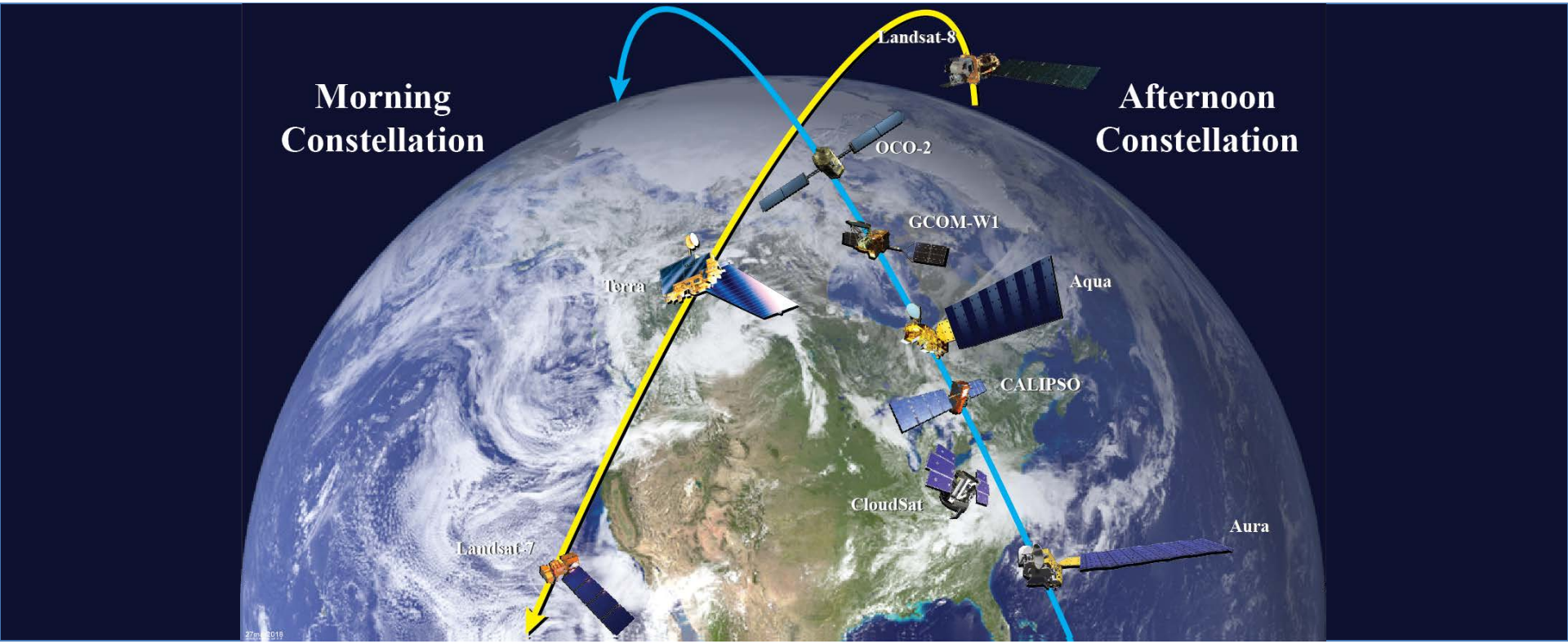
International Earth Science Constellation (ESC)



