Juno’s Lessons Learned at Earth Fly-by

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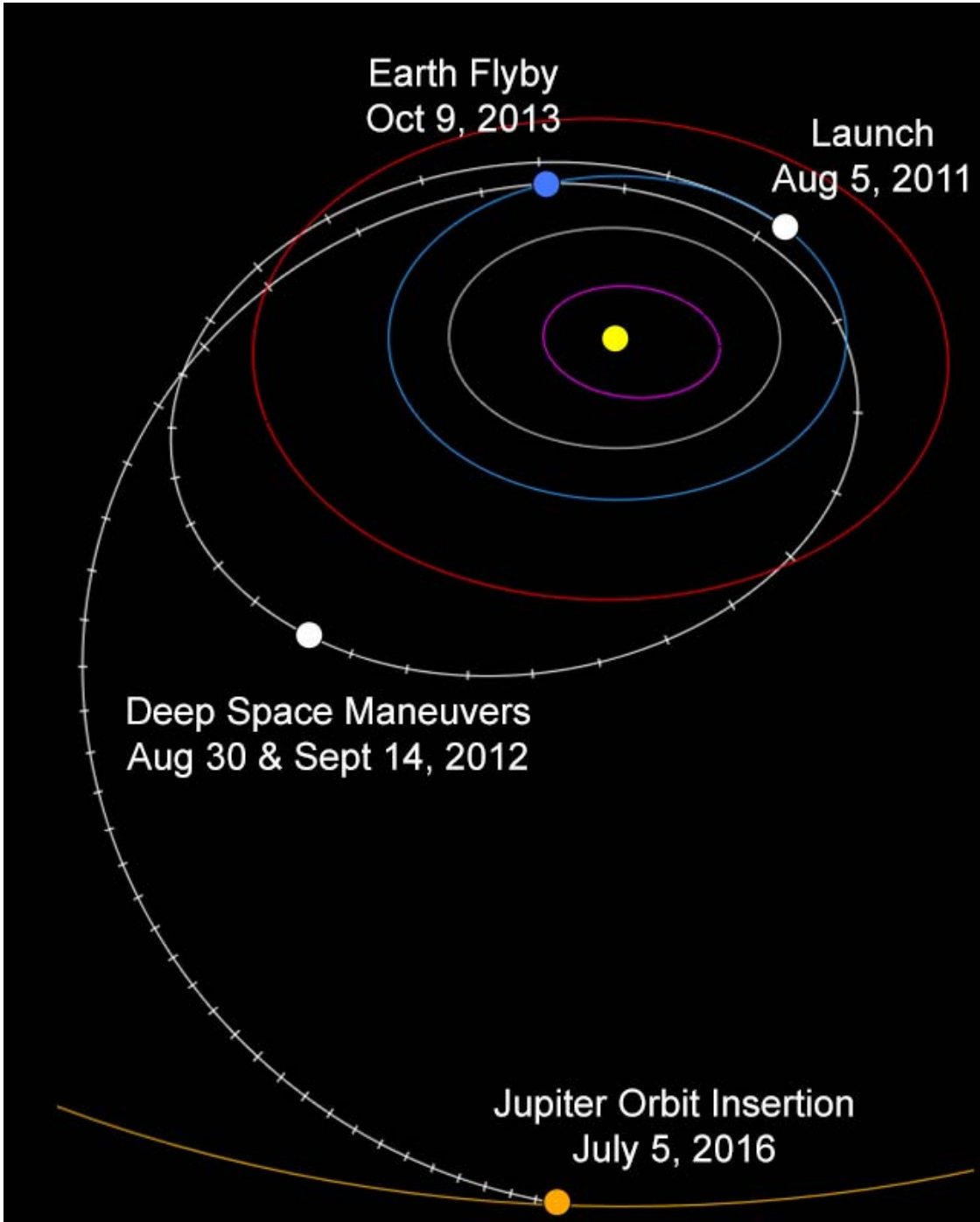
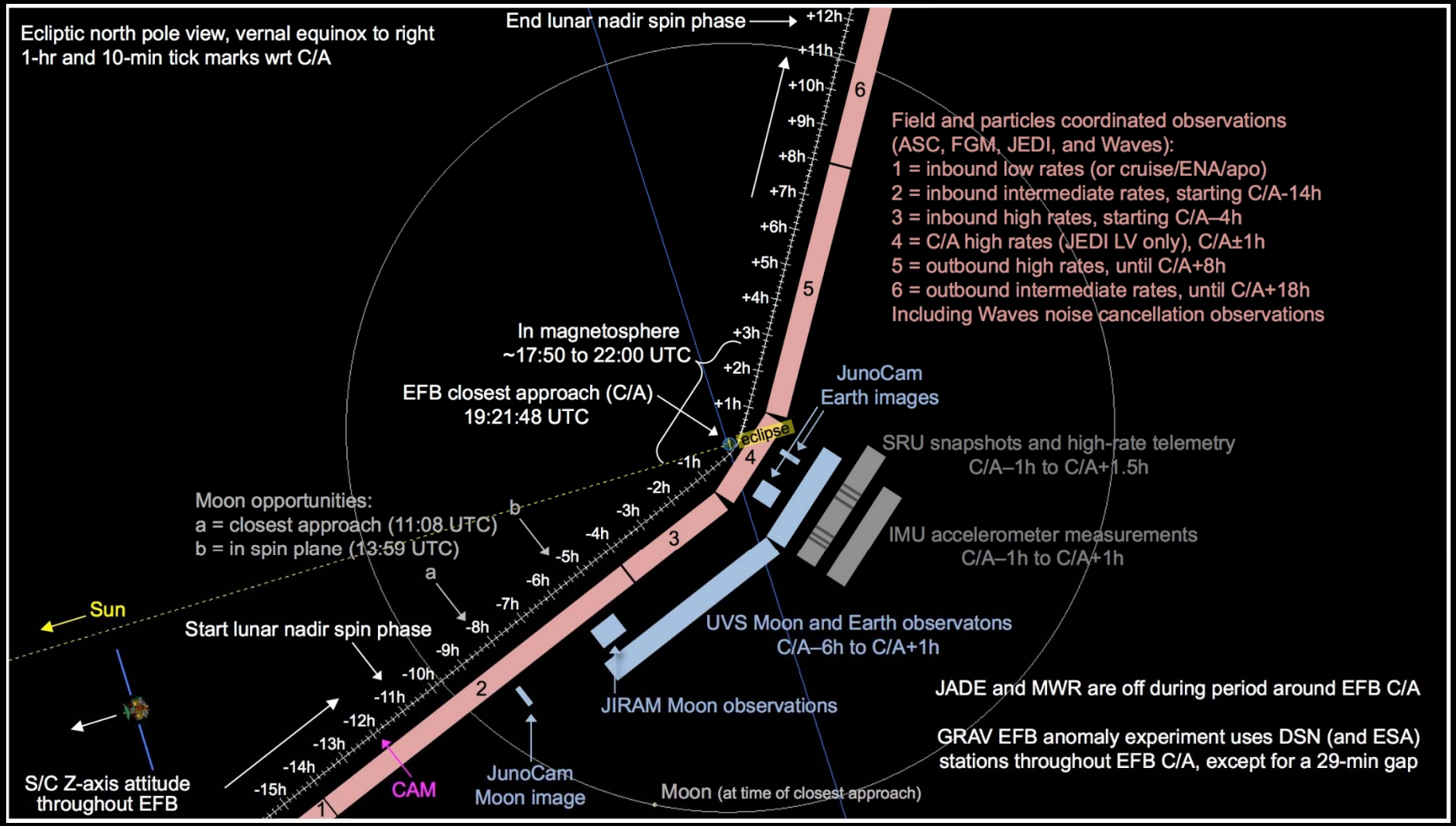
Cape Canaveral Air Force Station



