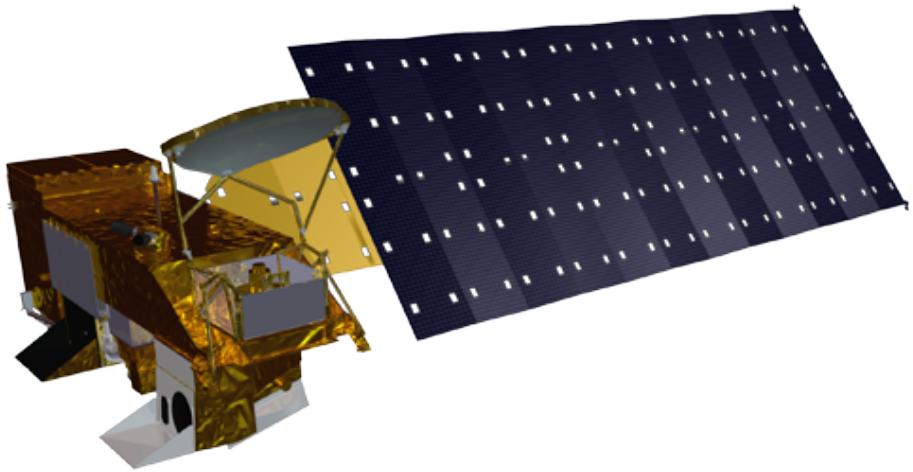


Status of the Aqua Mission

Claire L. Parkinson & William J. Guit

Aqua Project Scientist Aqua Mission Director

NASA Goddard Space Flight Center

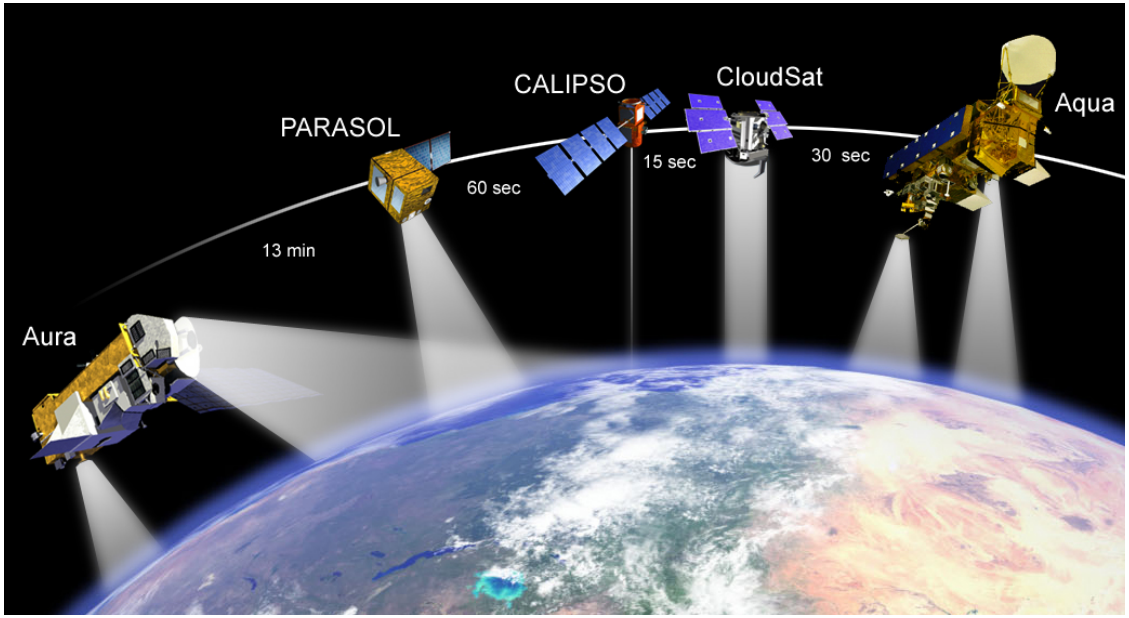
Presented at the MODIS/VIIRS Science Team Meeting, held at The Hotel at the University of Maryland, College Park, Maryland, November 19, 2019

Aqua Overview

- Launched May 4, 2002, with a design life of 6 years.
- Altitude of 705 km; 1:36 a.m. and 1:36 p.m. equatorial crossing times; in the A-Train (Afternoon Constellation) of satellites.
- Six Earth-observing instruments.
- Data used in thousands of scientific publications and wide-ranging practical applications.
- Likely can continue operating in the A-Train until 2022.