INTRODUCTION

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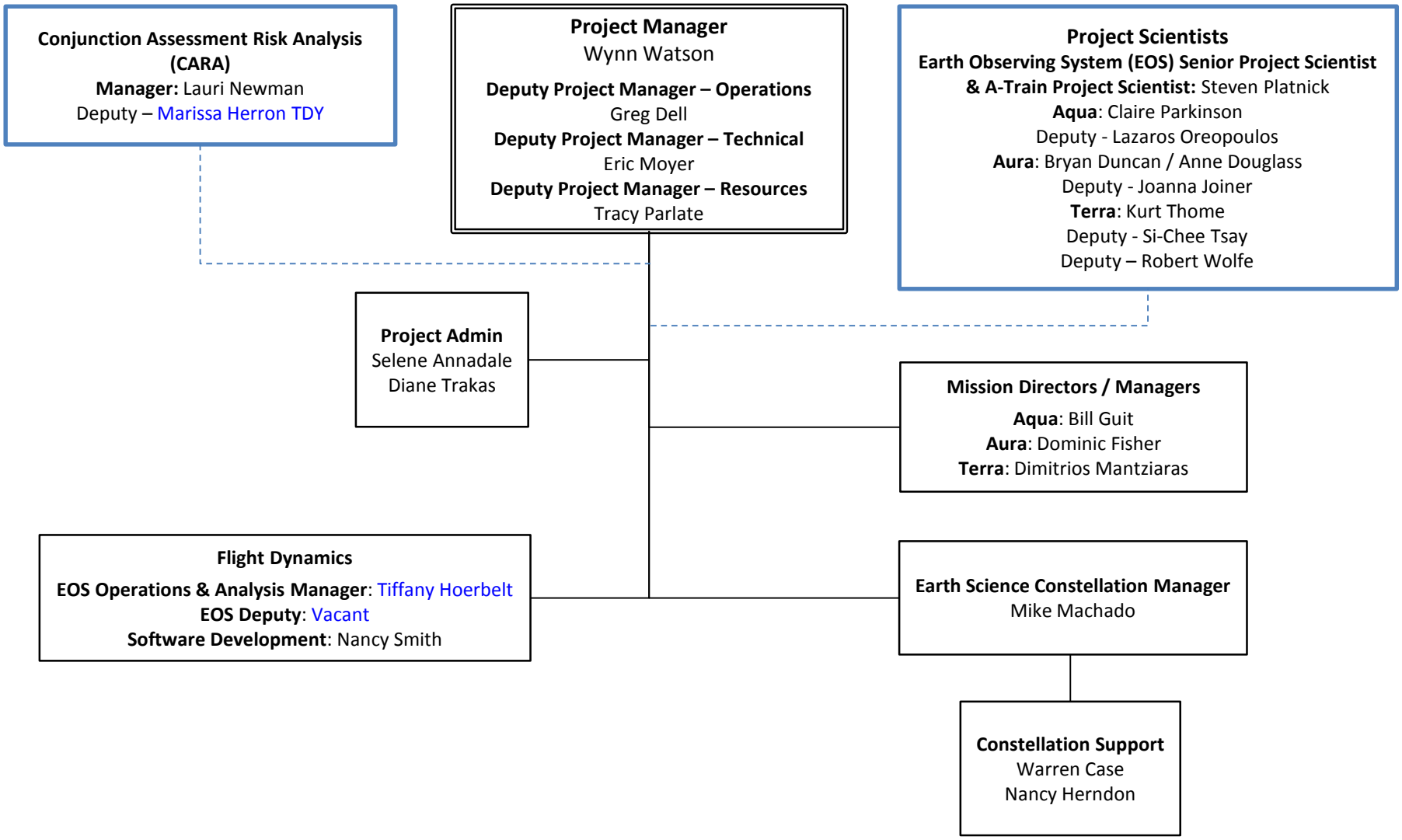
Welcome

- *Welcome to all the members of the Mission Operations Working Group (MOWG) of the International Earth Observing Morning and Afternoon Constellations!*
- *Thank you to our hosts from the United States Geological Survey (USGS)*
- *Welcome also to our guests from National Oceanic and Atmospheric Administration (NOAA), European Space Agency (ESA) and Satellite Servicing Projects Division (SSPD) as well as project scientists and our telecon participants.*
- *THANK YOU as always for your support!*

Earth Science Mission Operations (ESMO)

