

EOS Aura Science Team Meeting

Pasadena, California

August 27th – 29th, 2019

Mission Operations Working Group (MOWG) Report to the Aura Science Team

Presented by Dominic M. Fisher,
Aura Mission Director (GSFC – ESMO - Code 428/584)

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Aura Mission Operations Working Group (MOWG)

The MOWG, established in 1997, is dedicated to ensuring the health and safety of the Aura satellite (spacecraft bus and instruments) to enable science observations.

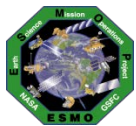
22 years of collaboration between the various Ops teams!



2019 Aura IOT/FOT MOWG Meeting Attendees



**August 27, 2019
Pasadena,
California**

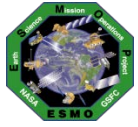


2019 Aura IOT / FOT MOWG Meeting (August 27th, 2019)



<u>Name</u>	<u>Affiliation</u>
Dominic Fisher	Aura MD / ESMO / GSFC
Bill Guit	Aqua MD / ESMO / GSFC
Chuck Hudson	Aura FSM / EOS / GSFC
Jacob Williams	Aura Instruments / EOS / GSFC
Mirna van Hoek *	OMI IOT Lead / KNMI
Nico Rozemeijer	OMI IOT / KNMI
Quintus Kleipool	OMI Calibration / KNMI
Richard Lay	MLS & TES PM / JPL
Ryan Fuller	MLS IOT / JPL
Carl Martin	EOS Support / NGAS
Elena Trenholme	Aura FDS / EOS / GSFC
Tiffany Hoerbelt	FDS Lead / ESMO / GSFC
Ava Afghahi *	Aura GNC / EOS / GSFC
Ricky Burcat *	Aura GNC / EOS / GSFC
Joshua Bowman *	Aura GNC / EOS / GSFC
Mike Stoddard *	OMI IAM Lead / NGAS

* Remote Support



Aura IOT / FOT MOWG

Key Meeting Objectives



- **Discuss current Aura spacecraft and instrument status**
- **Highlight any performance trends of note and project any impacts to continued operations**
- **Identify any operational changes that may be needed to ensure continued Aura operations**
- **Express any concerns or potential process improvements (i.e., any interface / ground system issues)**
- **Discuss future Aura spacecraft and instrument plans (i.e., A-train exit plans)**
- **Discuss preparations for 2020 Senior Review**

