned again 04/15/2012 – currently still "active"***
- **Communications (COMM) – Nominal**
- **Electrical Power System (EPS) – Nominal**
  - ***Solar Panel Connector Anomaly – ARE-3C (January 12, 2005)***
  - ***Solar Array Offset (Reported 11/17/09, Corrected 06/29/10 and each year since)***
  - ***Array Regulator Electronics (ARE) 5A Anomaly (03/12/2010) additional power drop on 04/25/2013***
    - » ***Simultaneously with GN&C Attitude Disturbance – attributed to MMOD Strike***
  - ***12/08/2014 ARE-4A power drop (first power drop anomaly in 15-months – last observed on Aura)***
  - ***Other older ARE Anomalies: ARE-5C (9/27/12 & 2/4/13), ARE-1A (3/12/10 & 11/5/11) & ARE-6A (9/14/13)***
    - » ***Estimated that Aura has lost 25 strings of solar cells out of a total of 132 strings***
    - » ***Aura continues to have significant power margin where the life limiting item is fuel***
- **Flight Software (FSW) – Nominal**
- **Guidance, Navigation & Control (GN&C) – Nominal**
  - ***Earth Sensor Assembly (ESA) Anomaly (05/29/2009) – Re-calibrated in Fall 2009***
- **Propulsion (PROP) – Nominal**
  - ***Dual Thruster Module (DTM-3) Anomaly (Aug 16, 2005)***
- **Thermal Control System (TCS) – Nominal**

Recent Activities
(October 2014 – May 2015)

- **26 CARA High Interest Orbital Debris Events (October 2014 – May 2015)**
  - **5 that required significant action (Tier 3 + Tier 4) plus 4 additional Tier 2 HIEs**
    - » See charts 18 & 19 and CARA presentation
  - **3 RMM/DAMs PLANNED – 0 APPROVED/LOADED/WAIVED-OFF – 0 EXECUTED**
  - **3 Routine DMUMs were re-scheduled/re-planned (CARA Tier 4 HIEs)**
  - **17 Potential High Interest Events (PHIEs – Tier 1's) required monitoring and/or planning**
- **No significant Instrument related anomalies – 1 minor spacecraft bus anomaly**
  - **12/08/2014 ARE-4A power drop anomaly**
- **Spacecraft Delta-V Maneuvers: 8 Routine DMUMs, 5 IAMs and 0 DAMs**
  - **8 Routine Drag Make Up Maneuvers (DMUMs): #'s 72-79**
    - » 2014: 10/10, 10/30, 11/25, 12/11, 2015: 1/6, 1/28, 2/20 and 4/9
  - **0 Debris Avoidance Maneuvers**
  - **5 Inclination Adjust Maneuvers:**
    - » 2015: 3/19 (#40), 3/26 (#41), 4/2 (#42), 4/16 (#43) and 4/23 (#44)
  - **3 DMUMs re-scheduled/re-planned due to post maneuver conjunctions of concern**
    - » 2015: 1/22, 2/5 and 2/18
- **1 Instrument Calibration Maneuver – MLS Moon Scan on 3/7/2015 (#10)**
- **ESMO Maneuver Planning Process Review (Final Report sent 4/20/2015)**

Planned Activities

- **June 2015: Drag Make Up Maneuver (DMUM) # 80**
- **Fall 2015: Earth Science Constellation(ESC)/A-Train MOWG**
  - Update propellant budget, decommissioning analysis, reliability predictions,…
- **January 2016: Flight Operations Annual Review (#9)**
- **Spring 2016: Afternoon Constellation Science Meeting and ESC MOWG**
- **Spring 2016: Annual Inclination Adjust Maneuvers (DRAFT SCHEDULE)**
  - 4/21/2016 (#45), 4/28/2016 (#46), 5/12/2016 (#47) & 5/19/2016 (#48)
- **May 2016: 2nd Annual CNES Conjunction Assessment Workshop (?)**
- **Mid-to-Long-Term Plans**
  - Routine Operations
- **Continue to improve Debris Avoidance Maneuver (DAM) responsiveness**
  - **Additional details in John Nidhiry's Quick DAM (QDAM) presentation**

New Quick DAM (QDAM) Operations Concept

In response to the constantly increasing number of predicted close approaches with orbital debris and operational satellites (High Interest Events – HIEs – see slide 18)

The EOS Flight Operations Team (FOT) has developed new ground system capabilities, operational procedures and products, to safely plan and execute Debris Avoidance Maneuvers (DAMs) in a significantly reduced amount of time (hours vs. days)

The new and improved procedures and products have….

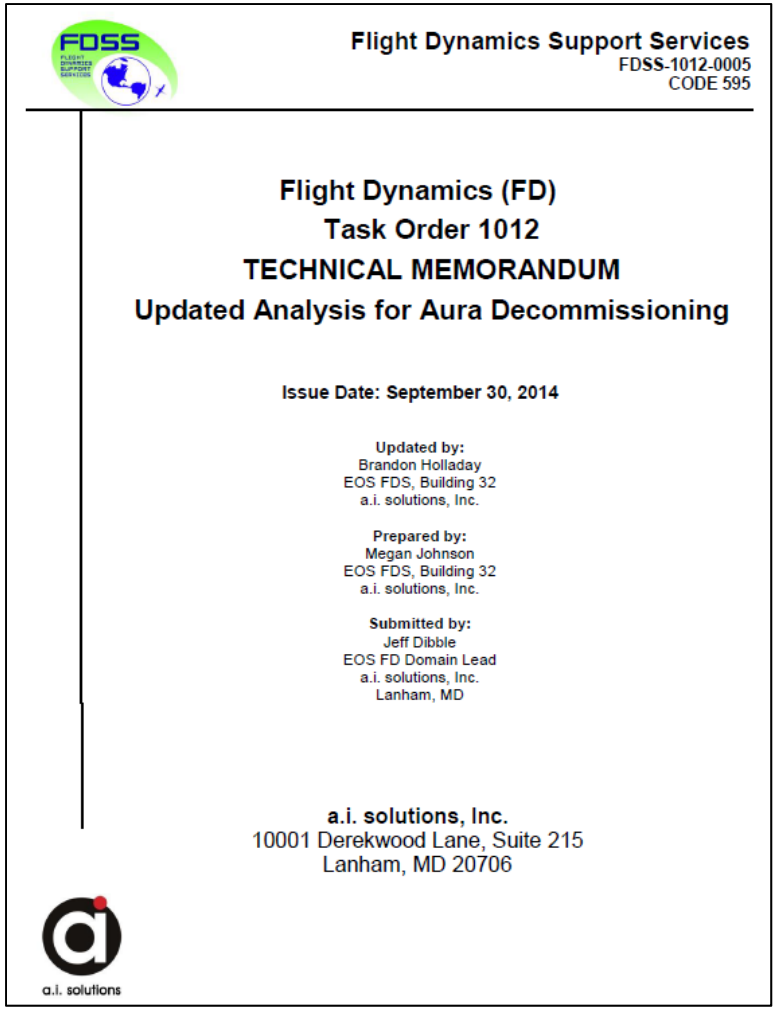
- **Eliminated the current critical path for instrument and communications subsystem commanding in the daily stored command load**
- **Required less personnel and man-hours for preparation**
- **Required fewer systems for preparation**
- **Required generation of fewer products**
- **Allows greater flexibility with burn duration and timing**