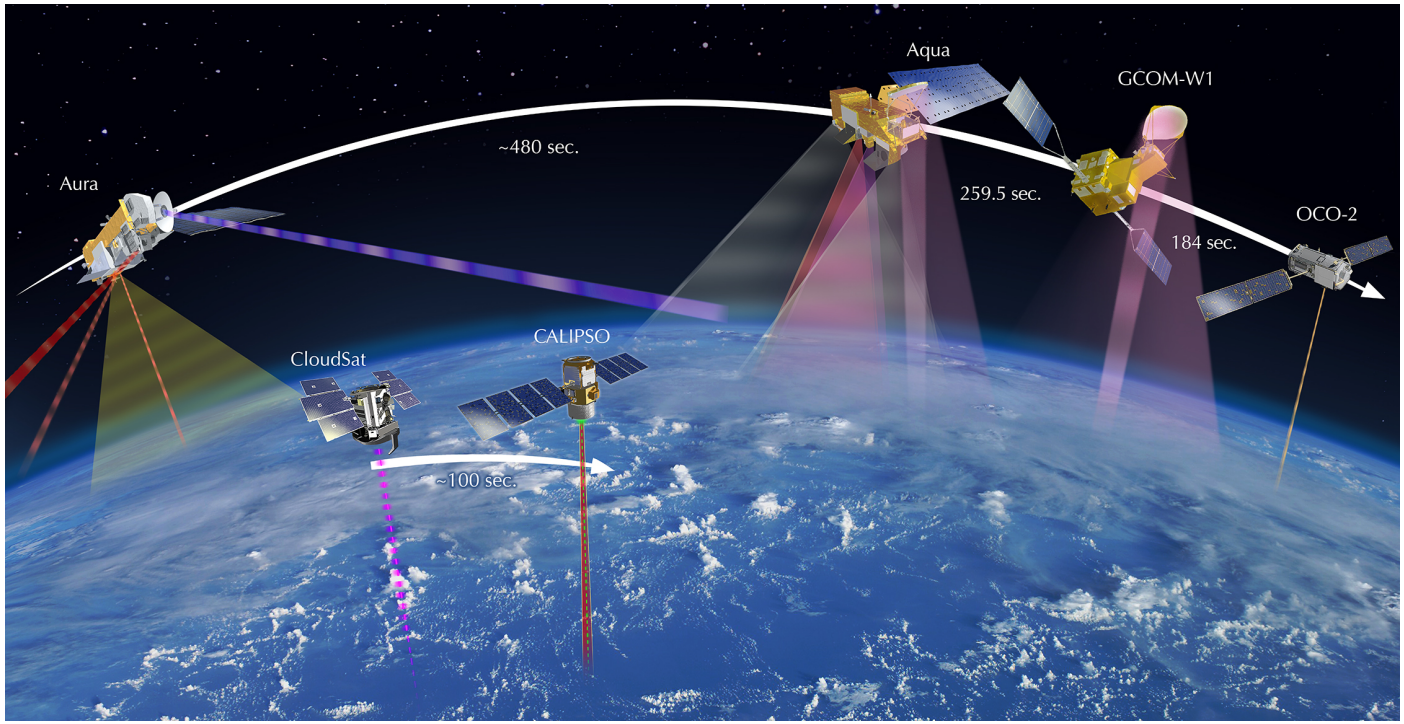
Aqua pre-launch (courtesy of Northrop Grumman)