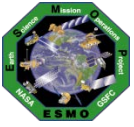


Aura IOT / FOT MOWG Meeting Agenda

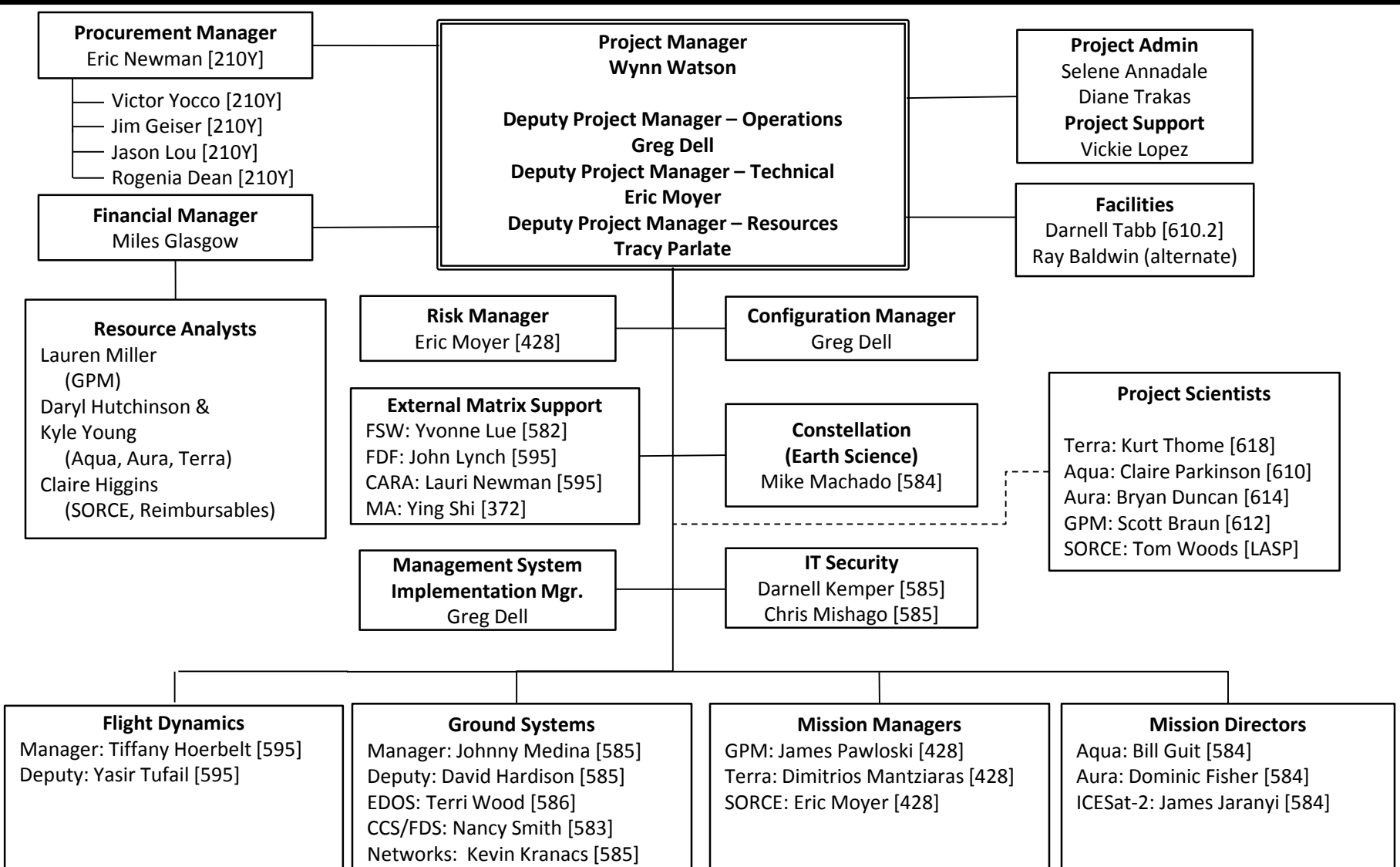
(August 27, 2019)

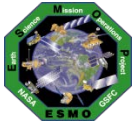


Time	Topic	Presenter
01:30	Welcome / Introduction	Fisher / All
01:35	GSFC ESMO Updates	Fisher
01:40	Aura Mission Status	Fisher
01:50	Aura Spacecraft / EOS Ground System Status	Hudson
02:10	EOS FDS Status	Trenholme
02:30	NGAS EOS Support Status	Martin
02:50	MLS Instrument Status	Fuller
03:10	BREAK (*Group Photo*)	
03:20	OMI Instrument Status	Van Hoek
03:40	TES Instrument Status (including Special Topic: Laser Testing Results)	Lay
04:00	Summary / Review Actions	All



ESMO Organization





Aura Spacecraft Subsystems



- **Command & Data Handling (CDH) – Nominal**
 - **Formatter Multiplexer Unit (FMU) / Solid State Recorder (SSR) Anomaly**
 - » Initial symptoms occurred December 4-18, 2007
 - » Newest symptoms started in January 2017 and remain active (impacting S-Band HK data capture)
- **Communications (COMM) – Nominal**
 - **Transmitter-B Reflected Power Anomaly (10/17/17, 01/05/18)**
- **Electrical Power System (EPS) – Nominal**
 - **Array Regulator Electronics (ARE) Anomalies:**
 - » *Solar Panel Connector Anomaly – ARE-3C (01/12/05) – loss of ~11 strings*
 - » *MMOD Strike – ARE-5A (03/12/10) – loss of ~6 strings*
 - **ARE Degradation (due to aging):**
 - » *ARE-5C (9/27/12, 2/4/13), ARE-1A (3/12/10, 11/5/11), ARE-5A (4/25/13), ARE-6A (9/14/13), ARE-4A (9/23/14, 12/8/14), ARE-1C (7/14/17, 12/22/17), ARE-2C (8/18/17)*
 - » *Estimated that Aura has lost 29 strings of solar cells out of a total of 132 strings (~78.0% remain)*
 - » *Aura continues to have significant power margin where the life limiting item is fuel*
- **Flight Software (FSW) – Nominal**
- **Guidance, Navigation & Control (GN&C) – Nominal**
- **Propulsion (PROP) – Nominal**
- **Thermal Control System (TCS) – Nominal**

