



Aura Science Team Meeting

Pasadena, CA

January 22nd – 24th, 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)**

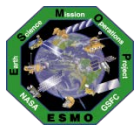
dominic.m.fisher@nasa.gov



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!

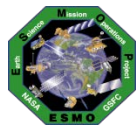


2019 Aura MOWG Meeting

(January 22nd, 2019)



<u>Name</u>	<u>Affiliation</u>
Dominic Fisher	Aura MD / ESMO / GSFC
Chuck Hudson	Aura FSM / EOS / GSFC
Jacob Williams	Aura Instruments / EOS / GSFC
Elena Trenholme	FDS / EOS / GSFC
Carl Martin	NGAS
Gerson Melgar	MLS / JPL
Richard Lay	MLS / TES / JPL
Scott Gluck	MLS / TES JPL
Mirna van Hoek	OMI IOT Lead / KNMI
Quintus Kleipool	OMI Calibration / KNMI

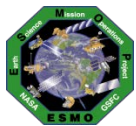


2019 Aura MOWG

Key Meeting Objectives



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

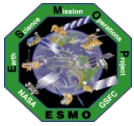


Aura MOWG Meeting Agenda

(January 22nd, 2019)

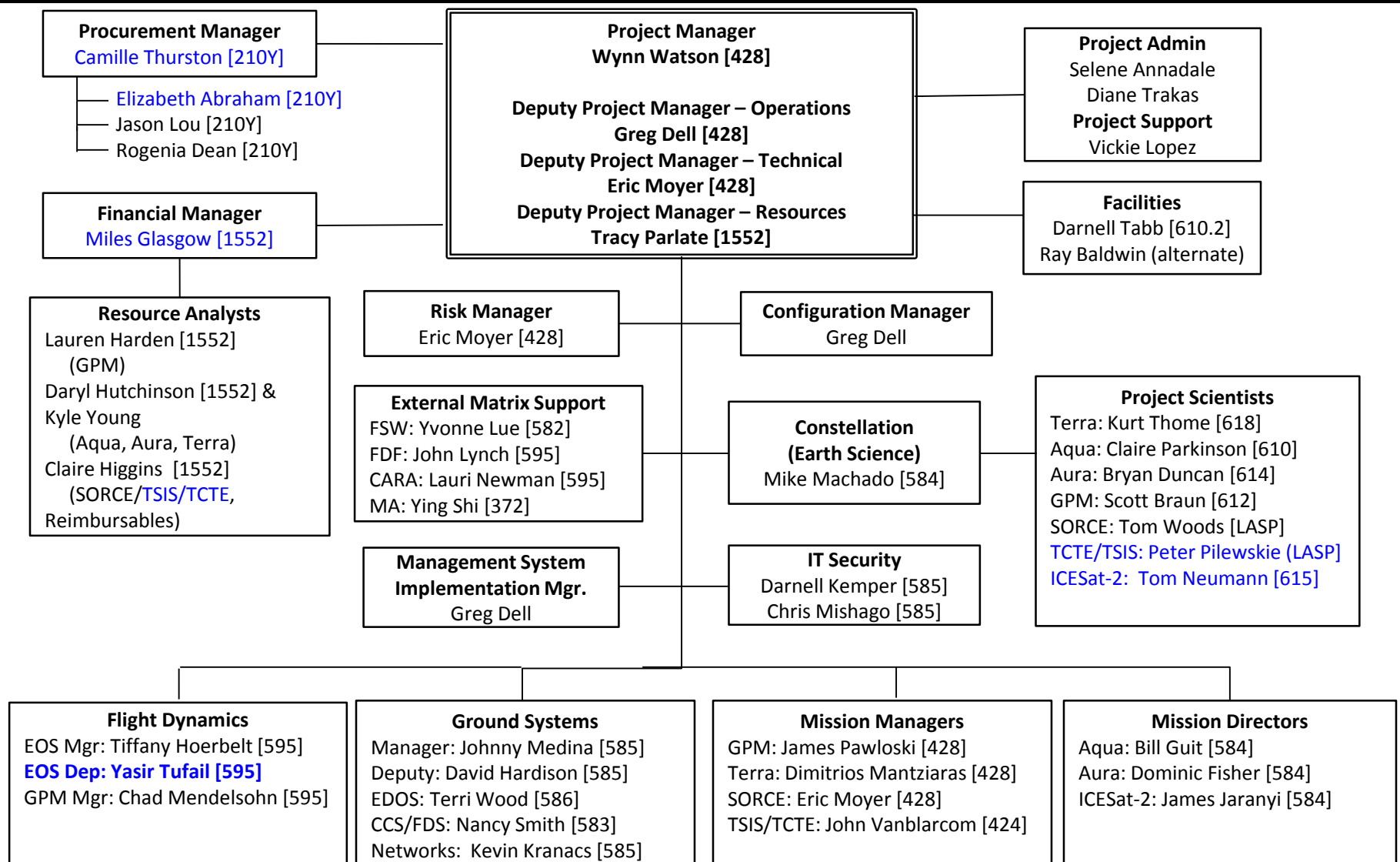


Time	Topic	Presenter
01:30	Welcome / Introduction	Fisher / All
01:35	GSFC ESMO Update	Fisher
01:40	Aura Mission Status	Fisher
01:50	Aura Spacecraft / EOS Ground System Status	Hudson
02:10	EOS FDS Status	Trenholme
02:20	NGAS Support Status	Martin
02:30	MLS Instrument Status	Melgar
02:50	BREAK	
03:10	OMI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



ESMO Organization

(Blue: Changes in 2018)





Aura's 14th Anniversary!



**Launch Date:
July 15, 2004**





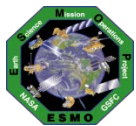
Aura Spacecraft Subsystems

(Blue: Changes in 2018)



- **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 (3/12/10) – 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)*
 - » *Updated analysis of ARE-4A revealed an additional 1 string lost around 9/23/14*
 - » *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

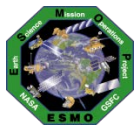


Summary of Activities

(Updates from 2018)



- **1 Spacecraft Bus Anomalies**
 - **COMM: 1 Transmitter-B Reflected Power Anomaly (01/05/18) (2nd occurrence)**
- **9 Instrument Anomalies**
 - **MLS: 1 Mid-Band LO Out-of-Lock Anomaly (02/23/18), 1 R1A Anomaly (06/05/18), 2 GME-B Anomalies (06/20/18, 10/25/18), 1 Survival Transition (07/10/18)**