DRAFT Spring 2016 Inclination Adjust Plan

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
27 EASTER	28	29	30	31	1 April	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20 Aqua IAM #48	21 Aura IAM #45	22	23
24	25	26	27 Aqua IAM #49	28 Aura IAM #46	29	30
1 May	2	3	4 Spring Break	5 Spring Break	6	7
8	9	10	11 Aqua IAM #50	12 Aura IAM #47	13	14
15	16	17	18 Aqua IAM #51	19 Aura IAM #48	20	21
22	23	24	25 Aqua Backup	26 Aura Backup	27	28

Propellant Usage
(Updated September 2014)

- **Initial Aura lifetime fuel analysis in 2006**
- **Detailed Aqua & Aura lifetime analysis in 2008**
  - Presented to MOWG and at Aura End of Prime Mission Review in September 2010
- **Initial Aura Decommissioning Plan was delivered in September 2012**
  - Updated Lifetime Estimates
- **Updated August 29, 2013**
  - **Updated propellant trends for IAMs & DMUMs**
  - **Updated definitive fuel usage**
  - **Updated predicted solar flux levels**
  - **Updated Constellation Exit Plan**
    - Safely exiting the Afternoon Constellation requires that Aura's final apogee be at least two kilometers below the minimum perigee of the other constellation members (692 km target)
    - Perform orbit lowering maneuvers centered at apogee and perigee (pairs of maneuvers)
- **Updated September 30, 2014**
  - **Updated propellant trends for IAMs & DMUMs**
  - **Updated definitive fuel usage**
  - **Updated predicted solar flux levels**
- **Annual updates will be provided**
  - **Final will be produced 60 days before start of decommissioning**



FDSS

Flight Dynamics Support Services
FDSS-1012-0005
CODE 595

Flight Dynamics (FD)
Task Order 1012
TECHNICAL MEMORANDUM
Updated Analysis for Aura Decommissioning

Issue Date: September 30, 2014

Updated by:
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Prepared by:
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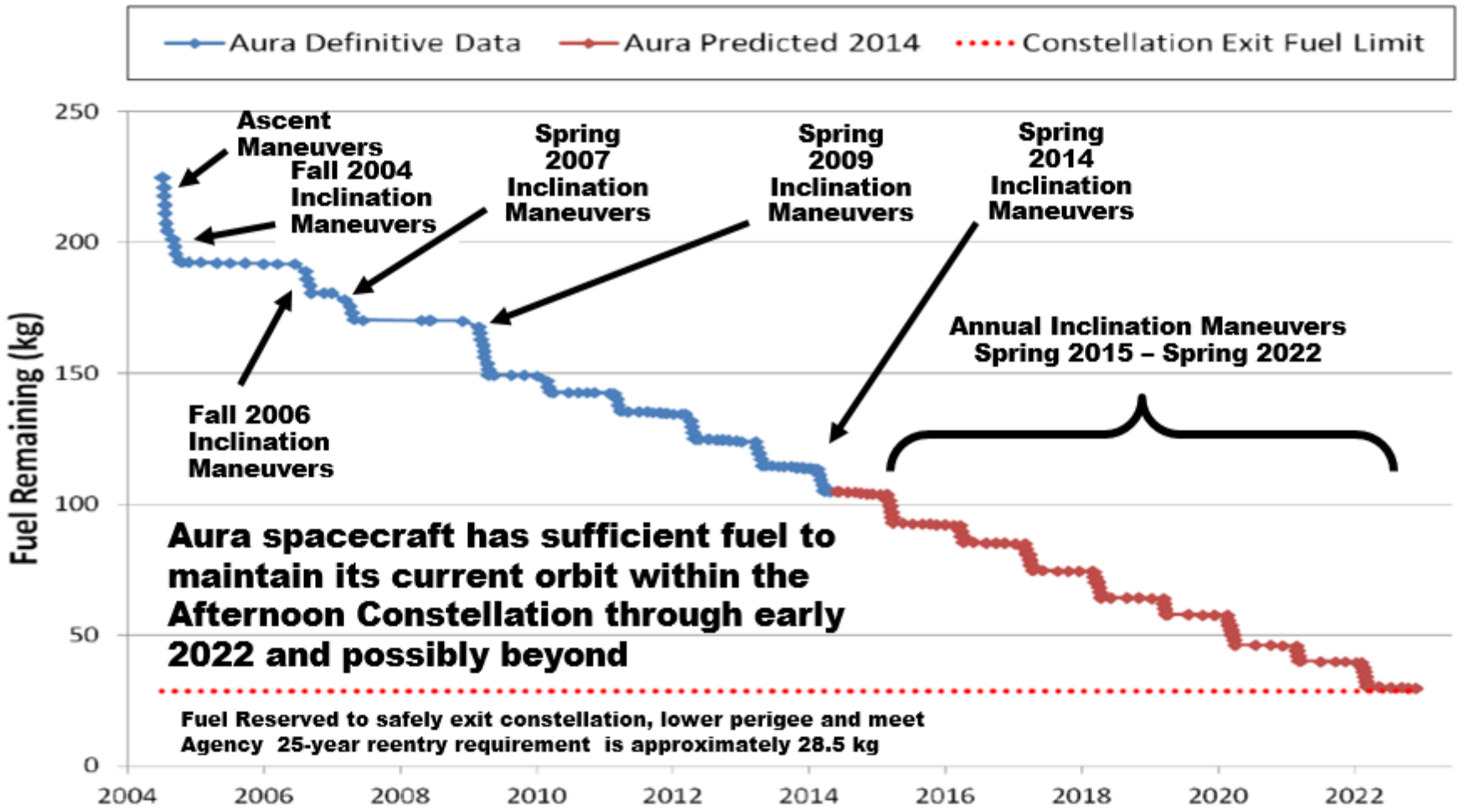
Remaining Fuel Estimate
(September 2014)

- **Long-term orbit simulations were run for Aura through Feb 2023**
  - **Used mean nominal Schatten solar flux predictions**
  - **Estimated the frequency of drag make-up maneuvers to maintain Aura's WRS-2 ground track requirements**
  - **Estimated the required number of annual inclination maneuvers for Aura to maintain it's mean local time (MLT) requirement**
  - **Did not include potential debris avoidance maneuvers**
  - **Utilized FreeFlyer 6.7.2 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 Aura show that the spacecraft will have sufficient fuel to maintain its current orbit within the Afternoon Constellation through at least early 2023 and possibly beyond**
- **Analyses are updated annually by ESMO Flight Dynamics Team after each series of inclination adjust maneuvers**

Fuel Usage: Actual & Predicted

(Updated October 1, 2014)