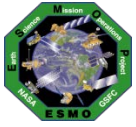
All subsystems configured to primary hardware



Summary of Activities (2019)



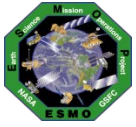
- **0 Spacecraft Bus Anomalies**
- **2 Instrument Anomalies**
 - **0 OMI Anomalies**
 - **2 MLS Anomalies**
 - » 1 Survival Mode Transition (01/27/19, recovered on 01/31/19)
 - TMON 19 (Stale Telemetry Monitor) triggered while in SAA region – same as July 2018 event
 - » 1 Receiver 2 Anomaly (07/18/19, recovered on 07/24/19)
 - 190 GHz R2 Receiver signal chain anomaly - identical to the occurrence in October 2012
- **13 Spacecraft Maneuvers**
 - **9 Drag Make-up Maneuvers (DMUMs # 118 – 126)**
 - » Routine: 01/17/19, 02/07/19, 04/17/19, 05/08/19, 05/30/19, 06/26/19, 07/18/19, & 08/15/19; Debris Avoidance Maneuver (DAM): 03/19/19
 - **4 Inclination Adjust Maneuvers (IAMs #59, #60, #61, #62)**
 - » IAM series completed successfully on 03/06/19, 03/13/19, 04/03/19, & 04/10/19
 - » First series to utilize the new reaction wheel yaw slew approach, instead of thruster based
 - » IAM #59 performance was ~12% COLD due to using simulated reaction wheel inputs
 - » Continue to observe degraded propulsion system performance
- **1 Instrument Calibration Maneuvers**
 - **MLS Yaw & Moon Scan #14 (03/22/19)**



Summary of Activities (2019)



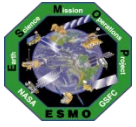
- **9 High Interest Orbital Debris Events (As of 07/31/19)**
 - 8 required planning and screening maneuver options (Tier 3)
 - 1 required executing a Debris Avoidance Maneuver (DAM) (Tier 4)
 - » Aura vs. 87932, TCA on 03/20/2019 @ 03:17:19 GMT
- **Partial Government Shutdown (12/22/18 – 01/25/19, 35 days)**
 - Postponed Aura Decommissioning Peer Review (*DRAFT*), Aura Science Team Meeting, ESMO Annual Review, CARA Devolution, Service Management Legacy Adapter Replacement Testing
- **TES Post-Decommissioning [Laser End-of-Life (EOL) Testing]**
 - TES decommissioning activities completed back on 01/31/18
 - Phase 1 Testing – 6-weeks of tests back in June & July 2018
 - Phase 2 Testing (ongoing) - Round 1 (November 2018) & Round 2 (April 2019)
- **CARA Devolution (Shifting Conjunction Assessment over to Mission Operations)**
 - Worked through updating documentation (MOU, Ops Con, Test Plan, etc.)
 - Continuing with Parallel Operations – working through planned success criteria
 - » CARA Devolution TRR held on 03/25/19; Parallel Ops started on 03/26/19



Summary of Activities (2019)