Gravity Assist from Earth

Galileo, Cassini, and New Horizons are just three examples of spacecraft using gravity assists to add energy to and/or change their trajectory to aid them in reaching their final objective.

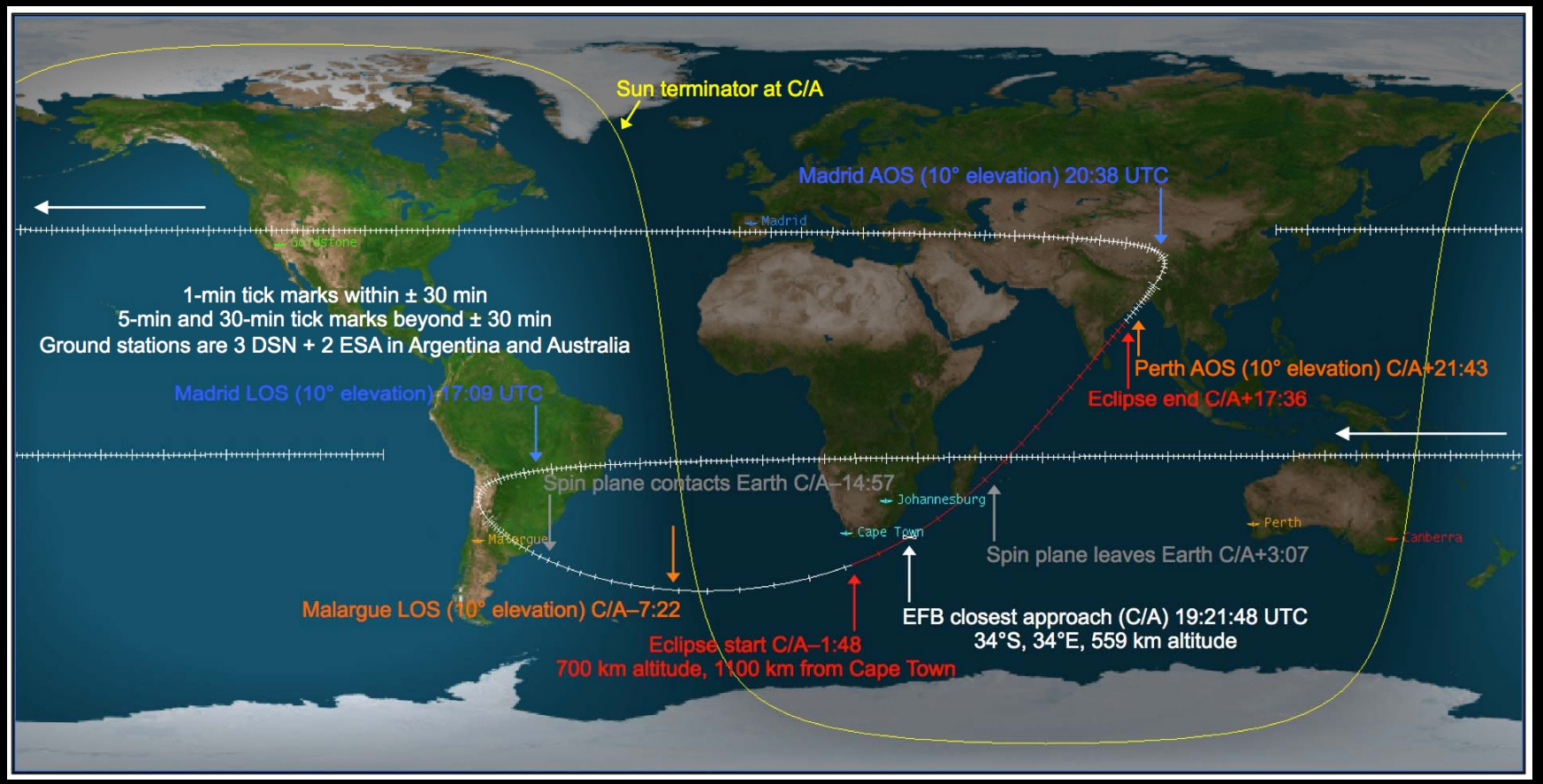
Instruments Active Approaching Earth



JunoCam Captures the Earth and Moon as Juno Approaches

Fly-By Ground Track

Eclipse and Safe Mode #1



What Happened (1)

- Communication among the teams on the project regarding the battery management was in terms of state of charge
- Further, the work was managed as battery state of charge
- During eclipse state of charge drops from 50% to 46% over about 20 minutes
  - Understood that 38% SOC was the fault protection trigger point

What happened (2)

- In reality, fault protection triggers on battery voltage at 28.7 volts
  - We entered eclipse at 29.3 volts as planned
  - With no power from the solar arrays and full load the battery droped 0.4 volts to 28.9 volts.
- We didn’t properly analyze the situation based on this difference and underestimated the margins

Starting to Recover (1)

Safe Mode #2

- When Juno enters safe mode the background sequence is halted
  - Thermal Electric Cooler on the Stellar Reference Unit remained set at -40º
  - Rebuilt sequence did not set TEC to its default setting as original sequence would have
  - When Juno turned to new attitude the SRU began warming but the TEC tried to keep it at -40o

Starting to recover (2)

- This caused the TEC to exhibit an unexpectedly large current draw
  - When it reached a certain point the SRU was marked failed (a redundant device)
  - The fault protection response was anticipated to be to swap SRUs but instead it requested safe mode.