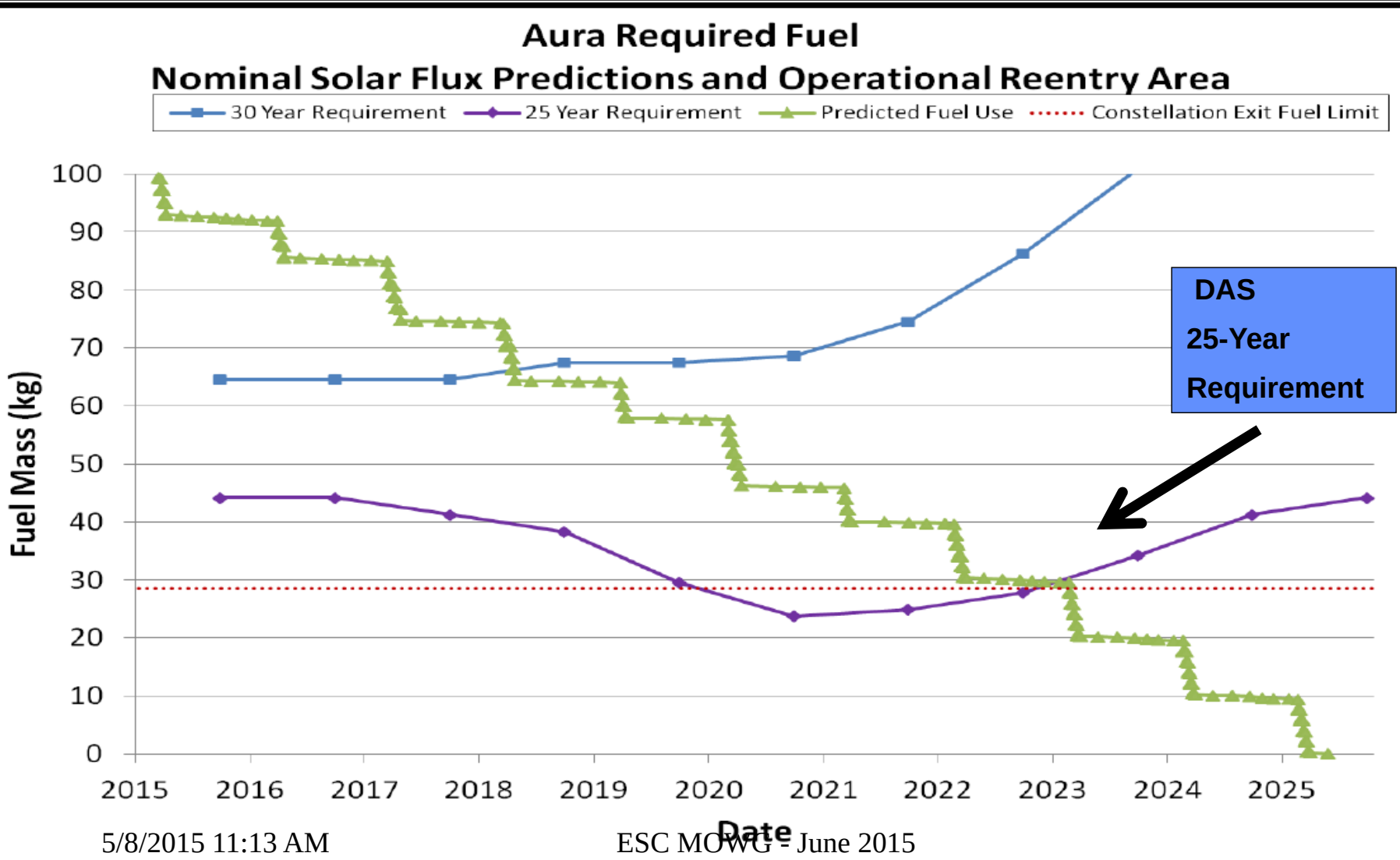
Debris Assessment Software

(September 2014)

- **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 2.0.2**
- **DAS requires several inputs describing the spacecraft's mission:**
  - **The operational orbit parameters**
  - **The mission launch date**
  - **Length of a mission's lifetime**
- **In turn, 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 NASA requirements**
- **Aura will have enough fuel onboard to safely exit the constellation and de-orbit to the DAS recommended perigee out through the 2023 time frame**

Aura DAS End of Life Predictions

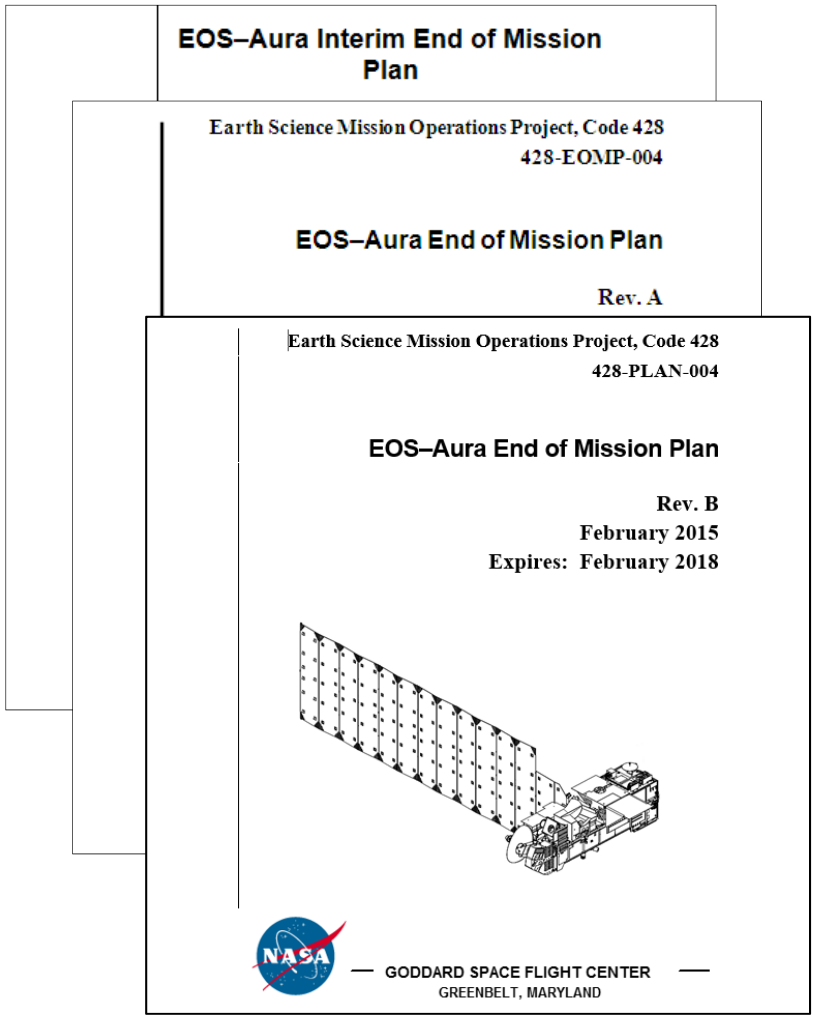
(September 2014)