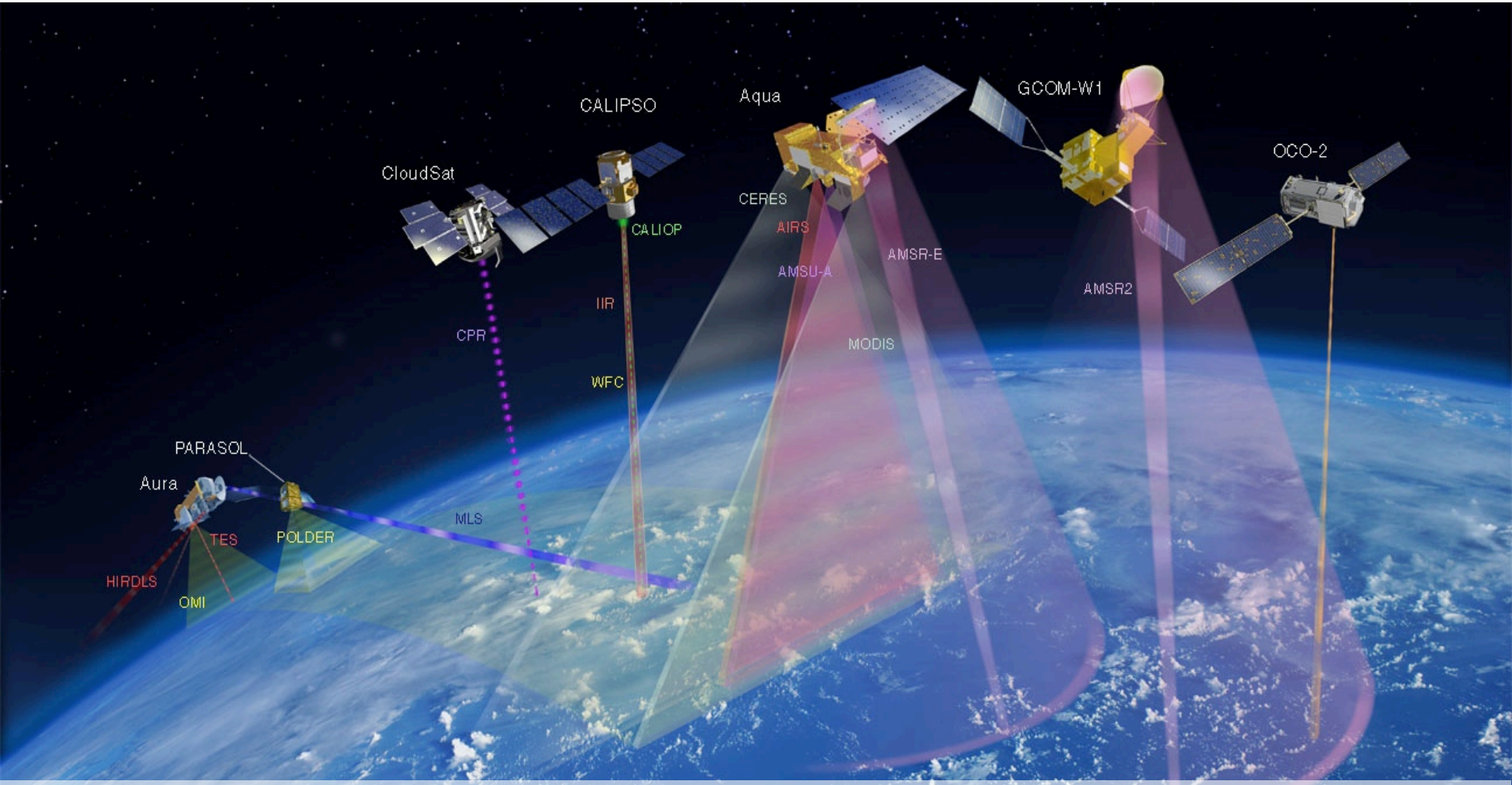


MOWG Charter

The Constellation mission teams enable nearly simultaneous science observations by coordinating their operations and cooperating with each other to ensure the safety of the constellations.

Mission Operations Working Group
June 12-14, 2018

A-Train Science Graphic
(*from Steve Platnick, A-Train Project Scientist*)



The Earth Science Mission Operations (ESMO) Project at the NASA Goddard Space Flight Center (GSFC) leads the Morning and Afternoon Constellation mission operations working group (MOWG) to address constellation safety. The MOWG goal is to ensure the safety of the constellation satellites to enable/maximize coincidental observations.