A-Train Satellites in 2006 and 2019

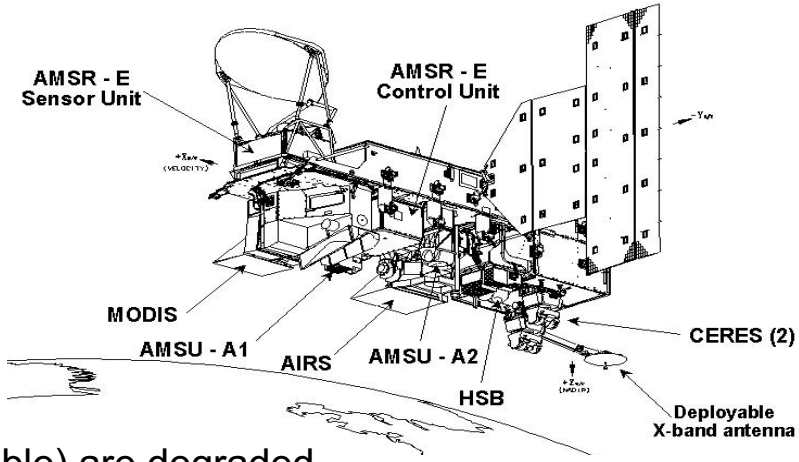


2006 A-Train
(art work by Alex McClung)

2019 A-Train and C-Train
(from Steve Platnick and the EOS Project Science Office)



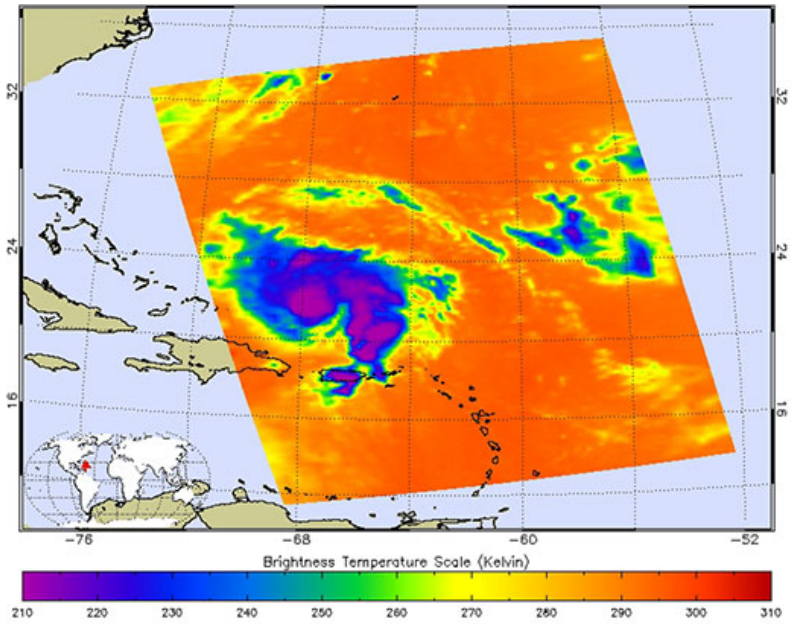
Aqua's Operating Earth-Observing Instruments*



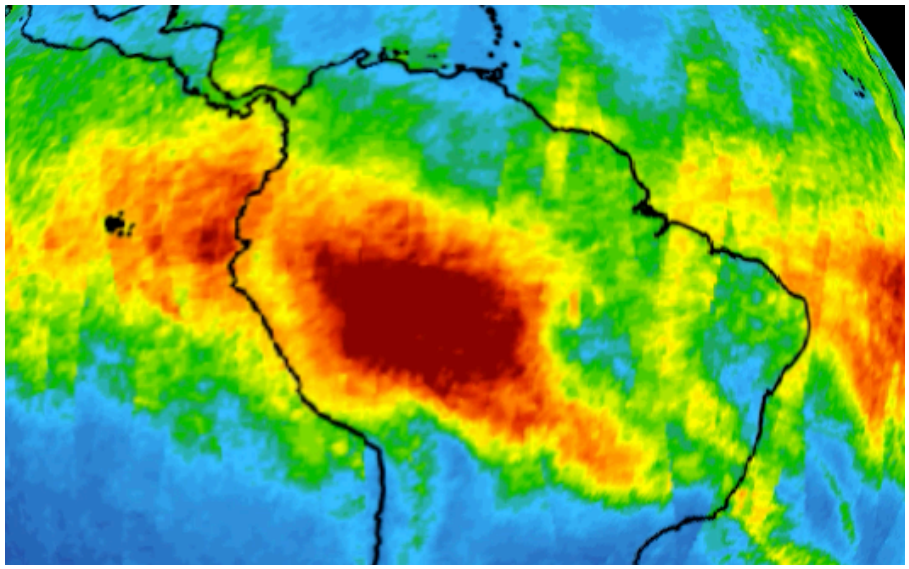
- Atmospheric Infrared Sounder (AIRS)
  - Excellent health.
  - Only ~ 200 of the 2382 channels (2378 infrared, 4 visible) are degraded.
- Advanced Microwave Sounding Unit (AMSU).
  - Fair health.
  - Nine of the 15 channels are performing well (including Channel 14, which had undergone an anomaly on 6/21/18 but recovered by 6/19/19) and another (Channel 6) is still providing useful data despite slowly degrading.
- Clouds and the Earth's Radiant Energy System (CERES; 2 copies).
  - Flight Model 3 (FM-3): Excellent health; all three channels are fully operational.
  - Flight Model 4 (FM-4): Good health; two of the three channels remain operational (the shortwave channel failed on 3/30/2005).
- Moderate Resolution Imaging Spectroradiometer (MODIS).
  - Excellent health.
  - Thirty-five of the 36 bands (visible to thermal infrared) operate well; the other, band 6, has been imperfect throughout the mission.
  - All components remain on primary hardware.
  - Three of the four 10 W lamps used for calibration have failed.

* Non-operating instruments: Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) and Humidity Sounder for Brazil (HSB).