Changes since last ESC MOWG

Aura End of Mission Plan

- **Initial draft February 2009**
- **Produced the first "Interim" End of Mission Plan (EoMP) in May 2011**
  - **Approved by NASA HQ July 2011**
- **Produced EoMP (Rev A): February 2013**
  - **Updated Lifetime Estimates (09/2012)**
  - **Added Small Object Collision Assessment**
- **Produced EoMP Rev B: February 2015**
  - **Final will be produced 60 days before EoM**
  - **Latest Annual Lifetime Estimate (09/2014)**
  - **Synopsis**
    - » Safely exit the A-Train Constellation
    - » Passivate Aura to the extent possible for uncontrolled reentry
    - » Aura 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**



Summary

- **Spacecraft Status - GREEN**
- **Instrument Status - GREEN**
  - **HIRDLS: Chopper Stalled 03/17/08 – Not collecting science data**
  - **MLS: Operating Normally – Only periodic Band 13 measurements**
    - » **THz module in Standby Mode – Tested Annually – Latest: 08/18/14 - 09/30/14**
    - » **08/06/2013: Band 12 Shut down (reached end of useful life – 2-year design)**
    - » **09/16/2013: 190 GHz Signal Chain Anomaly (Recovered 09/16/2013)**
    - » **08/19/2014: GHz Anomaly (SEU in SAA – recovered the same day)**
  - **OMI: Operating Normally**
    - » **Field-of-View Anomaly started in September 2007 – currently stable**
  - **TES: Operating Normally**
    - » **05/18/2014: TES ICS Stall #2 (Recovered 07/05/2014)**
    - » **07/09/2014: TES Laser A Failure (Switched to Laser B on 7/23/2014)**
      - **TES returned to routine Special Observation operations on 07/26/2014**
- **Data Capture/L0 Processing Status – GREEN**
  - **SSR Data Capture to 03/31/2015: 99.99511135 %**
- **Ground Systems – System Upgrades completed no current issues**
  - **Responding to new security requirements and upgrades to obsolete hardware or COTS systems, as required – Automation Effort underway**

Additional Charts

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 ESC MOWG in blue

- **<u>Mission Requirements</u>: Perform Drag Make-Up Maneuvers (DMUMs) to maintain Aura's Ground Track Error (GTE) with respect to the World Reference System (WRS-2)**
  - **Requirement: +/-20 Km as measured at the Descending Node**
- **To meet coincident viewing requirements, Aura's initial ground track was offset from Aqua's by one WRS path plus 25.4 Km**
  - **Aura was maintained -5.4 to -45.4 Km west of Aqua until late 2007**
  - **Since May 8, 2008, a new control box, +/- 10 Km from a +18 Km (east) offset of the Aqua WRS-2 path is used to maintain MLS-CALIPSO viewing request**
- **To date a total of 79 routine DMUMs have been performed**
  - **07/19/2012: DMUM # 43 No Yaw Slew Maneuver (NYS) #1 – NYS Maneuvers (37)**
  - **Last maneuver 04/09/2015 (#79) – Next maneuver June 2015 (#80)**
  - **Variation in performance from –6.7% (cold) to +5.3% (hot)**
- **Conducted 9 series of inclination adjustment maneuvers**
  - **Fall 2004 (4), Fall 2006 (4 of 6), Spring 2007 (4), Spring 2009 (9), Spring 2010 (3),**
  - **Spring 2011 (3), Spring 2012 (4), Spring 2013 (4), Spring 2014 (4) & Spring 2015 (5)**
  - **Variation in performance from -4.5% (cold) to +1.9% (hot)**

Aura Conjunction Assessment High Interest Events

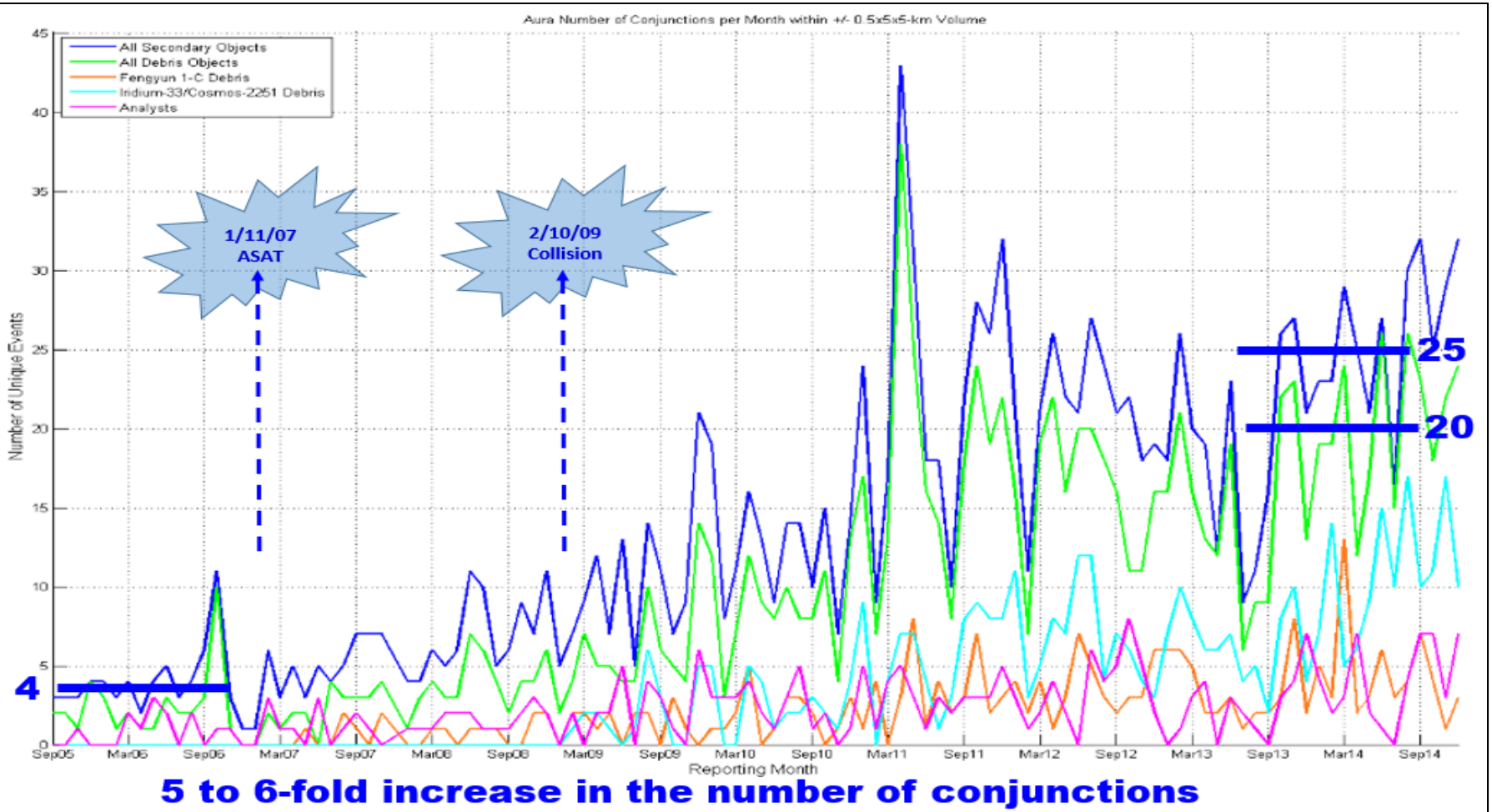
(10/1/14 – 5/31/15: 26+ CARA HIEs – 9 Required Significant Actions