 - **OMI: 3 OMI-IAM Warm Restart Anomalies (01/02/18, 04/30/18, 07/30/18)**
 - **TES: 1 ICS Stall (01/24/18) prior to instrument decommissioning (01/31/18)**
- **14 Spacecraft Maneuvers**
 - **8 Drag Make-up Maneuvers (DMUMs # 109 – 117)**
 - » 02/14/18, 05/03/18, 05/31/18, 06/28/18, 08/22/18, 09/19/18, 10/23/18, 11/08/18, 12/12/18
 - **6 Inclination Adjust Maneuvers (IAMs # 53 – 58)**
 - » 02/28/18, 03/07/18, 03/14/18, 03/28/18, 04/18/18*, 08/01/18**
 - * IAM #57 was initially planned for 04/11/18, Aqua post-maneuver debris concern
 - ** IAM #58 needed in order to keep phasing, Aqua used IAM to correct large RMM
- **1 Instrument Calibration Maneuvers**
 - **1 MLS Yaw & Moon Scan (#13) (03/03/18)**
- **2 Spacecraft Test Maneuvers**
 - **Reaction Wheel Assembly Yaw Slew Tests (#1b – 01/11/18, #2 – 11/30/18)**

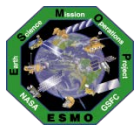


Summary of Activities

(Updates from 2018)



- **16 CARA High Interest Orbital Debris Events (Tiers 1-4) (As of 12/31/18)**
 - **11 required significant action (Tier 3)**
 - **0 required Debris Avoidance Maneuver (DAM); 1 required altering a DMU (Tier 4)**
 - » Tier 1 – Notify, Tier 2 – Briefing, Tier 3 – Plan, Tier 4 – Execute DAM or alter DMU
- **TES Instrument Decommissioning:**
 - **Decommissioning Review @ JPL – 01/18/18**
 - **Instrument reconfigured into decommissioned state – 01/31/18**
 - **Close-out Review & Science Highlights @ NASA HQ – 04/13/18**
 - **TES Laser End-of-Life (EOL) Testing -**
 - » **Phase 1 was approved on 05/14/18**
 - Characterized performance for Laser A & B under varying temps and input current
 - 6-weeks of tests from 06/04/18 to 07/27/18
 - Debrief of Phase 1 testing activities held on 08/07/18
 - » **Phase 2 was approved on 09/25/18**
 - Alternates leaving Laser A or B on for extended durations to characterize performance
 - Initial round of testing occurred on 11/15/18 & 11/16/18
 - Debrief of Phase 2 testing activities to be held during Aura STM MOWG on 01/22/19
 - Next round of testing is planned to occur in April 2019