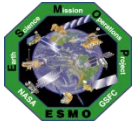
- **Aqua / Aura Maneuver Working Group**
 - Thruster Performance Degradation Investigation
 - Aqua RWA IAM Development
 - Aqua/Aura IAM Planning
 - Develop Retrograde Maneuver Capability for Aqua/Aura
- **Earth Science Constellation (ESC) Mission Ops Working Group (MOWG)**
 - Last Meeting: June 5th – 7th, 2019 @ Toulouse, France
 - Next Meeting: December 3rd – 5th, 2019 @ Gilbert, AZ
 - Present Aura Mission Status to the other member missions
 - Include updated lifetime and decommissioning plans
- **TrollSat Ground Station certification**
 - Mitigating potential scheduling conflicts with OCO-2 (Norway antennas)
 - Building off of successful testing that occurred in 2012 (X-Band downlink only)
 - EDOS has existing hardware to capture and deliver science data (SMAP)
 - FOT is identifying and developing ground system updates to accommodate



Upcoming Planned Activities

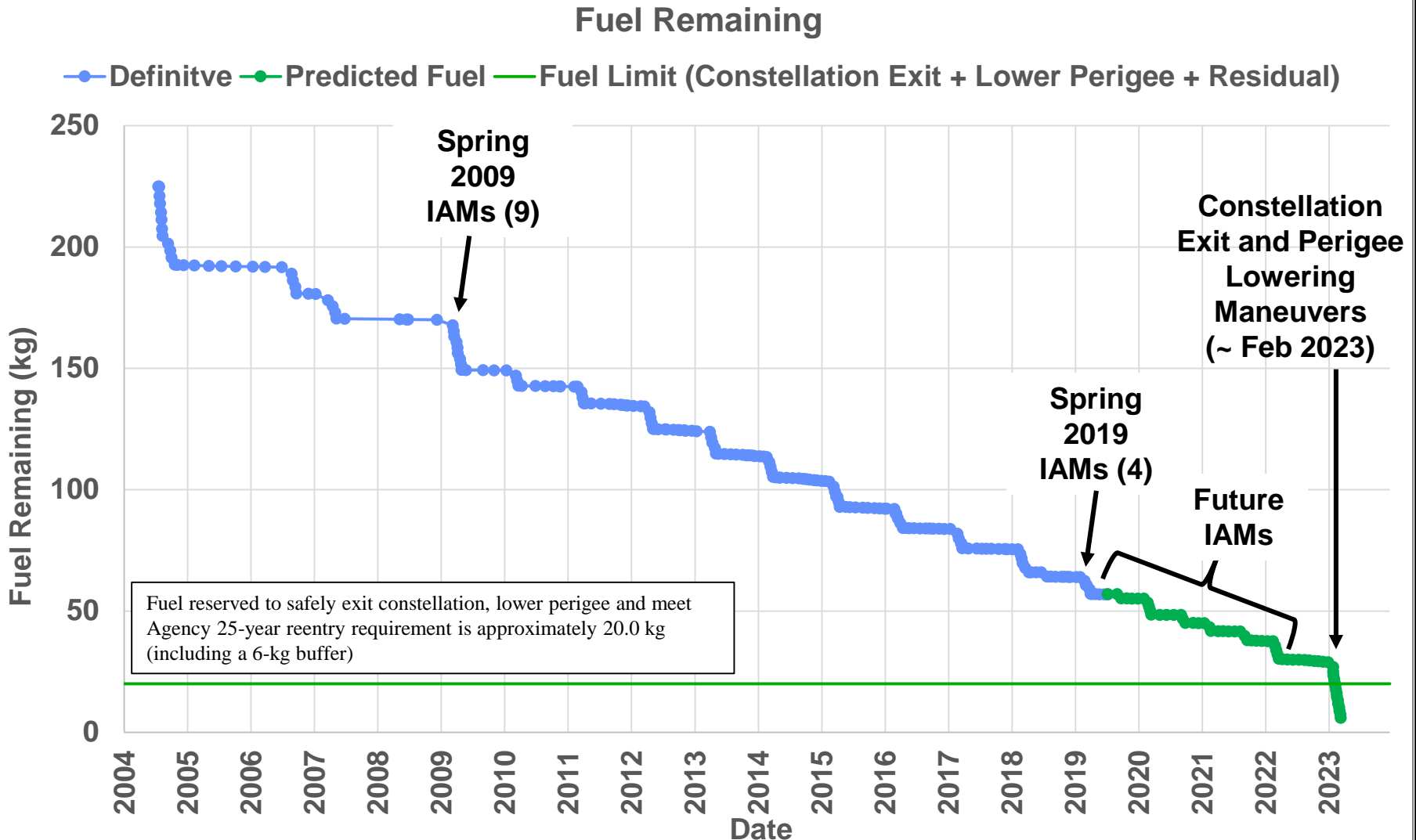


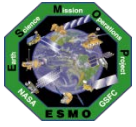
- **Aqua/Aura Maneuver Working Group:**
 - Continue Thruster Degradation Investigation
 - Aqua RWA Test Maneuver (#1) – November 2019
- **EOS Automation (EA) – automation of routine operations**
 - » EA Phase 3.3 – Fall 2019
- **Conjunction Assessment (CA) - continue to improve DAM execution**
 - » Complete parallel operations pilot program between ESMO / CARA – Fall 2019
- **October 2019: Fall Inclination Adjust Maneuver (1) – 10/03/19 (#63)**
- **December 2019: Earth Science Constellation (ESC) MOWG (Gilbert, AZ)**
 - Update propellant budget, decommissioning analysis, reliability predictions, etc.
- **January 2020: ESMO Annual Review #13**
- **March 2020: Senior Review Proposal submission**
- **March 2020: Spring Inclination Adjust Maneuvers (4)**
 - 3/4/20 (#64), 3/11/20 (#65), 3/18/20 (#66), 3/25/20 (#67), 4/1/20 (B/U)
- **Summer 2020: Earth Science Constellation (ESC) MOWG (TBC)**
 - Update propellant budget, decommissioning analysis, reliability predictions, etc.



Fuel Usage: Actual & Predicted

(Baseline Fuel Plan – Analysis Updated August 2019)