In Safe Mode Too Long? (1)

Safe Mode #3

- Juno fault protection reasserts safe mode (to maintain sun pointing) every 24 hours while it is in safe mode based on a timer
  - The timer did not reset during safe mode exit as was believed by the ops team
    - We launched in safe mode and stayed there 5 hr.
    - For safe mode #1, we remained in safe mode 5 hr
    - With 5 hours at launch and 5 hours at safe mode #1, we reentered safe mode just 14 hours after safe mode #2

In Safe Mode Too Long? (2)

- Disabling the fault protection did not reset the timer as assumed in the safe mode recovery process
- Proper way to reset it is to exit safe mode and then re-enable the timer

What We Learned About Safe Mode #1

- That 48.4% SOC with 5.11 amp current draw, voltage is <28.7
- If a fully validated model that properly predicted the battery voltage behavior were in use and had been run (and reviewed) for the EFB case, this condition would have been seen and could have been avoided.
- We had an inadequate process and poor communication for modeling and analysis of power system behavior

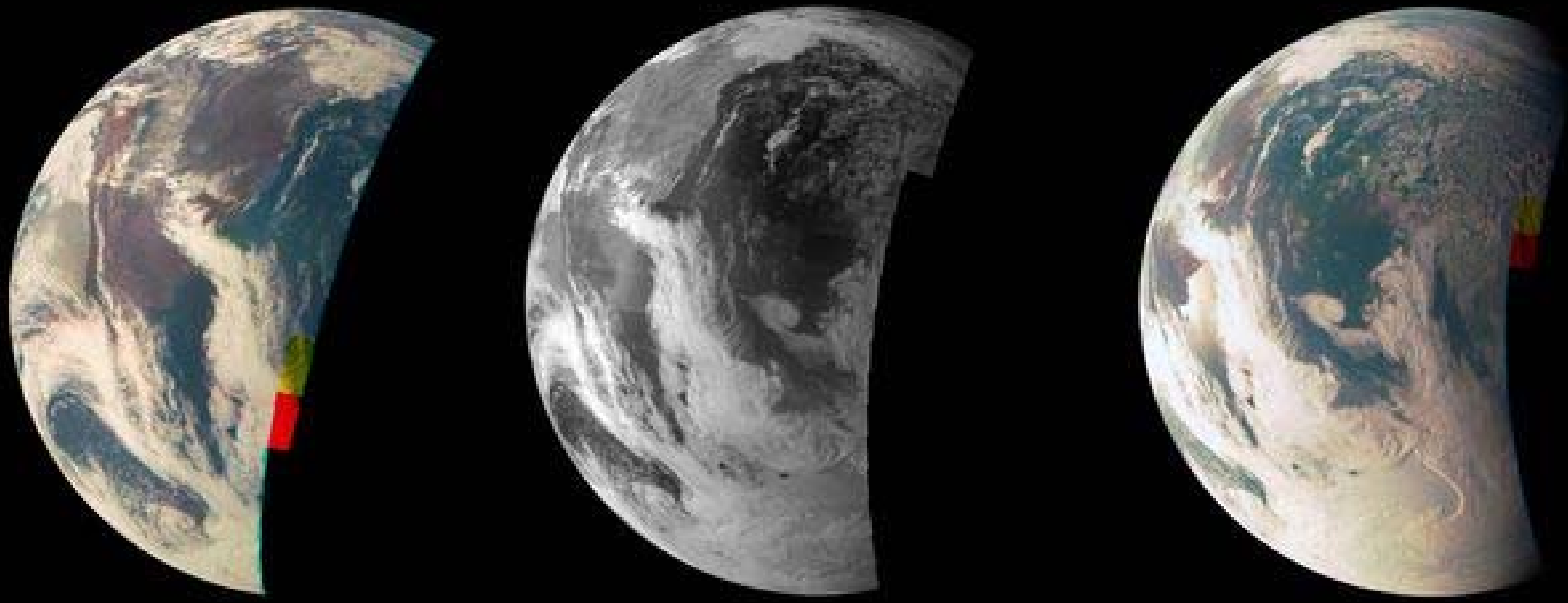
Was There Something To Do For Safe Mode #2