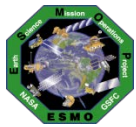


Summary of Activities

(Updates from 2018)



- **Aqua / Aura Maneuver Working Group:**
 - **Aura RWA Slew Maneuver Test (#1b) – 01/11/18**
 - » Yaw slew out to -25° at $0.096^{\circ}/s$ using reaction wheels, mimicking early orbit check-out tests
 - » Corrected RWA maneuver planning tool and wheel caging parameters – nominal performance
 - **Simulations found issues during abort scenario contingencies – mid-January**
 - » RWA Maneuver EPR, RWA Maneuver Test #2, & IAM #56 w/ RWA were subsequently postponed and efforts shifted to focus on 2018 IAM series execution
 - **Picked back up RWA maneuver development efforts after Spring 2018 IAM Series**
 - **Finished simulations for abort scenarios contingency responses – Summer 2018**
 - **Updated FM thresholds to address momentum and attitude errors – Fall 2018**
 - » AFM delivered new FM patch at the end of September 2018
 - » FOT checked out new patch to validate contingency procedures in October 2018
 - **Aura RWA Maneuver Engineering Peer Review (EPR) – 10/24/18**
 - » Independent panel provided concurrence to proceed with planned test maneuver activity
 - » Captured a few questions and actions in preparation for the test activity (no show stoppers)
 - » Presented preliminary plan to perform 2019 Aura IAM Series with RWAs
 - **Aura RWA Test Maneuver #2 – 11/30/18**
 - » Yaw slew out to -76.5° at $0.168^{\circ}/s$ using reaction wheels, mimicking IAM #59
 - » Maneuver timing and performance were as expected, similar to simulations



Summary of Activities

(Updates from 2018)

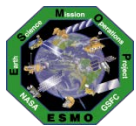


- **Aura Alternate Decommissioning Plan Evaluation**
 - **OMI Science Team Meeting @ De Bilt, Netherlands (3-days) – September 2018**
 - » OMI IOT / FOT MOWG – Meeting held on 09/12/18:
 - » Aura Early A-Train Exit Planning Discussion – Briefed Science Team leadership on 09/12/18
 - **Held splinter discussion with operations and science team about the implications of changing Aura's orbit**
 - **Initial assumptions for the early exit scenario included:**
 - » Full IAM Series through 2019
 - » MLT allowed to drift and Constellation Exit Maneuver (CEM) in May 2020
 - » MLT allowed to continue to drift until October 2025 (approximate MLTAN of 16:30)
 - » Perigee Lowering Maneuvers (PLM) to begin in October 2025
 - » **Note: With updated scheme assumptions have shifted ~1 year to now includes 2020 IAMs**
- **Aura Draft Decommissioning Review (*ESMO Internal Engineering Peer Review*)**
 - Document Phase F spacecraft activities, any new products to be developed for spacecraft / instrument calibration, proposed Engineering Tests, and Passivation Sequence
 - Internal review with ESMO Management – postponed from 01/09/19 – now 03/01/19