1. **09/26/2014: CA vs. 38472 on 10/01 at 09:00:37 GMT – Small miss distance CA (7 meters) with low-risk (1:83K) Pc (T1)**
2. **10/20/2014: CA vs. 82983 on 10/22 at 08:42:28 GMT – Medium-risk (Pc about 1 in 3700) CA that self-mitigated (T1)**
3. **11/07/2014: CA vs. 34822 on 11/10 at 23:57:06 GMT – Planned DAMs, required large maneuvers, suspended DAM planning (T3)**
4. **11/21/2014: CA vs. 26137 on 11/25 at 00:05:19 GMT – Planned DAMs, Pc rolled-off, suspended DAM planning (T2)**
5. **12/05/2014: CA vs. 81817 on 12/06 at 13:02:39 GMT – Short-notice (2.5-days) PHIE, requested MTS plots, self-mitigated (T2)**
6. **12/05/2014: CA vs. 38189 on 12/11 at 10:50:06 GMT – Repeating CAs, DMUM scheduled for 12/17 re-scheduled to 12/11 (T1)**
7. **12/24/2014: CA vs. 35185 on 12/25 at 05:57:58 GMT – Short-notice (12-hours), Pc 1 in 9K, never reported in another screening (T1)**
8. **12/25/2014: CA vs. 89305 on 12/30 at 09:40:06 GMT – Short-notice, repeating CAs, never reported in another screening report (T2)**
9. **01/19/2015: CA vs. 30085 on 01/24 at 13:34:35 GMT – DMUM (QDAM) Postponed #9 due to post-maneuver conjunction (T4)**
10. **01/25/2015: CA vs. 38237 on 01/26 at 20:48:30 GMT – 8+ repeating CAs (T1)**
11. **01/24/2015: CA vs. 87471 on 01/28 at 09:10:03 GMT – Monitor only, no action required (T1)**
12. **02/02/2015: CA vs. 37770 on 02/07 at 02:16:20 GMT – Postponed 2/5 DMUM, Planned DAMs, 3 HIEBs (T4)**
13. **02/16/2015: CA vs. 32084 on 02/18 at 22:36:55 GMT – 2/18 QDAM Postponed (T4)**
14. **02/18/2015: CA vs. 82593 on 02/21 at 19:04:30 GMT – Monitored but no action (T2)**
15. **04/13/2015: CA vs. 36491 on 04/15 at 21:51:15 GMT – Planned DAMs, risk rolled-off with updated tracking (T3)**

Aura Summary: 3 DAMs Planned, 0 DAMs Executed, 3 DAMs self-mitigated, 0 DAMs approved and waived-off
3 Routine maneuvers rescheduled (Tier 4s)

Aura Conjunction Assessment Statistics

(September 2005 thru December 2014)

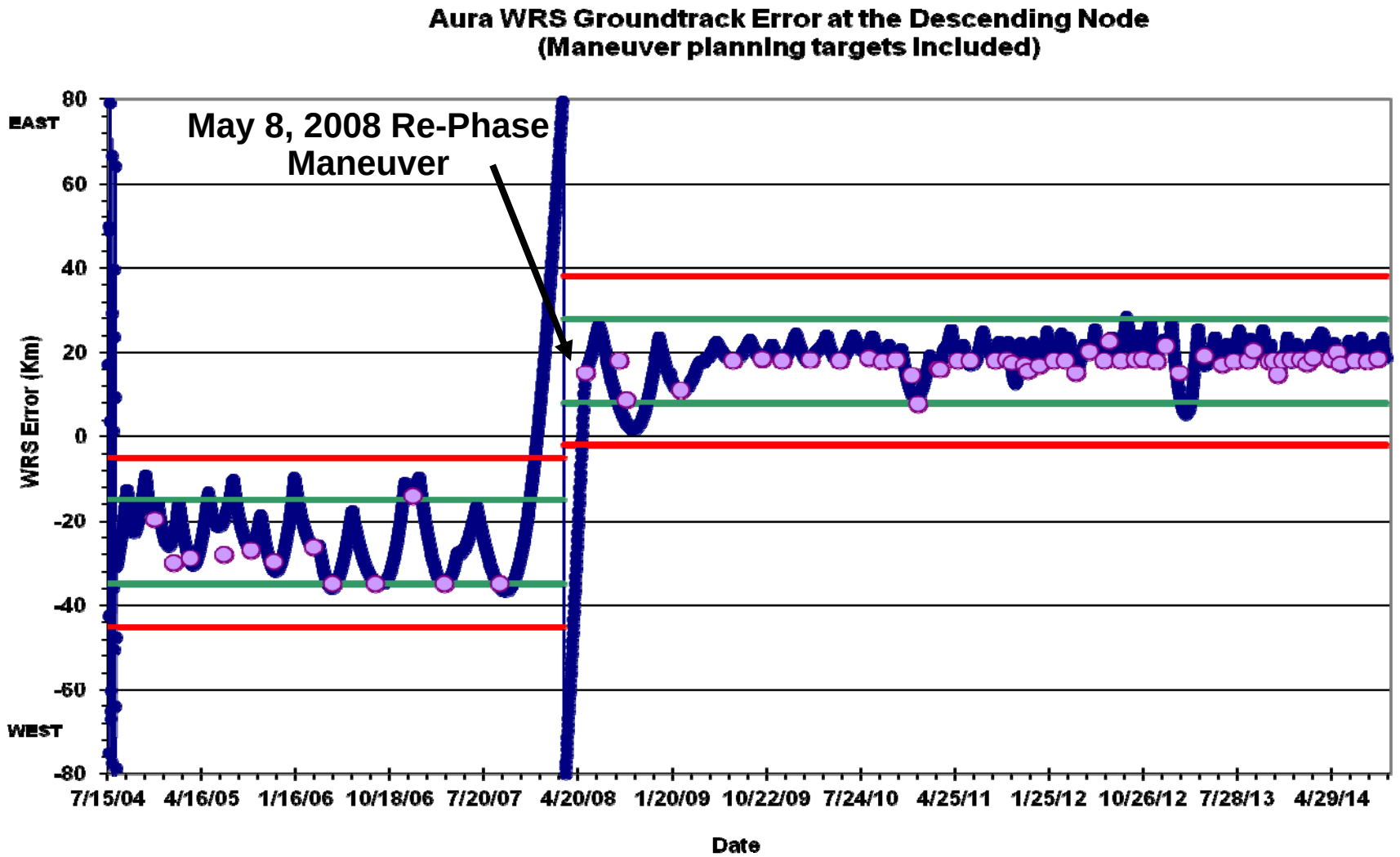


5 to 6-fold increase in the number of conjunctions

CREDIT: CARA Team & Ryan Frigm

WRS Ground Track Error (GTE)