Constellation History

- **Morning Constellation:** Officially began in 1999 with the Landsat-7 launch in April and Terra launch in December. EO-1 and SAC-C successfully joined in November 2000. Landsat-8 launched in February 2013.
- **Afternoon Constellation (A-Train):** Began with the Aqua launch in May 2002, followed by Aura in July 2004, PARASOL in December 2004, and the joint CALIPSO/CloudSat launch in April 2006 ("formation flying")
- **A-Train Mission Operations Working Group (MOWG):** Officially met for the first time in March 2003, preceded by exploratory discussions between LaRC (John Stadler) and GSFC in 2002 (Angie Kelly, Bill Guit and Lauri Newman)
- **Later A-Train missions followed:**
  - **OCO (2010) and Glory (2011)** launches failed
  - **GCOM-W1** successfully launched in May 2012
  - **OCO-2** successfully launched in July 2014
- **Constellation Evolution**
  - CloudSat Exited A-Train on Feb 22, 2018
  - Landsat-9 launch and overlap with Landsat-7

Significant Meeting Topics

- NASA Headquarters Perspective
- Current state of the missions / Evolution of the Constellation
- CloudSat A-Train exit and extended operations orbit
- Inclination Adjust Maneuver (IAM) Results
- Constellation Coordination System (CCS) Release 2018.1 status
- Constellation Visualization Tool (CVT) status
- Conjunction Assessment Risk Analysis (CARA) status
- Special Topics
  - Annual Variations in Aqua's Mean Local Time and Inclination
  - CARA Conjunction Assessment (CA) short course
  - Simulated small-object close approach statistics
  - Interesting conjunction event statistics for ESC member missions
  - CARA CA Devolution
  - ESMO and JPL's approach to CARA CA Devolution
  - Satellite Servicing Projects Division (SSPD) and Restore-L
  - Progress and advances with covariance realism and Pc uncertainty calculations
  - Brute Force Monte Carlo (BFMC) high-precision Pc calculation service

State of the Constellations

- **Morning Constellation**
  - Terra and its 5 instruments are performing nominally.
  - Landsat 7 and Landsat 8 are performing nominally
  - EO-1 was decommissioned and passivated on March 30, 2017
- **Afternoon Constellation**
  - Aqua, Aura, CALIPSO, GCOM-W1, and OCO-2 are performing nominally
  - CloudSat exited the constellation on February 22, 2018 - still part of the Constellation MOWG family!
  - Continue to monitor TanSat neighbor activity for close approaches

Constellations are operating successfully and producing valuable science data
Excellent cooperation! Still growing and learning!

International Earth Observing Constellation

Mission Operations Working Group

December 6-8, 2017

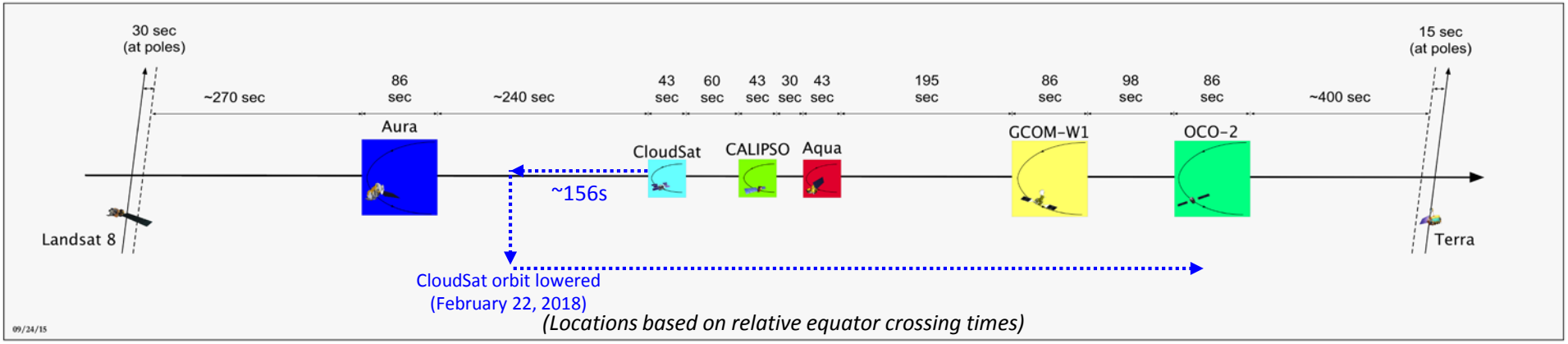
NASA Kennedy Space Center

Since the last meeting . . .