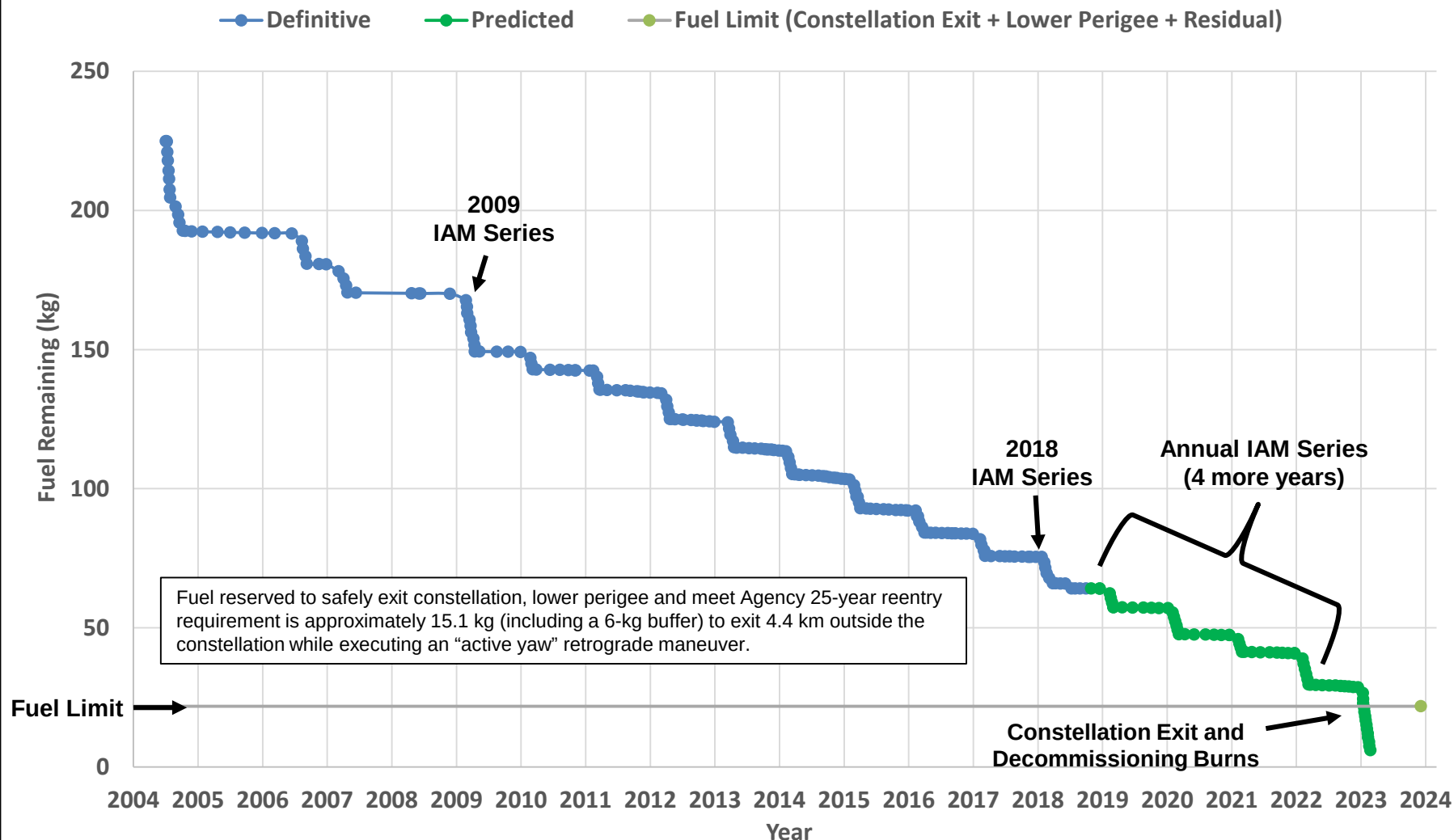
Planned Activities

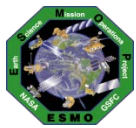
- **Aqua/Aura Maneuver Working Group:**
 - Prepare for 2019 IAM Series – entire series to utilize RWA yaw slew approach – Winter 2019
 - Determine if further test maneuvers are necessary – proposed TM #3 in Summer 2019
 - Continue development of retrograde maneuver capability – throughout 2019
- **Aura Alternate Decommissioning Plan Evaluation (Early A-Train Exit Scenario)**
 - Discuss during Aura Science Team Meeting – January 2019
- **February 2019: ESMO Annual Review #12**
- **March 2019: Annual Inclination Adjust Maneuvers**
 - 3/6/19 (#59), 3/13/19 (#60), 3/21/19 (#61), & 3/27/19 (#62)
- **June 2019: Earth Science Constellation (ESC) MOWG (Location Toulouse, FR)**
 - Update propellant budget, decommissioning analysis, reliability predictions, etc.
- **Summer 2019: EOMP and Decommission Plan (Lifetime Analysis) Updates**
 - Updates will lead into 2020 Senior Review Proposal cycle
- **Mid-to-Long-Term Plans:**
 - **EOS Automation (EA) – automation of routine operations**
 - » Close-out of EA development and continue with FOT scripting enhancements
 - **Continue to improve RMM / DAM execution**
 - » Support ESMO / CARA devolution initiative



Fuel Usage: Actual & Predicted

(Current Baseline Plan – Analysis Updated November 2018)