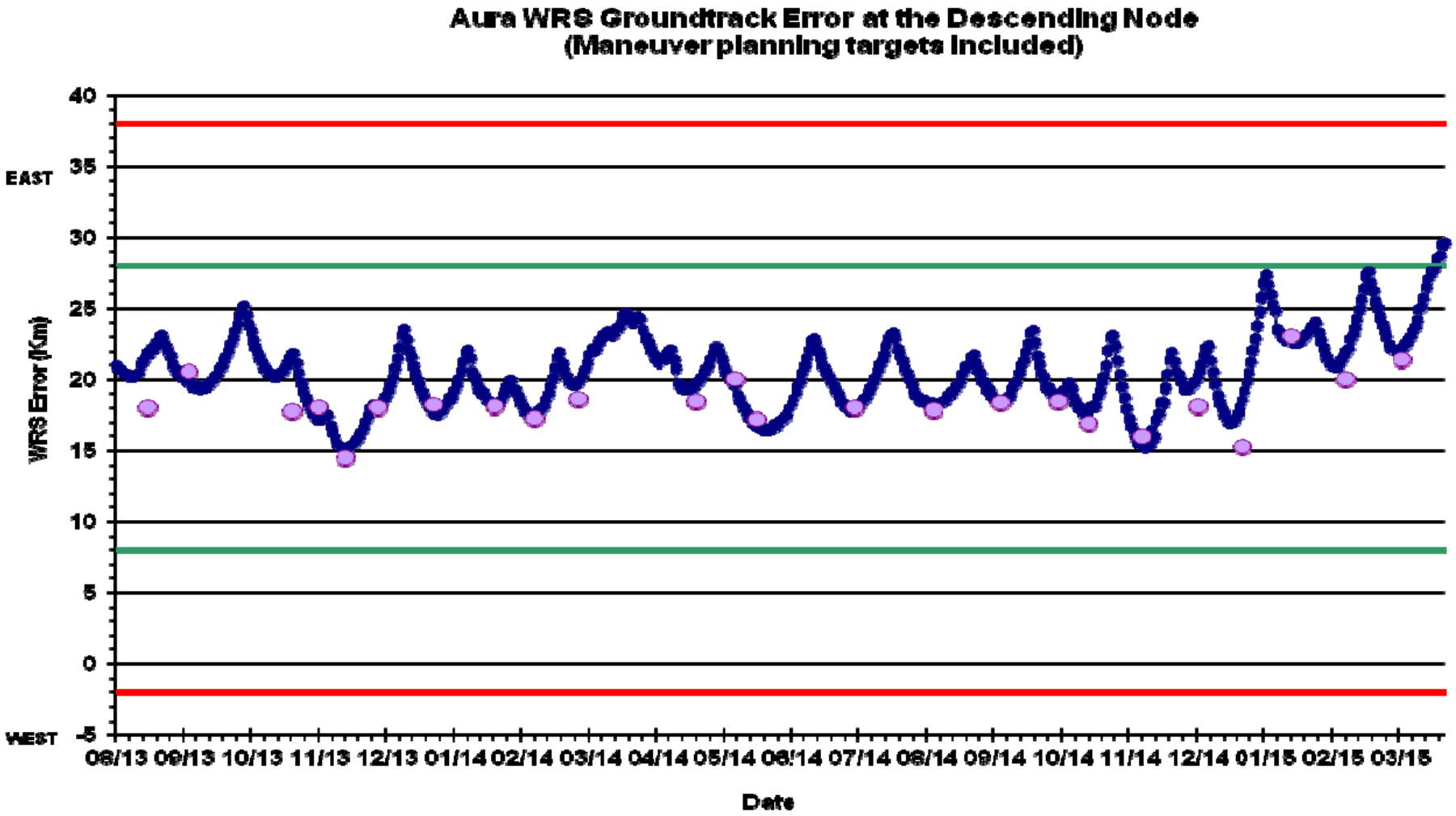
(As of March 2015)



WRS Ground Track Error (GTE)

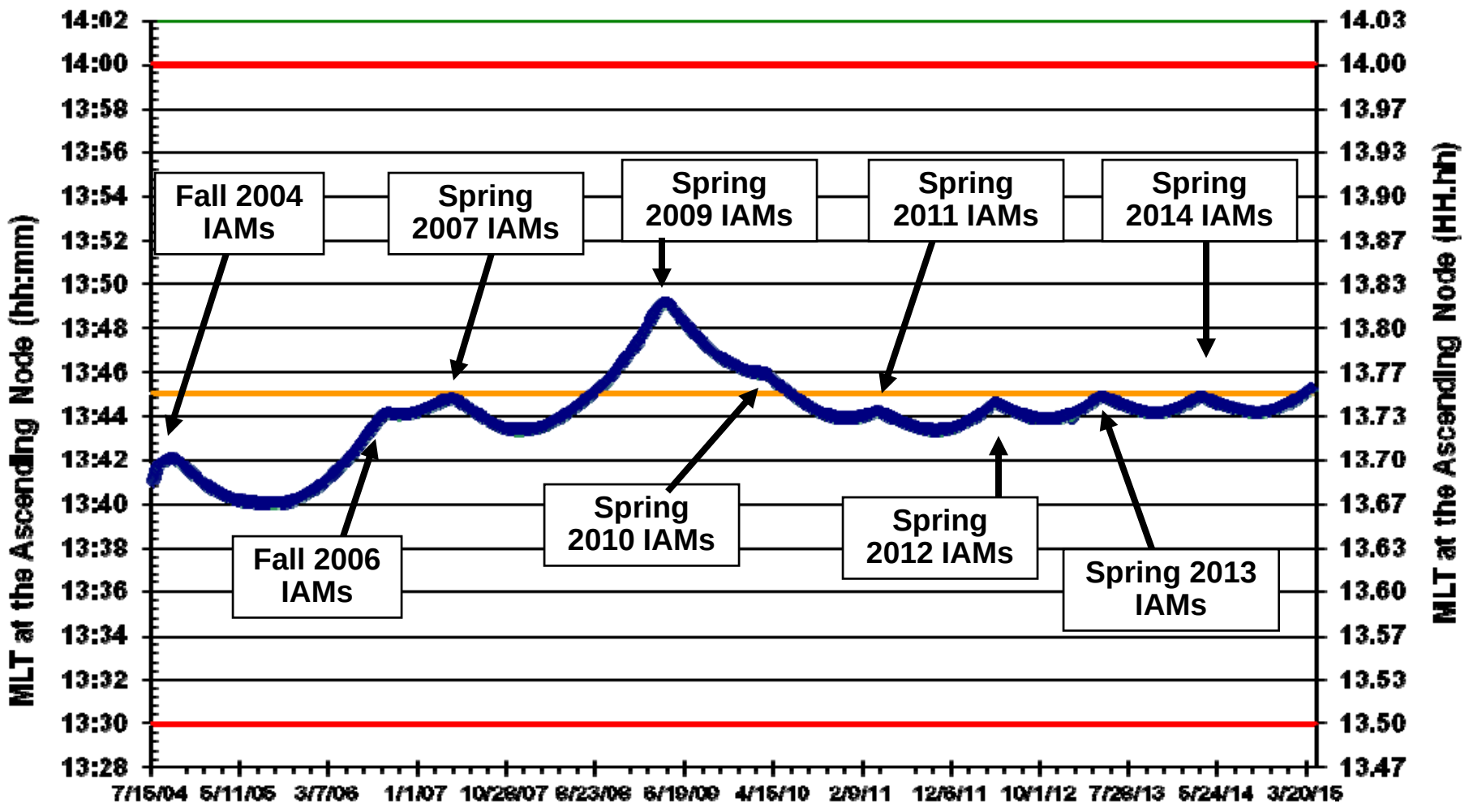
(As of April 8, 2015)

