National Aeronautics and Space Administration

Laboratory

direct readout

Aging Gracefully in the EOS Constellation

CSPP User's Group 2022

*developing technologies for **real-time** collection, processing, and distribution of Earth science data*

The Direct Readout Laboratory (DRL) at NASA's Goddard Space Flight Center develops technologies to maximize the utility of Earth science data for real-time decision-making.

- The DRL serves as the bridge between user needs and mission objectives.
- The DRL's technology development process stresses continuity and standardization.
- DRL technologies enable instant access to instrument data and derivative products from the Aqua and Terra missions and, in the future, the NPP and NPOESS missions.
- DRL technologies are designed to be scalable, extensible, portable and easy to use.

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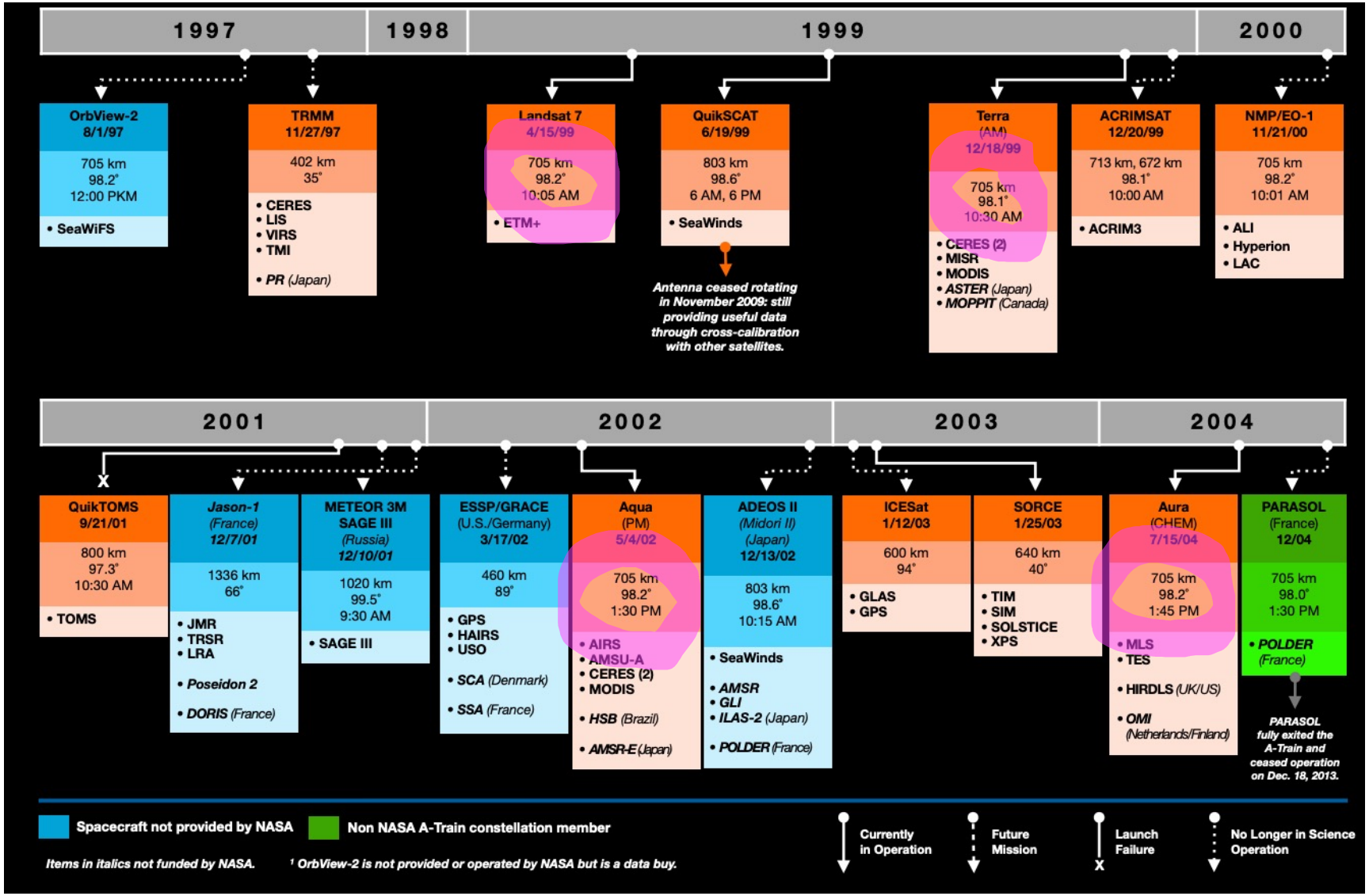
directreadout.sci.gsfc.nasa.gov