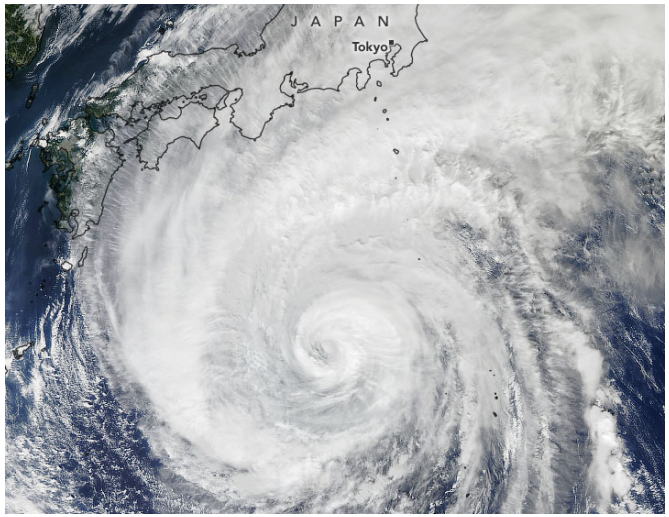
Recent Aqua Imagery



AIRS image of Hurricane Dorian, 8/29/19



AIRS image of carbon monoxide at ~18,000 ft, from Brazilian fires, 8/20-22/19



Aqua MODIS image of Typhoon Hagibis approaching Japan, 10/11/19

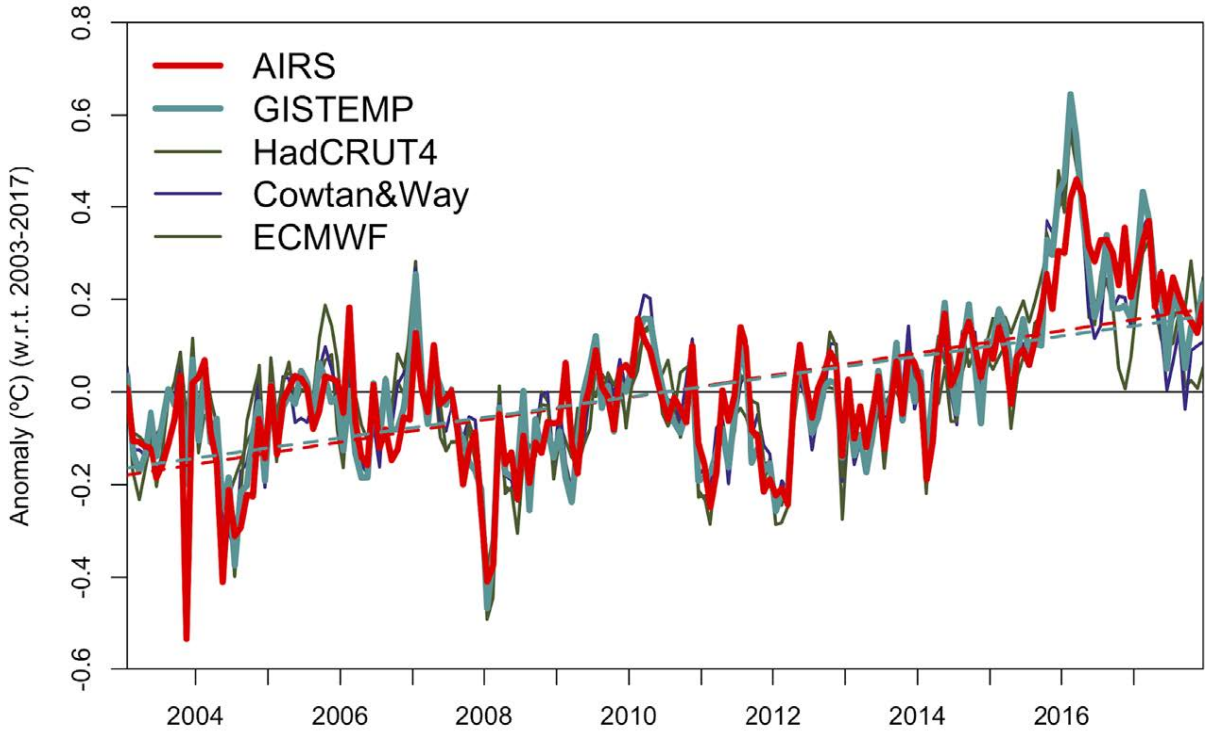
Aqua MODIS image of Australian fires, 11/7/19

Aqua MODIS image of sediment-laden waters in the Bay of Fundy, 10/20/19

(AIRS images from airs.jpl.nasa.gov; MODIS images from earthobservatory.nasa.gov)

Sample Recent Aqua Science Result, from Susskind *et al*. 2019

Global Monthly Mean Surface Temperature Anomalies
from AIRS data and four in situ data sets