DMUM #79 CAM



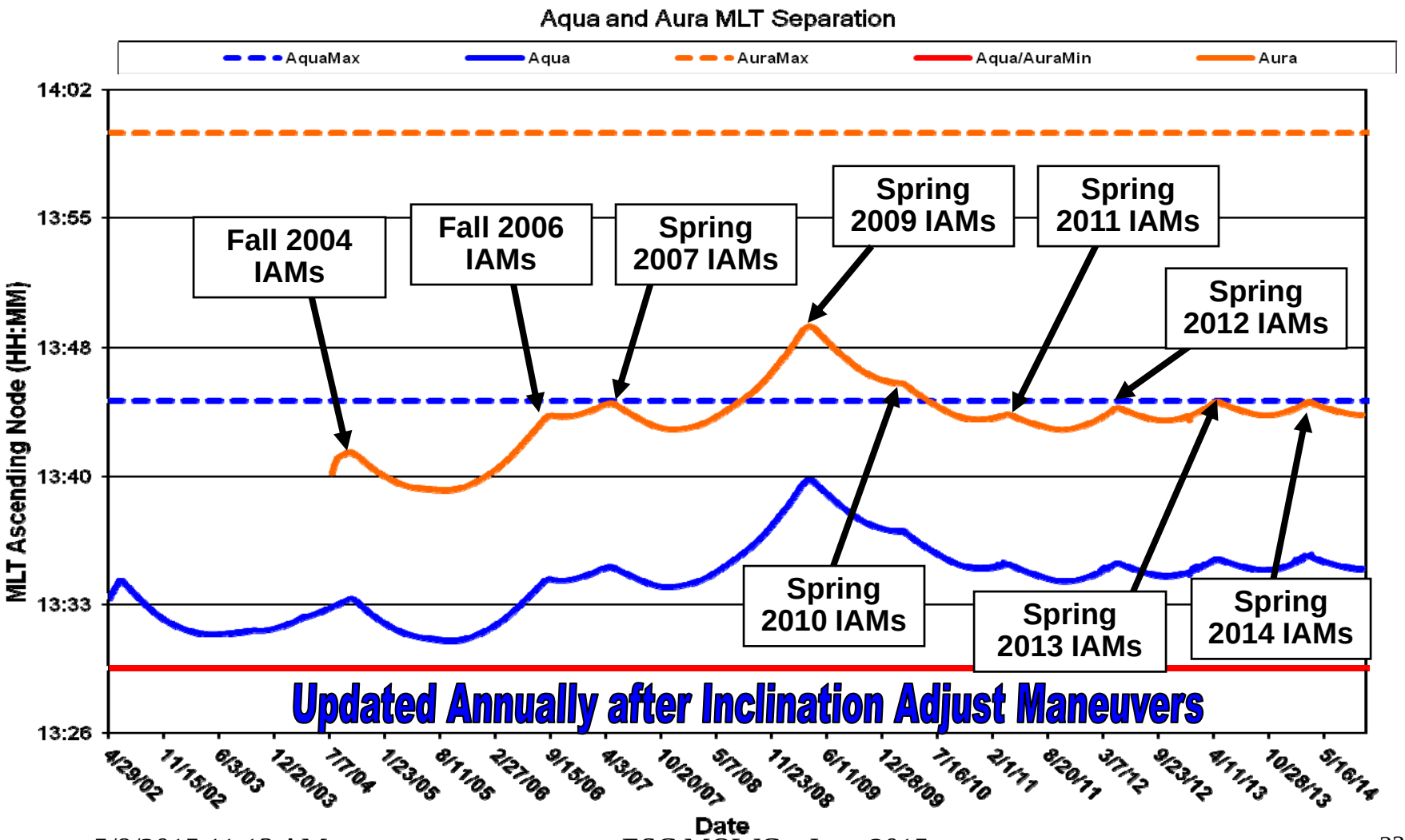
Aura MLT @ Ascending Node

(As of March 2015)



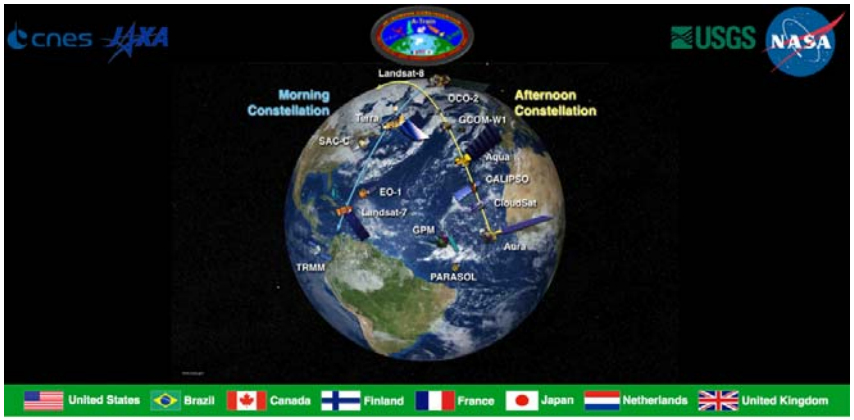
Aqua/Aura Mean Local Time (MLT)

@ Ascending Node



Inclination/MLT Maintenance

(Results and Long-Term Plan)



International Earth Science Constellation
Mission Operations Working Group
June 02-05, 2015

Aqua and Aura Results from Spring 2015 IAM Campaign

Avery C. Ruèl & David A. Tracewell
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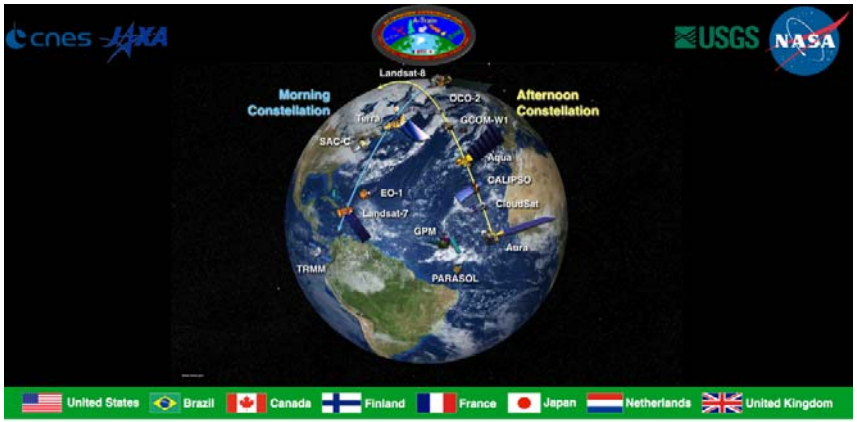