- We don’t have adequate tools to check and verify the states on the spacecraft
- We found we didn’t have enough staff to properly review all the flight telemetry and analyze data while at the same time conducting flight operations

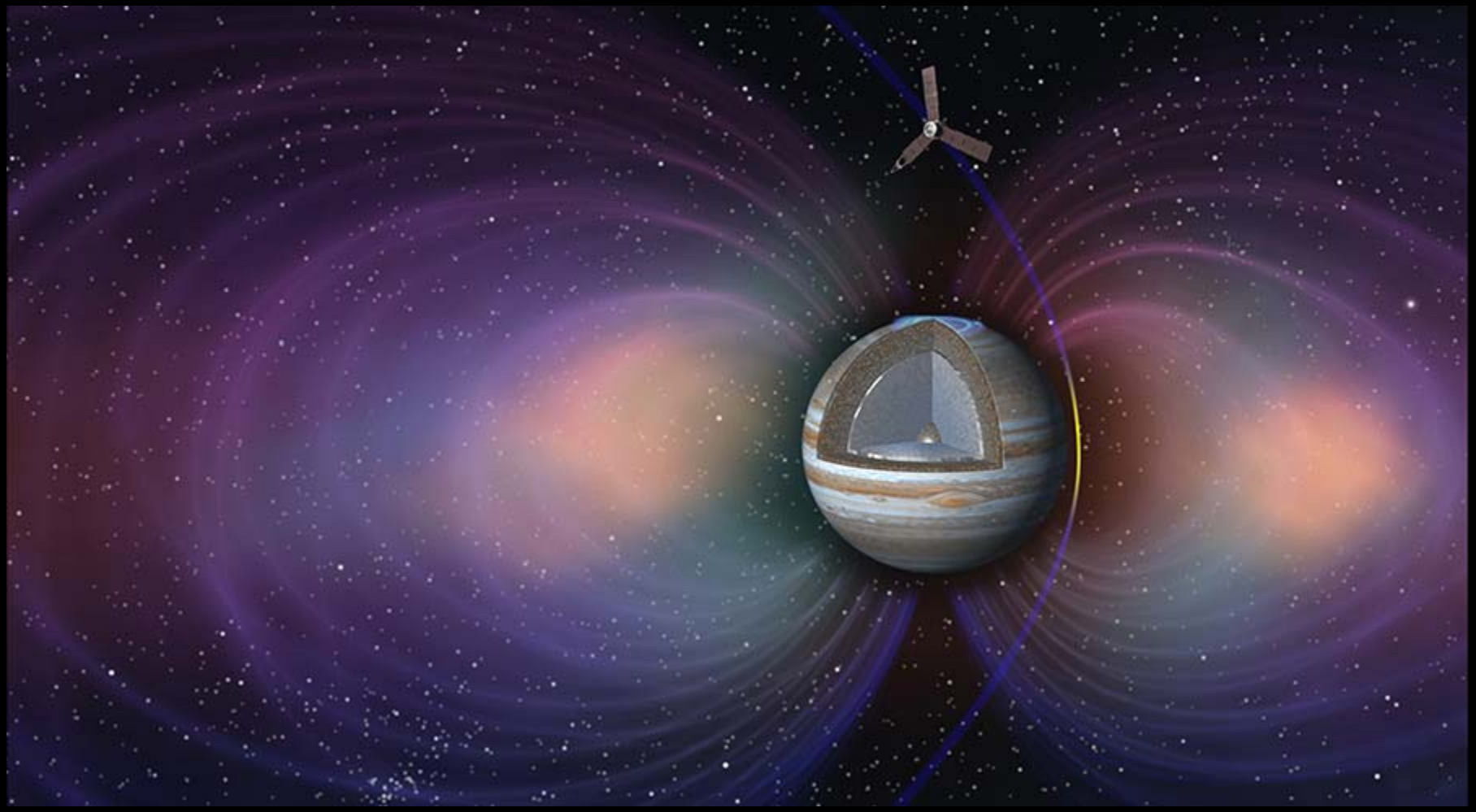
And Finally Safe Mode #3

- The reset mechanism for the Sun-Earth Tag-up timer was not clearly communicated from pre-launch development to the operational team
  - The correct value of the timer was not verified after launch or safe mode #1 exit
  - All fault protection timers need to be very visible in telemetry and the proper value must be clearly