- Aura Tropospheric Emission Spectrometer (TES) decommissioned on January 31, 2018
- CloudSat exited the constellation on February 22, 2018. Proceeded to CALIPSO graveyard orbit and resumed science
- NASA Senior Review completed; Phase-F inputs to NASA HQ
- CCS Release 2018.1 deployed to operations April 11, 2018
- Orbital debris continues to complicate our station-keeping
- We continue to monitor TanSat crossings with Constellation missions (next crossings August – October)
- NASA HQ Decadal Survey Briefing to Earth Science Stakeholders on May 10, 2018
- Constellation Visualization Tool (CVT) Software Release Request Authorization approved! Available via NASA software catalog:

  https://software.nasa.gov/

Afternoon Constellation
Current Orbital Configuration



(Locations based on relative equator crossing times)

Mission Operations Working Group
June 12-14, 2018

Afternoon Constellation 2018 IAM Calendar (Final)

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
February 2018	11	12 ▲ TanSat - OCO-2	13	14	15	16 ▲ TanSat - GCOM-W1	17
	18	19 *President's Day (U.S.)*	20	21 ►**GCOM-W1 #1**	22 ►**CALIPSO #1** ▲CloudSat exit	23	24 ▲ TanSat - Aqua
	25	26 ▲ TanSat - CALIPSO	27	28 ►**Aura #1**	**March 1** ►**Aqua #1**	2	3
March 2018	4	5	6	7 ►**Aura #2**	8 ►**Aqua #2** ►**OCO-2 #1**	9 ▲ TanSat - Aura	10
	11 *Daylight saving time starts (U.S.)*	12	13	14 ▲GCOM-W1 retrograde ►**Aura #3**	15 ►**Aqua #3** ►**OCO-2 #2** ▲CloudSat orbit lower	16	17
	18	19	20	21 *Spring Equinox (Japan)*	22	23	24
	25 *Daylight saving time starts (France)*	26	27	28 ►**Aura #4** ▲CloudSat orbit lower	29 ►**Aqua #4** ►**OCO-2 #3**	30	31
April 2018	**April 1** *Easter (U.S./France)*	2 *Easter Monday (France)*	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18 ►**Aura #5**	19 ►**Aqua #5**	20	21
	22	23	24	25 ►**CALIPSO #2** ►**GCOM-W1 #2**	26 ►**OCO-2 #4**	27	28