International Earth Science Constellation
Mission Operations Working Group
Jun 2-4, 2015

Aqua and Aura 2015 MLT Prediction Changes

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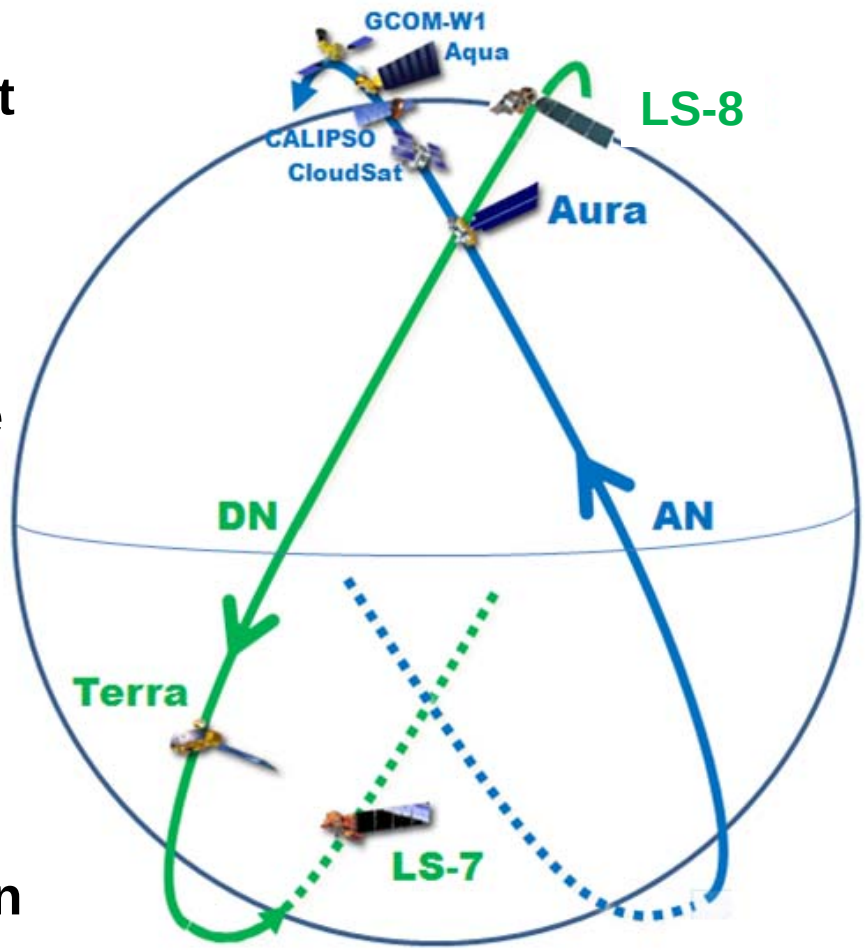
Aura and Landsat-8 (LS-8) Orbit Phasing

With Aura in the intersection point LS-8 will be ~ 77 seconds away from the intersection Point worse case

Typically 420 – 480 seconds

Terra ~ 30 min behind LS-7

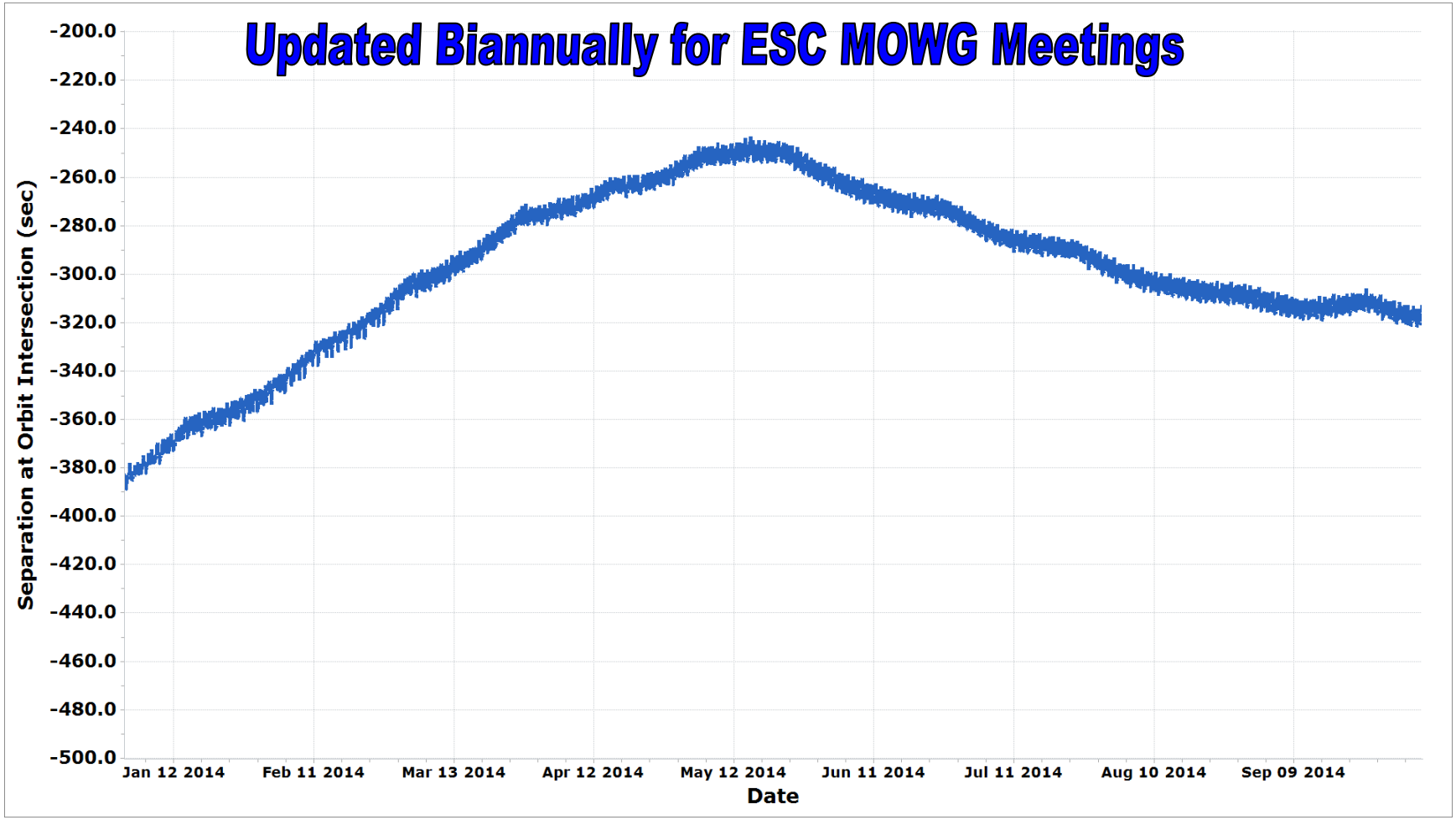


1 Orbit = ~ 100 minutes

By Design – LS-8 and LS-7 are ½ orbit apart

LS-8/Aura Phasing at Poles

@ Northern Intersection Point



Questions