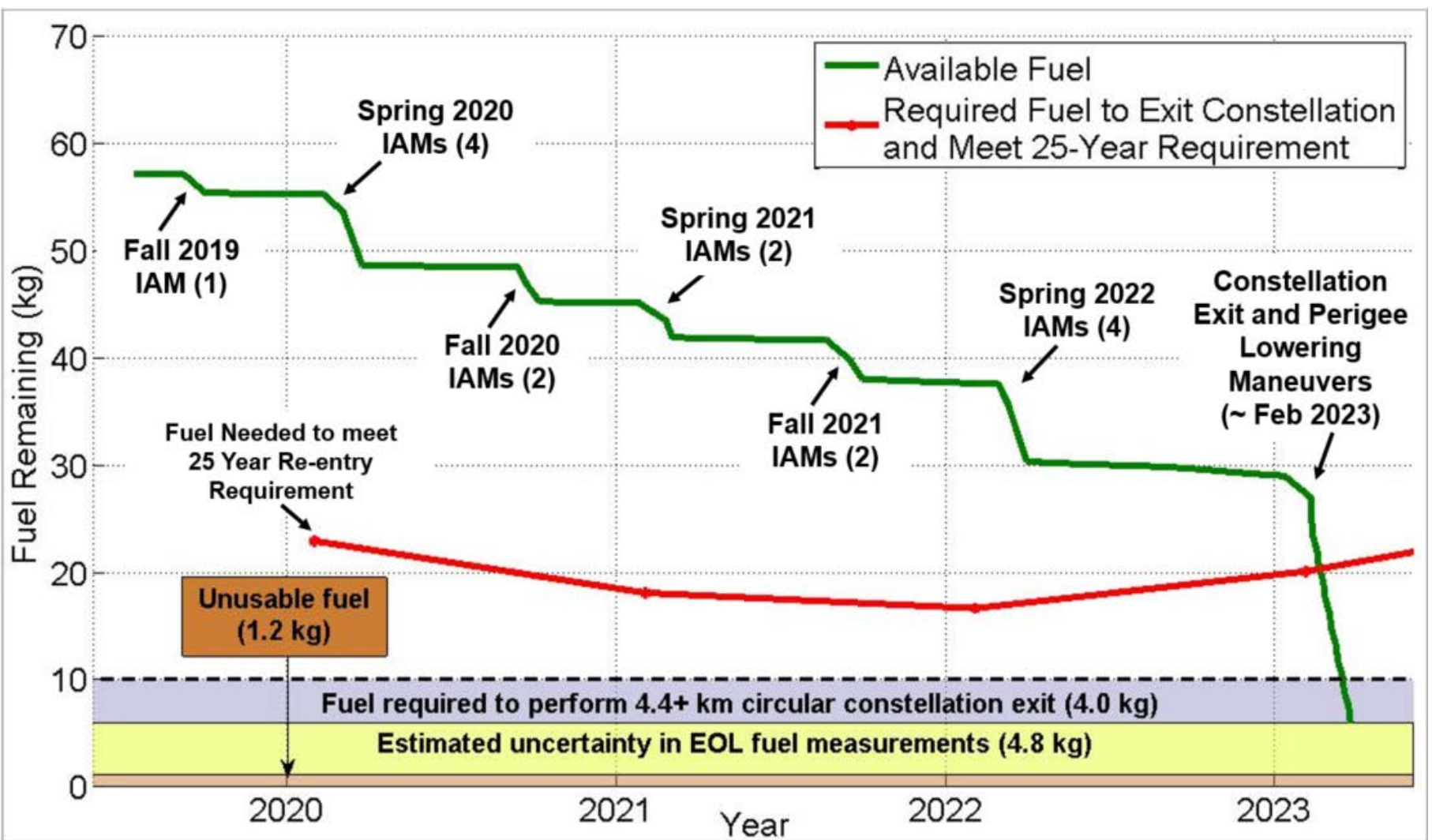


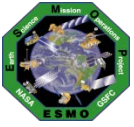


Aura End of Life Predictions



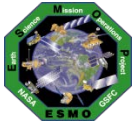
(Baseline Fuel Plan – Analysis Updated August 2019)





Overall 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)
 - » 06/04/2018: 118 GHz Receiver-1A (R1A) Anomaly (Recovered 06/11/18)
 - » 06/20/2018: GHz Mirror Electronics (GME-B) Anomaly (Recovered 06/26/18)
 - » 07/10/2018: MLS Survival Mode Transition (Recovered 07/18/18)
 - » 10/25/2018: GHz Mirror Electronics (GME-B) Anomaly (Recovered 10/25/18)
 - » 01/27/2019: MLS Survival Mode Transition (Recovered 01/31/19)
 - » 07/18/2019: 190 GHz Receiver-2 (R2) Anomaly (Recovered 07/24/19)
 - OMI: Operating Normally
 - » 07/30/2018: OMI IAM Warm Restart (Recovered 07/31/18)
 - TES: Instrument Decommissioned on 01/31/18
- **Data Capture/L0 Processing Status – GREEN**
 - SSR Data Capture to 07/31/19: 99.99505737%
- **Ground Systems – GREEN**
 - Responding to new security requirements and upgrades to obsolete hardware or COTS systems, as required
 - 12/18/2018: Online (Eclipse) Build 21.01 ORR
 - 02/06/2019: EOS Automation (EA) Release 3.2.2 eORR



Flight Operations Team (FOT) Status



- Data Capture Rates continue to be stellar (+99.99%)
- 1 Data Loss (Ops Error) this year; first in +6 years
- Spacecraft risks remain stable with FMU/SSR anomaly recovery remaining the top risk
- Continue to review any outdated Operations Agreements with IOTs
- Reviewing draft Instrument Safe / Survival SOPs with IOTs
- FOT capturing routine instrument activities in standard operating procedures
- TES Decommissioning completed in January 2018
- Maneuver development efforts to utilize the reaction wheels is a priority (IAMS / Retrograde)

Project Overview / Objective

Aura Features
Launch Date: July 15, 2004 (Delta, VAFB)
Orbit:
192 km alt
88.2 Incl
1:47 PM
Instrument P
HIRDLS
LIN - OBS
MIS - M
OIDS - O
TES - T
Project Man
Spacecraft P
ASDC, Aeron
Instrument O
Mission Durr
Begin on 7/15