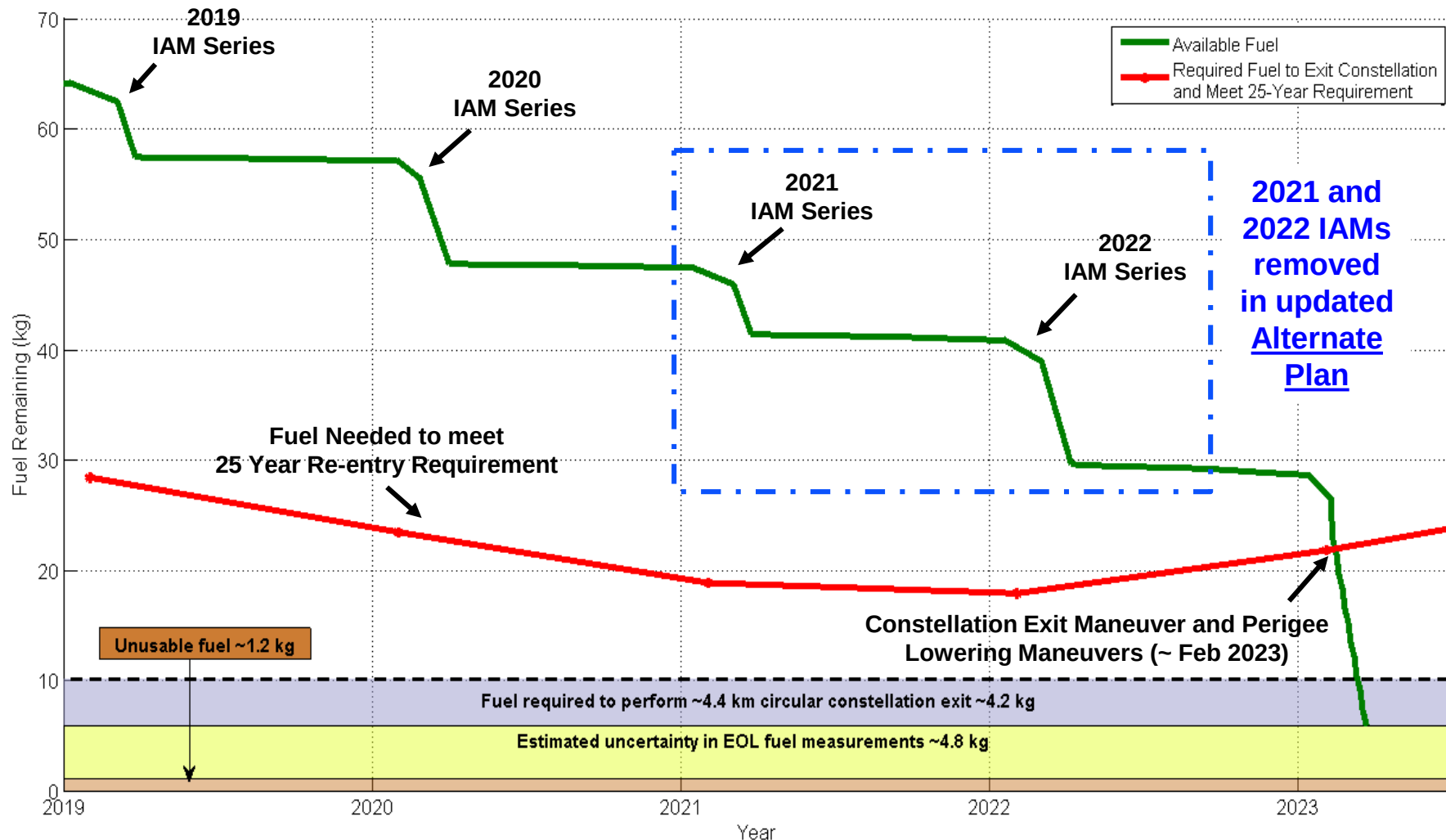


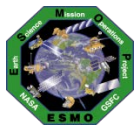


Aura End of Life Predictions



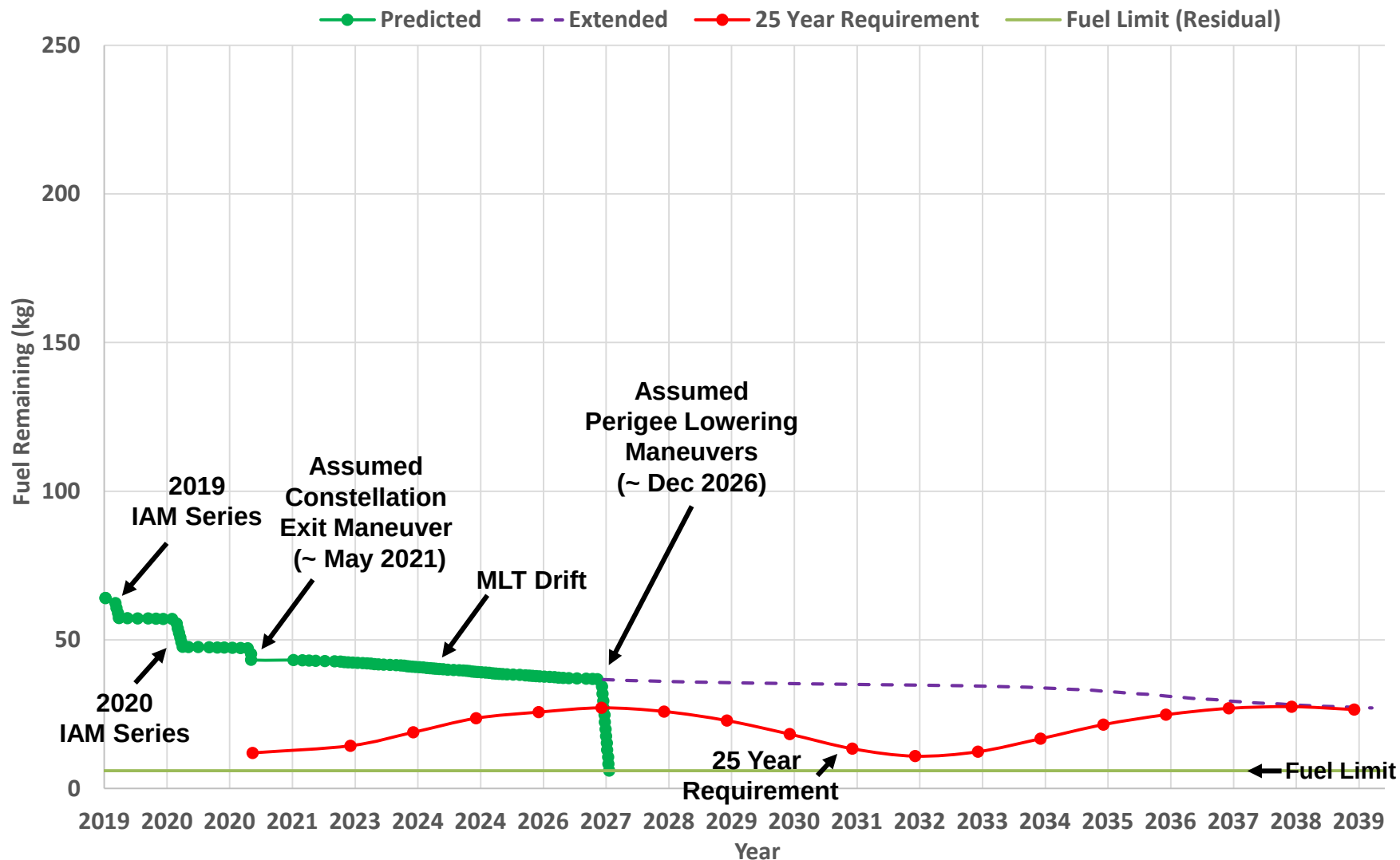
(Current Baseline Plan – Analysis Updated November 2018)

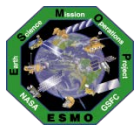




Fuel Usage: Actual & Predicted

(New Alternate Plan – Analysis Updated November 2018)



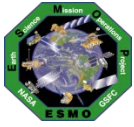


Overall Summary

(Updates from 2018)



- **Spacecraft Status – GREEN**
 - COMM: **Transmitter-B Reflected Power Anomaly (01/05/18) – No active impact**
- **Instrument Status - GREEN**
 - HIRDLS: Chopper Stalled 03/17/08 – Not collecting science data
 - MLS: Operating Normally
 - » 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)
 - OMI: Operating Normally
 - » 01/02/2018: OMI IAM Warm Restart (Recovered 01/03/18)
 - » 04/30/2018: OMI IAM Warm Restart (Recovered 05/01/18)
 - » 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 12/31/18: 99.99598444%
- **Ground Systems – GREEN**
 - 05/01/2018: MMS Build 25.2.0 Transition for Aura
 - 12/18/2018: EOS Automation (EA) Release 3.2 ORR
 - 12/18/2018: Online (Eclipse) Build 21.01 ORR



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 (Dedu, USAF)
Orbit:
192 km alt
REL Incl:
1-47 PM
Instrument P:
HIROLES
LIR - CHS
MLS - M
OAS - O
TES - T
Project Man:
Spacecraft P:
AUX, Aeron
Instrument O:
Mission Days:
Began on 7.15