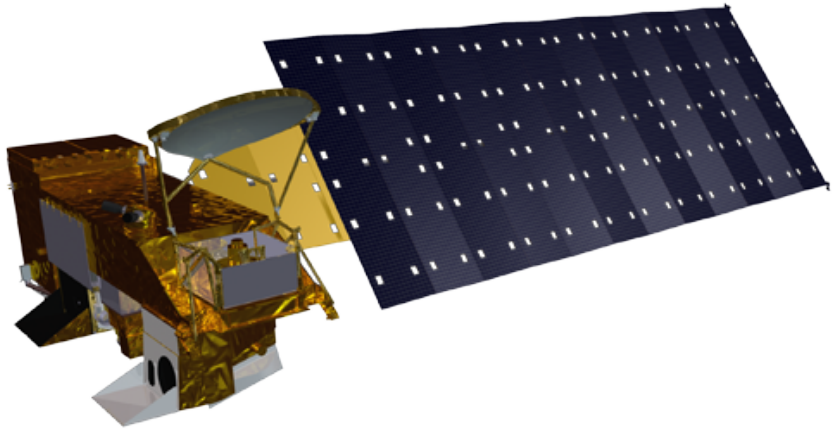


"We show in this paper that satellite-based surface temperatures can … help to improve surface-based data sets in a way that can be extended back many decades …"

(plot and quote from J. Susskind, G.A. Schmidt, J.N. Lee, and L. Iredell, 2019: Recent global warming as confirmed by AIRS, *Environmental Research Letters*, 14, 044030)

GISTEMP = Goddard Institute for Space Studies surface temperature analysis; HadCrut4 = Hadley Center & Climatic Research Unit temperatures; Cowtan&Way = Cowtan and Way 2014, *Q. J. Royal Meteorological Society*; ECMWF = European Centre for Medium-Range Weather Forecasts.

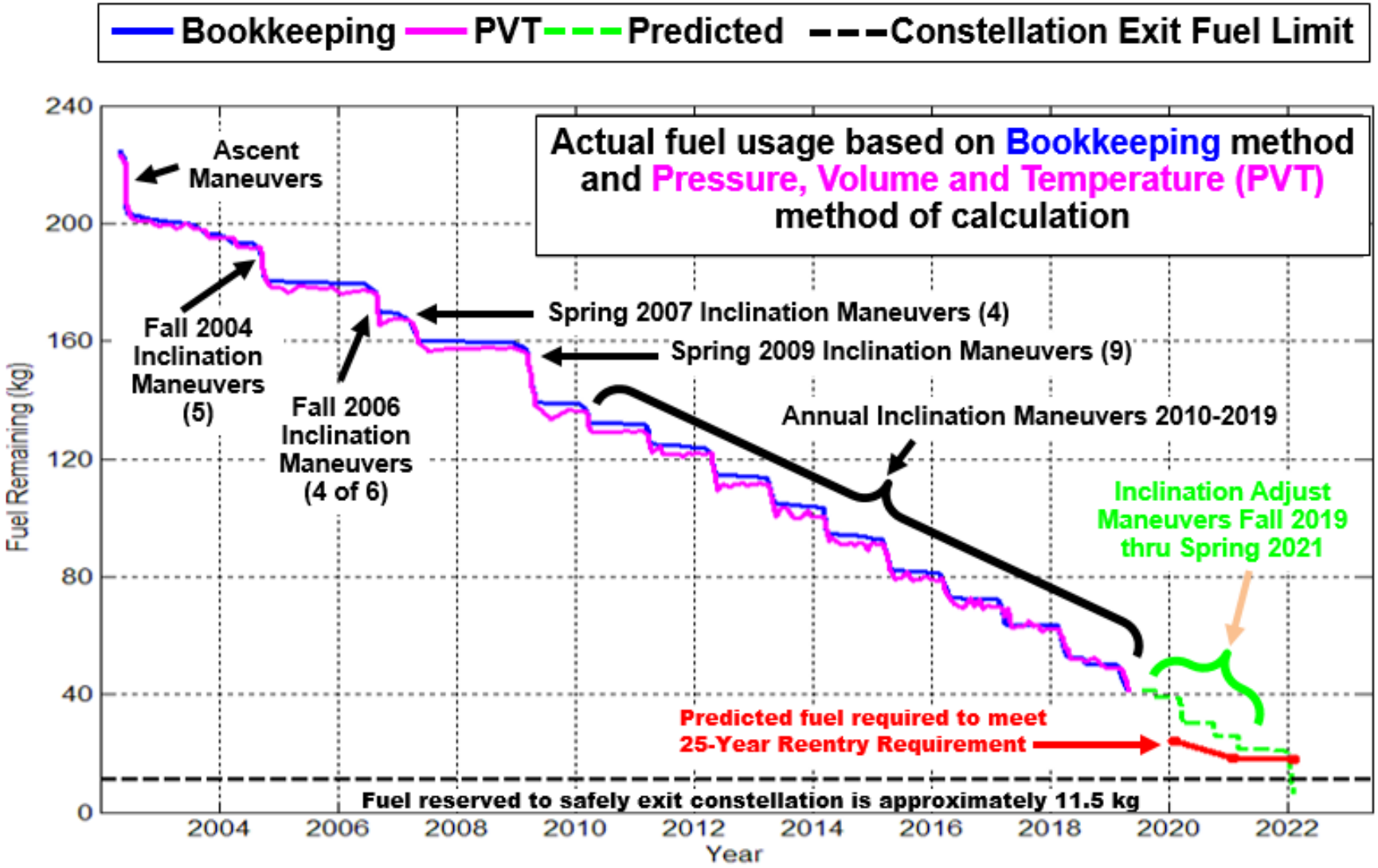
Status of the Spacecraft Bus, Solar Array, Battery, and Data Capture