EOS-Aura 2015 Summary

EOS-Aura 2016 Summary

Aura 2015 Spacecraft Risk Matrix

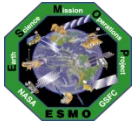
Aura 2015 Spacecraft Risk Matrix Details

Aura Staffing

Position	Prime	Back-Up
FSM	Charles Hudson	Benee Durham
CDH	vacant	Jason Webber
COMM	Christopher Thompson	Christos Galitsatos**
EPS/TCS	Christos Galitsatos**	Samuel Lewis**
FSW	Cara Smith	Mike Cabrera
GNC	Samuel Lewis**	Samuel Lewis**
	Damien Rogier	Damien Rogier
	Joshua Bowman	Joshua Bowman
INST	Jacob Williams	Byron Graves

**Tri-Mission Certified

All positions have identified back-up ready to support on-call duties if required



MLS Instrument Operations Team (IOT) Status



EOS MLS Contact Information

	Office	Cell Phone	Home Phone	Email Address
Devon Meyer Operations Team Lead	310 84-4800	310 465-0070	NA	devonm@jpl.nasa.gov
Marcus Robinson Lead Operations Team	310 84-4807	310 467-2107	(310) 967-7076	mrc@jpl.nasa.gov
Mark Morley Operations Team	310 84-2884	310 444-8916	NA	markm@jpl.nasa.gov
Robert Janel Instrument Specialist	310 84-4284	310 465-8286	NA	robjanel@jpl.nasa.gov
Ron Collins ML FSW Specialist	310 84-4281	NA	NA	ronc@jpl.nasa.gov
Eric Melnick Project Manager	310 84-4800	408-428-6200	(310) 352-0776	ericm@jpl.nasa.gov
Wesley Lutz Principal Investigator	310 84-4284	310 218-0504	NA	wslutz@jpl.nasa.gov

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- MLS GHz mechanisms continue to operate within their nominal range
- AAA continues to exhibit excellent performance
- MLS THz mechanism has had limited periods of operation, THz is currently in stand-by mode
- Significant events have included Moon Tracks #13, Survival Recovery, and R2 Anomaly
- Continue with MLS routine and calibration activities
- Next Moon Track (#14) targeted for March 2020
- Next THz OH measurement targeted for TBD
- Monitor R2 voltage, adjust if needed



OMI Instrument Operations Team (IOT) Status



- There have been 0 anomalies in 2019; compared to 3 anomalies in 2018 (only 6 since launch):
 - No OMI-IAM warm restarts around the SAA in 2019
 - No impact on science quality
- Instrument performs nominally (with exception of row anomaly)
- CCD temperatures are very stable
- All three mechanisms behaving nominally
- Life limited items (mechanisms, internal calibration source) still within budget
- Instrument degradation is very slow
- >99% of all measurements are according to Nominal Operations Baseline

Overall current status

Instrument Status

Survival Mode anomaly: Impact on science

Spacecraft Status

FMU anomaly

Operations Status

General

Conclusion

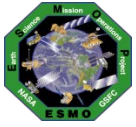
- The instrument status is very good
- The instrument degradation is very slow
- No issues (except for the row anomaly)
- Science data is of very high quality

OUTLOOK

The Instrument Operations Team expects to operate the instrument without any problems for the next coming years.

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AURA MOWG, Rotterdam, 31 August 2016



TES Instrument Operations Team (IOT) Status



• Candidate cause is single event upset in ICS controller and encoder read back resulting in control drive response

 - Multiple Stalls have occurred since late July

 • The established TES ICS recovery procedure has been able to restore full travel in each of these recent cases within 36 hours

 - Prior Stall in 2016 was in January

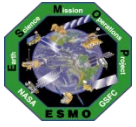
 • Again the TES ICS recovery procedure restored full travel was restored within 24 hours

 - Stalls occurring 2015 were in August (2) and November (1)

 • In each case the standard TES ICS stall recovery process was successful

 The slide also includes logos for NASA Jet Propulsion Laboratory and JPL at the bottom."/>