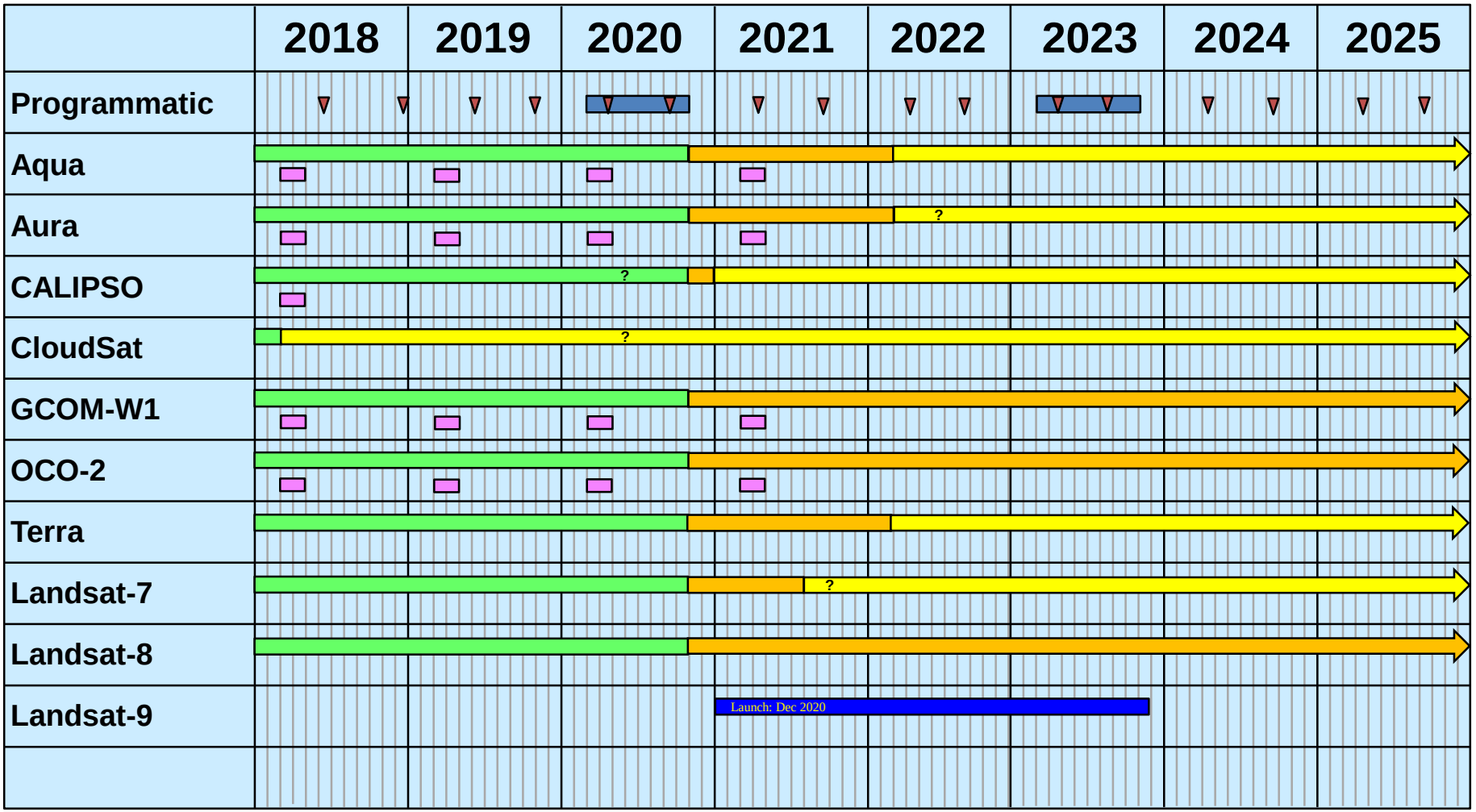
KEY: ►= Inclination adjust maneuver ▲ = Other maneuver ▲ = TanSat crossings

Mission Operations Working Group

June 12-14, 2018

A-Train Long Range Plan

Inputs needed from MOWG teams



Upcoming Events . . .

- ***Terra Summer IAM*** — ***June 2018***
- ***TanSat crossings with A-Train*** — ***Late Summer 2018***
- **Fall / Winter MOWG Meeting** — ***December / January***
  Sponsor: ??
  Location TBD – GSFC, JPL, or Stennis?
- ***EOS Annual Review*** — ***January 2019***
  - ***Possible overlap with MOWG?***
- ***Spring / Summer MOWG Meeting*** — ***June / July 2019***
  Sponsor: ??
  Location TBD – GSFC, JPL, France, Japan?

Mission Operations Working Group
June 12-14, 2018

ESC MOWG Action Items
June 2017 MOWG meeting (1 of 3)

#	Assignee	Description	Status / Due Date
1706 -01	ESMO (Case)	ESMO to add a requirement to the Operations Coordination Plan for all MOWG mission teams to supply their orbit lowering and decommissioning plans at 18 months before planned orbit lowering.	**OPEN /** December 2017 Discuss this and other changes to the *Operations Coordination Plan* at the MOWG meeting in December 2017.
1706 -02	ESMO (Machado)	Provide M. Garcia/OCO-2 with a copy of the annual review agenda for Aura. More generally, to invite MOWG teams to attend future Annual Reviews.	**PARTIAL /** December 2017 Mike Machado distributed the Annual Review materials to all teams on June 29, 2017. The process to invite other teams to attend future Annual Review will be discussed at the MOWG meeting in December 2017.
1706 -03	OCO-2 (M. Garcia)	JAXA is planning to fly AMSR-3 passive radiometer on the next GoSat satellite. Ask the OCO-2 science team for ideas for synergism between an OCO-2 type instrument (GoSat) and a passive radiometer (AMSR-3). Request submitted by Elena Lobl.	**CLOSED/** November 27,2017 David Crisp/OCO-2 (e-mail on November 22, 2017) noted that *"… the factor that limits the synergy between AMSR-E, AMSR-2, and OCO-2 is the very large difference in surface footprint size. The only AMSR-2/AMSR-E channel that has a footprint that fits within the less than 10-km wide OCO-2 swath is the 89 GHz channel. The footprints in the other channels are much wider (12-62 km). In addition, co-manifesting AMSR-3 and GOSAT-3 might be feasible if the GOSAT-3 instrument is a grating spectrometer instead of a Fourier Transform Spectrometer (FTS). If the GOSAT-3 instrument is an FTS, the vibrations introduced by the AMSR-3 antenna would almost certainly compromise its performance."*