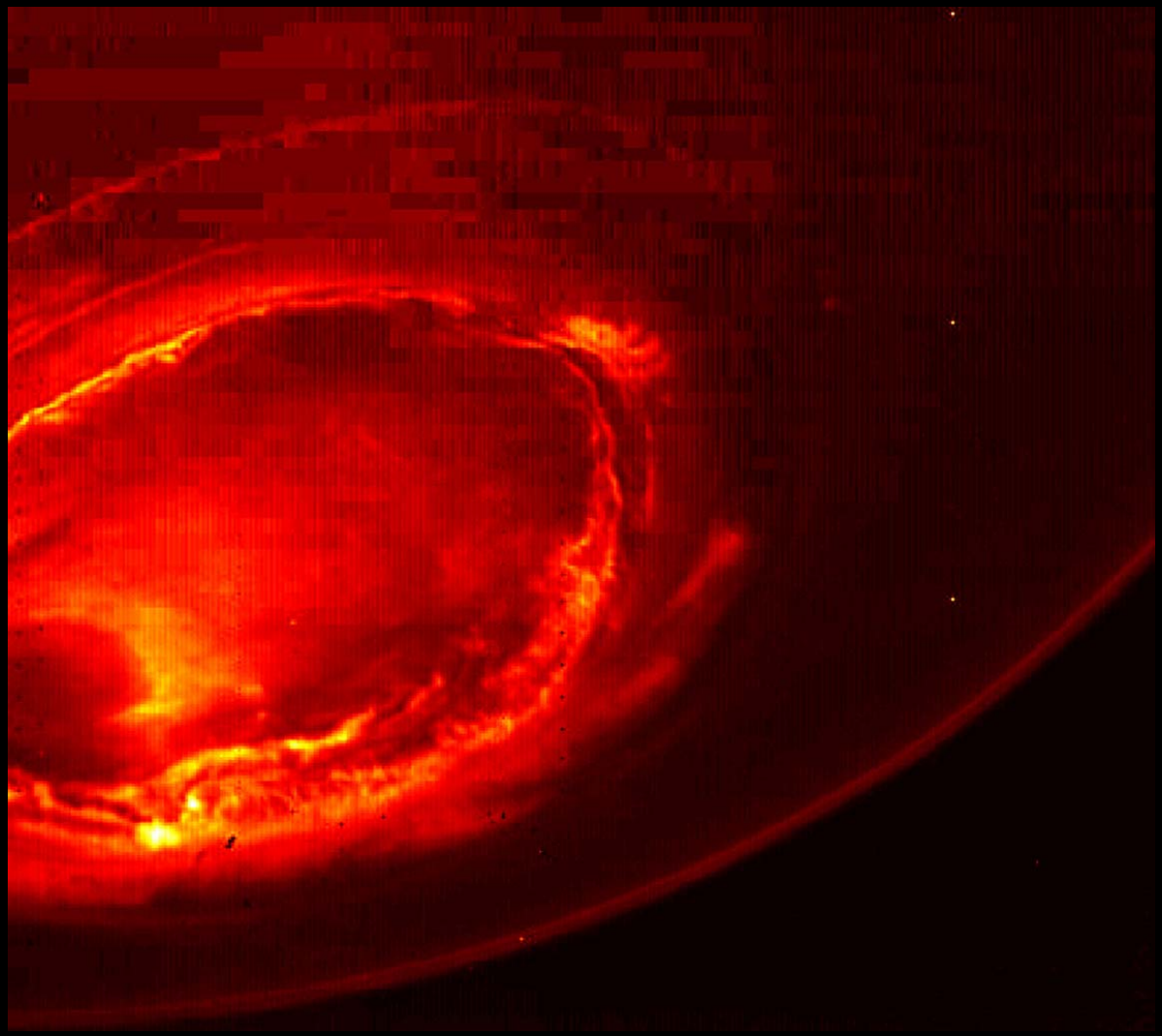
So We Learned a Lot from Earth Fly-by



As We Proceed to Learn More About Jupiter



And Enjoy her Beauty



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