EOS-Aura 2015 Summary

EOS-Aura 2016 Summary

Aura 2015 Spacecraft Risk Matrix

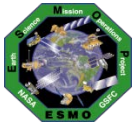
Aura 2015 Spacecraft Risk Matrix Details

Aura Staffing

Position	Prime	Back-Up
FSM	Charles Hudson	Benee Durham
CDH	vacant	Jason Webber
COMM	Christopher Thompson	Christos Galatsatos**
EPS/TCS	Christos Galatsatos**	Samuel Lewis**
FSW	Cara Smith	Mike Cabrera
GNC	Samuel Lewis**	Samuel Lewis**
	Damien Roesler	Damien Roesler
	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



Overview

MLS Instrument Significant Events
Oct. 2015 – Sep. 2016

MLS Close Watch Trends
R4 Receiver LO IF Power Monitor, full mission trend

Trend Updates
Band 12 (N20), full mission trend

Operational Plans

EOS MLS Contact Information

	Office	Cell Phone	Home Phone	Email Address
Jason Meyer	010 5A-400	010 465-0070	NA	jasonm@jpl.nasa.gov
Marcus L. Meyer	010 5A-400	010 465-0070	NA	marcusl@jpl.nasa.gov
Mark Morris	010 5A-400	010 465-0070	NA	markm@jpl.nasa.gov
Robert J. Smith	010 5A-400	010 465-0070	NA	robj@jpl.nasa.gov
Don Coffey	010 5A-400	010 465-0070	NA	donc@jpl.nasa.gov
MLI FOM (Scientist)	010 5A-400	010 465-0070	NA	mlifom@jpl.nasa.gov
Principal Investigator	010 5A-400	010 465-0070	NA	pi@jpl.nasa.gov

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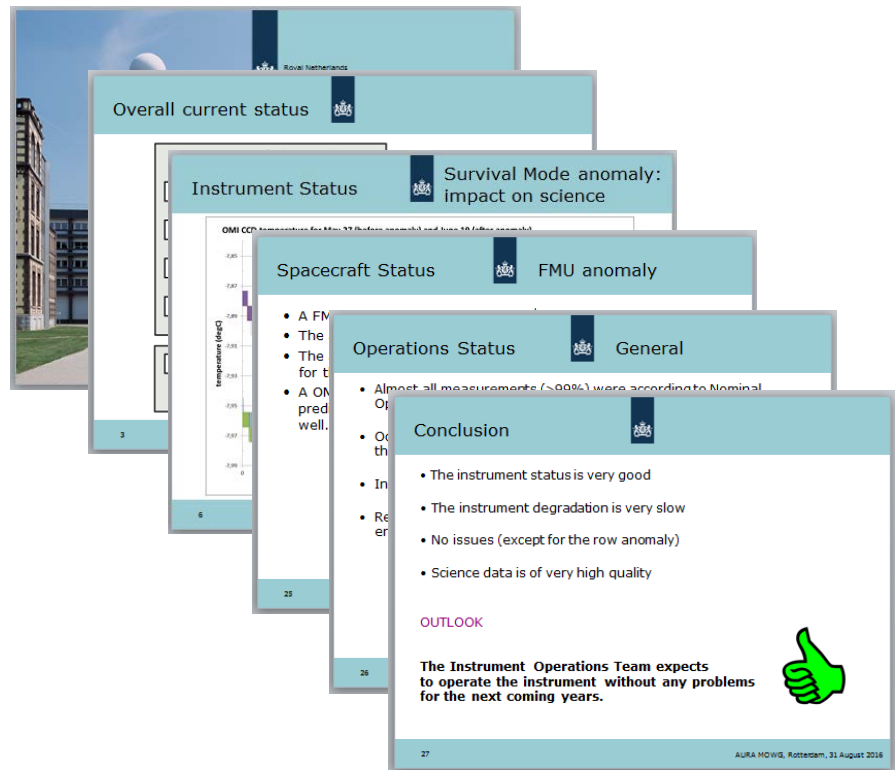
- MLS GHz mechanisms continue to operate within their nominal range
- Outside of GME-B anomalies, AAA continues to exhibit excellent performance
- THz is currently in stand-by mode with potential for one more THz OH measurement
- Significant events since the last STM have included Moon Tracks #12 & #13, attenuation updates, and survival mode recovery
- Continue with MLS routine and calibration activities
- Next Moon Track (#14) targeted for March 2019