Mission Operations Working Group
June 12-14, 2018
ESC MOWG Action Items
June 2017 MOWG meeting (2 of 3)

#	Assignee	Description	Status / Due Date
1706 -04	OCO-2 (M. Garcia)	OCO-2 to provide the list of A-Train science data (e.g., MODIS) that they require/want in order for OCO-2 to perform their science data processing. Requested by Steve Platnick.	**CLOSED / June 14, 2017** Response supplied by Mark Garcia/OCO-2: *OCO-2 requires **no** data from the A-Train for operational processing. However, the OCO-2 science data processing tools do use the MERRA aerosol product, which in turn uses MODIS data (an indirect benefit from maintaining our position wrt Aqua).* *Although the data products are not used operationally, the real benefit from coordinated observations with the A-Train (or 705 km Constellation) instruments has been observed in the research area. Examples of OCO-2 science publications that make use of the other 705 km Constellation science products are seen with researchers using the MODIS cloud data for a number of assessments of the 3D effects of clouds; using Cloudsat and CALIPSO, focused on cloud retrievals, for an assessment of the impact of cloud height on retrieval errors; using OMI NO2 data record in their analysis (from Aura), as well as MOPITT data from Terra.*
1706 -05	ESMO (Machado) and all teams	ESMO to provide a template for the long term plans for all MOWG missions and distribute to teams. The teams will fill out and return. The information will subsequently be provided to the Decadal Survey team.	**CLOSED / June 24, 2017** Template was mailed out to all teams on June 19. Responses were received from MOWG teams by June 24.

Mission Operations Working Group
June 12-14, 2018

ESC MOWG Action Items
June 2017 MOWG meeting (3 of 3)

#	Assignee	Description	Status / Due Date
1706-06	All teams	All teams to supply their organization chart(s) to Mike Machado/ESMO.	**OPEN** / Spring 2018 MOWG meeting M. Machado is requesting that the MOWG teams supply their latest organization charts at the Spring 2018 MOWG meeting.
1706-07	ESMO (Machado)	Notify the MOWG members when the Constellation Visualization Tool (CVT) software is available from the NASA software catalog, identify any distribution limitations, and supply the necessary information to download the software.	**OPEN /** As soon as information is available
1706-08	ESMO (Case)	Schedule a splinter session the next MOWG meeting to present an overview and status of the ESMO's collision avoidance automation process.	**CLOSED /** October 20, 2017 The requested presentation was included in the agenda for the December 2017 MOWG meeting.
1706-09	ESMO FD (Tracewell)	Work with Mark Vincent to define additional TanSat analyses to be conducted.	**CLOSED/** July 14, 2017 M. Acocella/OCO-2 supplied long term ephems on June 28 and July 14.
1706-10	ESMO (Case)	Investigate possibility of holding the December MOWG meeting at the KSC Visitor Center and announce the findings. The goal is to announce a decision on the planned location in the near future.	**CLOSED/** August 2, 2017 The KSC Visitor Center Complex is not available for the December MOWG meeting
1706-11	CARA	Provide CARA's best information on the size and characterization of the object catalog.	**OPEN /** December 2017 (at MOWG meeting)
1706-12	CARA	Provide an updated "debris by altitude" presentation.	**OPEN /** December 2017 (at MOWG meeting)