- TES decommissioning activities completed back on 01/31/18
- Continue to perform TES Post-Decommissioning [Laser End-of-Life (EOL) Testing]
- Phase 1 Testing – 6-weeks of tests back in June & July 2018
- Phase 2 Testing (ongoing) - Round 1 (November 2018) & Round 2 (April 2019)
- Phase 2 Testing Round 3 planned for October 2019

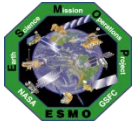


Aura MOWG Meeting Action Items



Action Items Captured

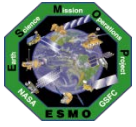
Review / Update Operational Agreements (OAs) (due Spring 2020)	FOT / IOTs
Update Safe / Survival Mode Standard Operating Procedures (SOPs)	FOT / IOTs
Prepare for 2020 Senior Review Proposal (Draft inputs due January 2020)	FOT / IOTs



Summary

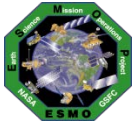


The Mission Operations teams, both flight and instrument, are dedicated to keeping Aura operational for as long as possible



**Thank You
Dank Je Wel
Kiitos**

Questions?



Back Up Slides



Abbreviations / Acronyms List



ARE –	Array Regulator Electronics	GME -	GHz Mirror Electronics	MOWG –	Mission Operations Working Group
A-Train -	Afternoon Constellation	GNC –	Guidance Navigation & Control	NASA –	National Aeronautics & Space Administration
CARA –	Conjunction Assessment Risk Analysis	GPM -	Global Precipitation Measurement	NGAS -	Northrup Grumman Aerospace Systems
CCD -	Charge Coupled Device	GSFC –	Goddard Space Flight Center	OA -	Operations Agreement
CCS -	Constellation Coordination System	HIE –	High Interest Event	OMI –	Ozone Monitoring Instrument
CDH –	Command & Data Handling	HIRDLS –	High Resolution Dynamics Limb Sounder	ORR –	Operational Readiness Review
COMM -	Communications	HK -	Housekeeping	PROP -	Propulsion
COTS -	Commercial-off-the-Shelf	HQ -	Headquarters	R1A -	Receiver-1A
DAM –	Debris Avoidance Maneuver	IAM –	Inclination Adjustment Maneuver or Interface Adapter Module	R2 –	Receiver 2
DAM -	Debris Avoidance Maneuver	ICS –	Interferometer Control System	RMM –	Risk Mitigation Maneuver
DMUM –	Drag Make-up Maneuver	IOT -	Instrument Operations Team	RW –	Reaction Wheel
EA –	EOS Automation	IT -	Information Technology	RWA –	Reaction Wheel Assembly
EDOS -	EOS Data & Operations System	JPL -	Jet Propulsion Lab	SAA -	South Atlantic Anomaly
EOL -	End of Life	kg -	kilogram	SMLA-R –	Service Management Legacy Adapter Replacement
EOS –	Earth Observing System	km –	kilometer	SOP -	Standard Operating Procedure
EPR -	Engineering Peer Review	KNMI -	Royal Netherlands Meteorological Institute	SORCE -	SOlar Radiation & Climate Experiment
EPS –	Electrical Power System	L0 –	Level-Zero	SSR –	Solid State Recorder
ESC –	Earth Science Constellation	MA -	Mission Assurance	TCA –	Time of Closest Approach
ESMO –	Earth Science Mission Operations	MD -	Mission Director	TCS –	Thermal Control System
FDF -	Flight Dynamics Facility	MLS –	Microwave Limb Sounder	TES –	Tropospheric Emissions Spectrometer
FDS –	Flight Dynamics System	MLT -	Mean Local Time	TRR –	Test Readiness Review
FMU –	Formatter Multiplexer Unit	MMOD –	Micrometeorite Orbital Debris		
FOT –	Flight Operations Team	MMS –	Mission Management System		
FSM -	Flight Systems Manager	MO –	Mission Operations		
FSW –	Flight Software	MOU –	Memorandum of Understanding		
GHz -	Gigahertz				