OMI Instrument Operations Team (IOT) Status

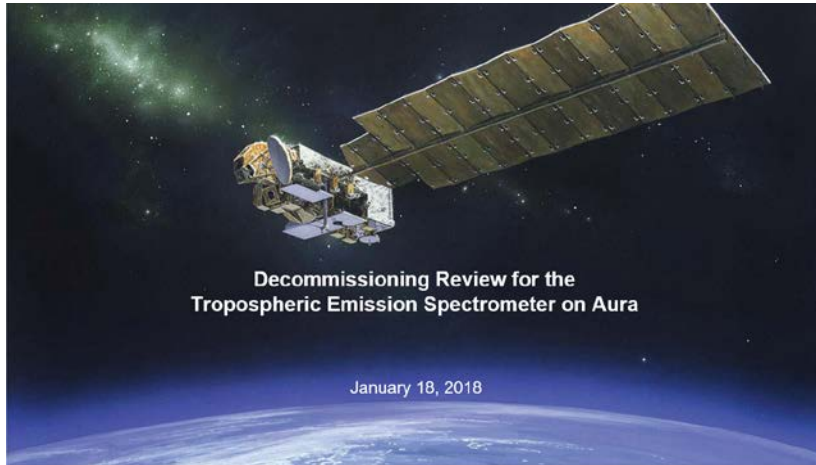


- There were 3 anomalies in 2018; none of which impacted the OMI science data (only 6 since launch):
 - 3 OMI-IAM warm restarts around the SAA
 - No impact on science quality
- Instrument performs nominally (with exception of row anomaly)
- CCD temperatures are very stable
- All three mechanisms behaving 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





TES Instrument Operations Team (IOT) Status



Decommissioning Review for the
Tropospheric Emission Spectrometer on Aura

January 18, 2018



Decommissioning Review for the Tropospheric Emission Spectrometer on Aura

Richard Lay (398A), Project Manager
Dr. Kevin Bowman (329G), Principal Investigator
Dr. Jose Macias (5150), Mission Assurance Manager
Mark Fujishin (8800), Earth Science Missions Manager

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- Following guidance from the 2017 Senior Review, the TES instrument was decommissioned in January 2018
- Science highlights and close-out plans briefed to NASA HQ in April 2018
- IOT support to ramp down as close-out activities take place
- End-of-life engineering testing with the laser system approved to continue



Summary



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

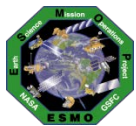


**Thank You
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Questions?

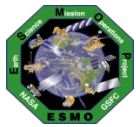


Back Up Slides



Abbreviations / Acronyms List

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



Aura MOWG Meeting

Detailed Agenda



GSFC ESMO Update

ESMO Organization

Fisher

Aura Mission Status

Mission Summary

Fisher

Spacecraft Subsystem Summary

Recent Activities

Planned Activities

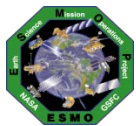
Overall Summary

Additional Slides – Spacecraft Maneuvers, Ground Track, HIEs, Data Capture, & Ops Error Stats



Aura Spacecraft / EOS Ground System Status

	Overview	FOT
	2018 Summary (Status, Statistics, Special Activities, Maneuvers, Anomalies)	
	Spacecraft Risk Matrix	
	Aura FOT Staffing	
	Documentation (Ops Agreements, SOPs, Export Control Assessment, Senior Review)	
	Fault Management Readiness	
	Maneuver Working Group	
	EOS Automation (Ground System)	



Aura MOWG Meeting

Detailed Agenda



MLS Status

	Overall Status	MLS IOT
	MLS Significant Events	
	Close Watch Trends	
	Trend Updates	
	Operational Plans	
	MLS Team Updates	

OMI Status

	Instrument Status	OMI IOT
	Spacecraft Status	
	Operations Status	
	Focus is on those items that can potentially impact the quality of the science data.	

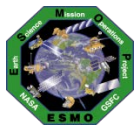


Aura MOWG Meeting Detailed Agenda



TES Status

	Instrument status	TES IOT
	End of Life Laser Testing Results	
	Documentation	
	Updates as a result of Decommissioning	
	Status on Close-out Activities	



Aura MOWG Meeting Action Items



Status Action Items

	Review Operational Agreements (OAs)	FOT / IOT
	Review Safe / Survival Mode Standard Operating Procedures (SOPs)	FOT / IOT
	Prepare for Spring 2019 IAM Series using reaction wheels	FOT / IOT
	Continue evaluation of impacts of an early exit from the A-Train	FOT / IOT
	Prepare for Senior Review inputs (Spring 2020)	FOT / IOT