Meeting Logistics

- **Presentations**
  - Please e-mail your presentation updates to warren.f.case@nasa.gov and nancy.c.herndon@nasa.gov
  - All the presentations will be made available after the meeting via Goddard server. Download instructions will be sent.
  - Let us know if your presentations are "***not for public view***".
- **Telecon Number: 844-467-4685; passcode 930459#**
- **Traditional group photo –** Day 1 during afternoon break
- **Wi-Fi access**

Other Scheduled Activities

- **Wednesday**
  - **Conjunction Assessment Short Course**
  - **Good Earth State Park at Blood Run**
    http://southeastsouthdakota.com/outdoor-adventure/state-parks/sioux-falls/good-earth-state-park-at-blood-run/
  - **Minerva's Restaurant**
    http://www.minervas.net/minervas-sioux-falls/
- **Thursday**
  - **Restore L Seminar**
  - **Earth Resources Observation and Science (EROS) Center Tour**
    USGS EROS, 47914 252nd St, Garretson, SD 57030

ESC MOWG Dress Shirts!

- Over the years there has been lots of interest in MOWG shirts
- Let us know if you are interested in purchasing a dress shirt (men's or women's Long Sleeve Easy Care Shirt) with embroidered text
- See Mike, Bill, Warren, Nancy for more info

Embroidery:

Earth Science Constellation
Mission Operations Working Group

ありがとうございます

Arigatou Gozaimasu

Merci

Thank you

Questions?

Mission Operations Working Group
June 12-14, 2018
Abbreviations / Acronyms List

AIRS	Atmospheric Infrared Sounder
ALI	Advanced Land Imager
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
AMSR2	Advanced Microwave Scanning Radiometer 2
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CA	Conjunction Assessment
CAM	Command Authorization Meeting
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CARA	Conjunction Assessment Risk Analysis
CCR	Configuration Change Request
CCS	Constellation Coordination System
CNES	Centre National d'Etudes Spatiales
CRMS	Collision Risk Management System
CVT	Constellation Visualization Tool
DAM	Debris Avoidance Maneuver
DB	Direct Broadcast
DO-OP	Daylight Only Operations
EAR	Export Administration Regulations
EO-1	Earth Observing-1
EOMP	End of Mission Plan
EOS	Earth Observing System
EROS	Earth Resources Observation and Science
ESA	European Space Agency
ESC	Earth Science Constellation
ESDIS	Earth Science Data and Information System
ESMO	Earth Science Mission Operations
ETM+	Enhanced Thematic Mapper Plus (Landsat 7)
FAQ	Frequently Asked Question
FDS	Flight Dynamics System
FOT	Flight Operations Team
FSW	Flight Software
FY	Fiscal Year
GCOM-W	Global Change Observation Mission – Water
GMT	Greenwich Mean Time
GS	Global Survey
GSFC	Goddard Space Flight Center
HIE	High Interest Event
HQ	Headquarters
IAM	Inclination Adjustment Maneuver
ISS	International Space Station
ITAR	International Traffic in Arms Regulations
JAXA	Japan Aerospace Exploration Agency
JPL	Jet Propulsion Laboratory
JPSS	Joint Polar Satellite System
JSC	Johnson Space Center
JSpOC	Joint Space Operations Center
KSC	Kennedy Space Center
LaRC	Langley Research Center
MLT	Mean Local Time
MMOD	Micrometeorite Orbital Debris
MOWG	Mission Operations Working Group
NASA	National Aeronautics & Space Administration
NET	No Earlier Than
NGAS	Northrop Grumman Aerospace Systems
NOAA	National Oceanic and Atmospheric Administration
OCO	Orbiting Carbon Observatory
OIIR	NASA Office of International and Interagency Relations
ORR	Operational Readiness Review
PS	Project Scientists
RMM	Risk Mitigation Maneuver
RWA	Reaction Wheel Assembly
SAC-C	Satellite de Aplicaciones Cientificas (Scientific Application Satellite)
SC	Spacecraft
S5P	Sentinel-5 Precursor
SNPP	Suomi National Polar-orbiting Partnership
SWIR	Short Wave Infrared
TBD	To Be Determined
TES	Tropospheric Emission Spectrometer
USGS	U.S. Geological Survey
WRS	World Reference System