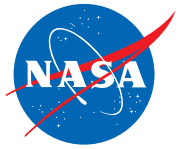


- Overall status – Excellent
- All components remain on primary hardware.
- Lifetime estimates for the Aqua solar array and battery if Aqua were to remain in its A-Train orbit:
  - The Solar Array could likely operate at least until early 2028 (113 of the 132 strings of solar cells continue to operate).
  - The main Aqua battery could likely last 152,000 Earth orbits, until December 2030 (all 24 cells remain fully operational).
- So far in 2019 there have been three days with data losses.
  - 3/17/19 (about 6 seconds of missing data; recovered through direct broadcast).
  - 7/18/19 (about 42 seconds; not recovered).
  - 10/11/19 (about 57 minutes; over half recovered).

(Aqua visualization by Marit Jentoft-Nilsen)

Timeline of Aqua Fuel Levels

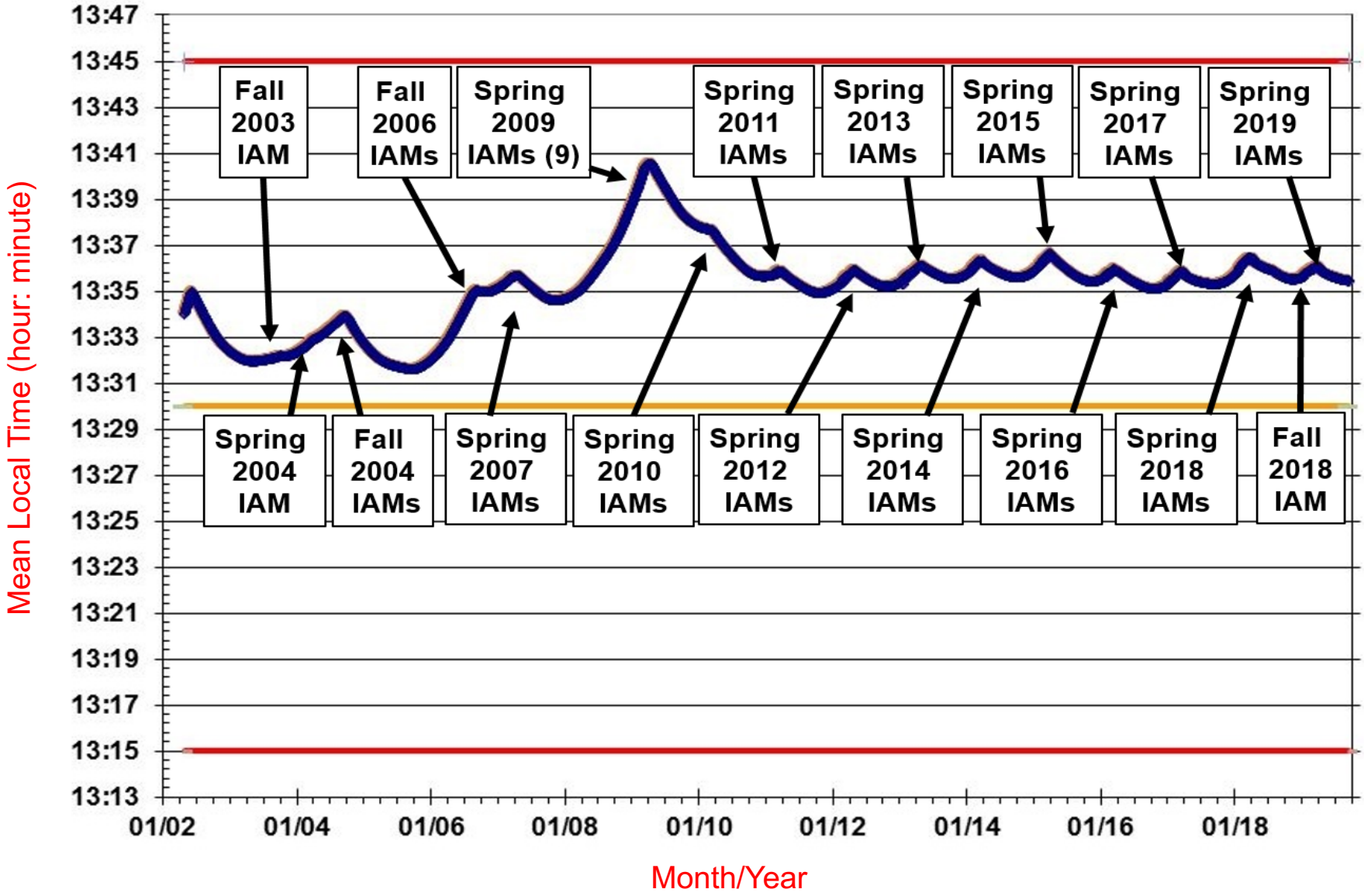




Fuel-Saving Plans

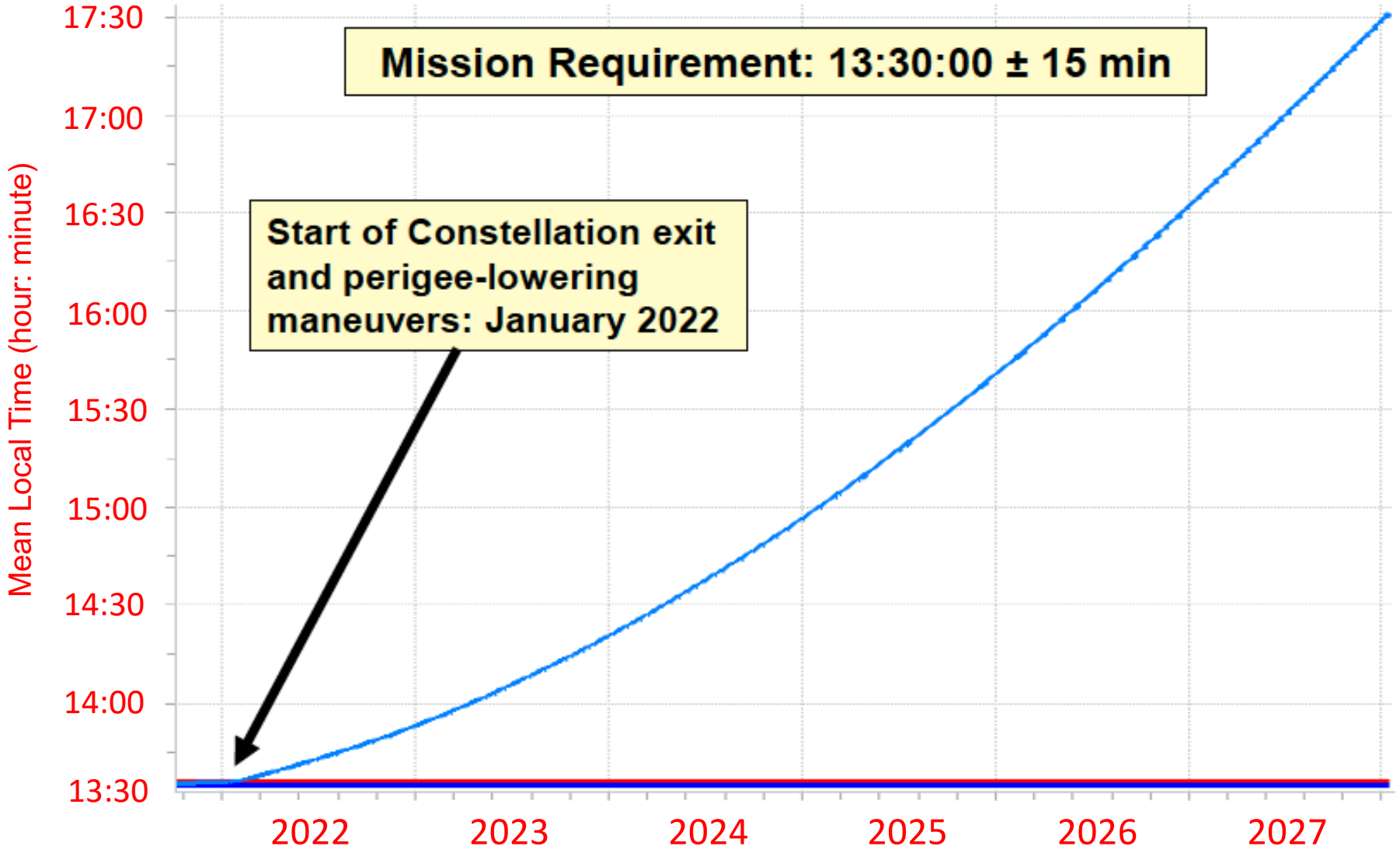
- Use reaction wheels rather than thrusters to position the spacecraft for future Inclination Adjust Maneuvers (IAMs).
  - Saves fuel (and also provides more flexibility, allowing smaller, more frequent IAMs, and more accurate management of the change in the orbit's semi major axis)
  - Takes longer
  - Reaction wheel portion was successfully tested on 11/14/19.
- Perform IAMs in both spring and fall.

History of Aqua's Mean Local Time at the Northward Equatorial Crossing



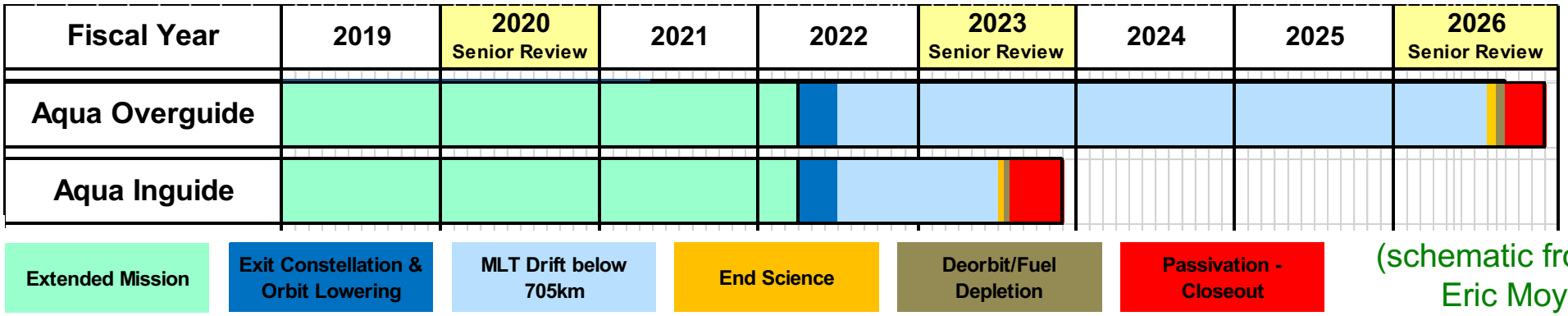
IAM = Inclination Adjust Maneuver

Predicted Mean Local Time Trajectory
If Aqua Exits the A-Train in January 2022



Budget Complications

- In-Guide budget provided by NASA HQ to the Aqua, Terra, and Aura Project Scientists, for the annual budget exercise, spring 2019
  - No cuts through FY22
  - Major cuts FY23 and beyond
- In-Guide decisions for the Aqua mission
  - Give the science teams the full amount they need for a complete Phase F
  - Exit the A-Train in 2022
  - End the mission (passivate the spacecraft) in 2023
- Over-Guide request
  - Maintain full budget as planned in 2018
  - Exit the A-Train in 2022
  - Continue to collect data until about 2026



(schematic from Eric Moyer)

2020 Aqua Senior Review

- Key: The Aqua Senior Review proposal needs to make a convincing case that the Aqua mission should be continued.
  - Highlight exciting science already done with Aqua data.
  - Indicate additional science that could be done with Aqua data, including data collected after exiting the A-Train.
  - Illustrate valuable practical applications of Aqua data.
- Senior Review timeline.
  - 12/8/19, Senior Review Kickoff at a Townhall Meeting at AGU.
  - 3/6/20, Likely due date for the Senior Review proposals.
  - March – April 2020, Review of the proposals by the Senior Review Panel.
  - Mid-May 2020, Likely Aqua presentation to the Senior Review Panel, answering whatever questions they might have.

Concluding Summary

- The Aqua mission continues to collect valuable data from the AIRS, AMSU, MODIS, and CERES instruments.
- Fuel limitations will likely lead to Aqua's exiting the A-Train in early 2022, with a descent to approximately 4.4 km below the A-Train orbit.
- After exiting the A-Train, Aqua could continue to collect valuable science data, at a lower altitude, drifting with later equatorial crossing times, for several years.
- The spacecraft will be passivated when the data are no longer valuable, likely about 2026, unless budget or fuel considerations lead to earlier passivation.