Background

- NASA Goddard Space Flight Center (GSFC) built many spacecraft in the Earth Observing System (EOS) constellation
- NASA Developed instrument data processing algorithms for MODIS on the Terra and Aqua platforms
  - Expanded to support other NASA instruments (e.g. AIRS, AMSU, CERES)
  - Develops algorithms for SNPP/JPSS VIIRS and other instruments
  - Currently developing algorithms and testbeds for JPSS-2
- Mission Operations Centers (MOCs) for Aqua, Aura, Terra and Landsat 7 (to name a few) are located on the GSFC campus
  - Aqua and Terra currently producing weather data from Polar LEO
  - Landsat 7 is operated by NASA as a client for an upcoming satellite servicing mission OSAM-1 (more on this later!)
- These spacecraft were all launched between 1999-2004
  - How are they affected by age?
  - How does that affect the science?

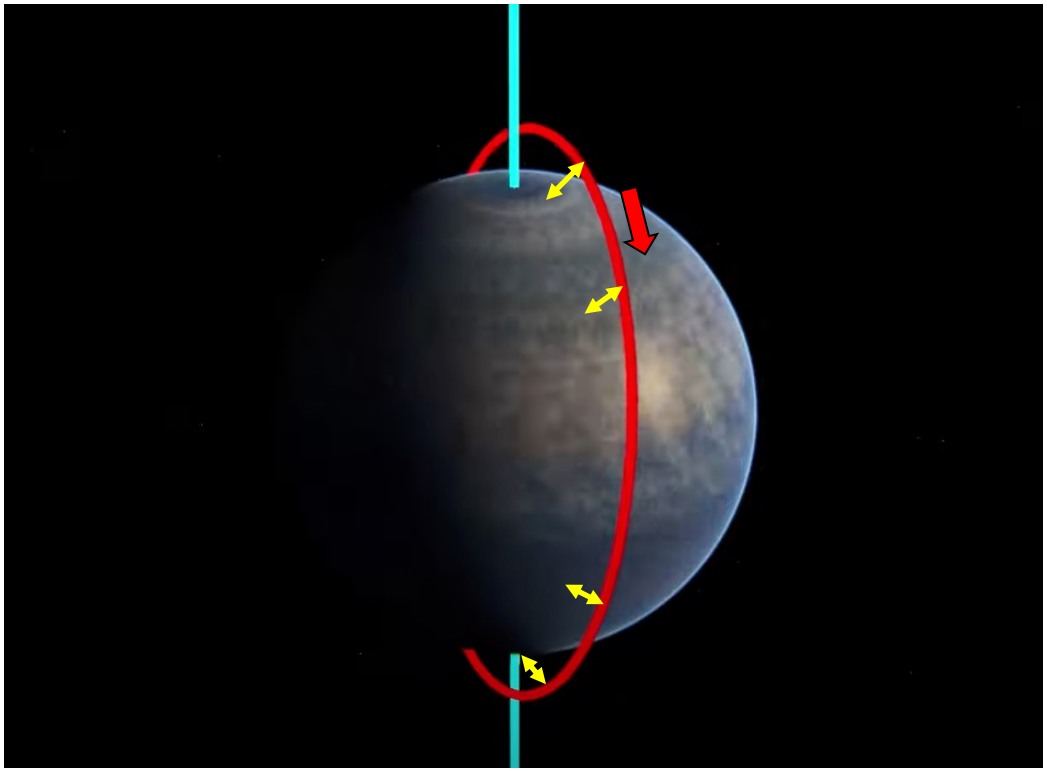
EOS Mission Profiles 1997-2004

source: https://eospso.gsfc.nasa.gov/files/mission_profile.pdf, current as of 2017



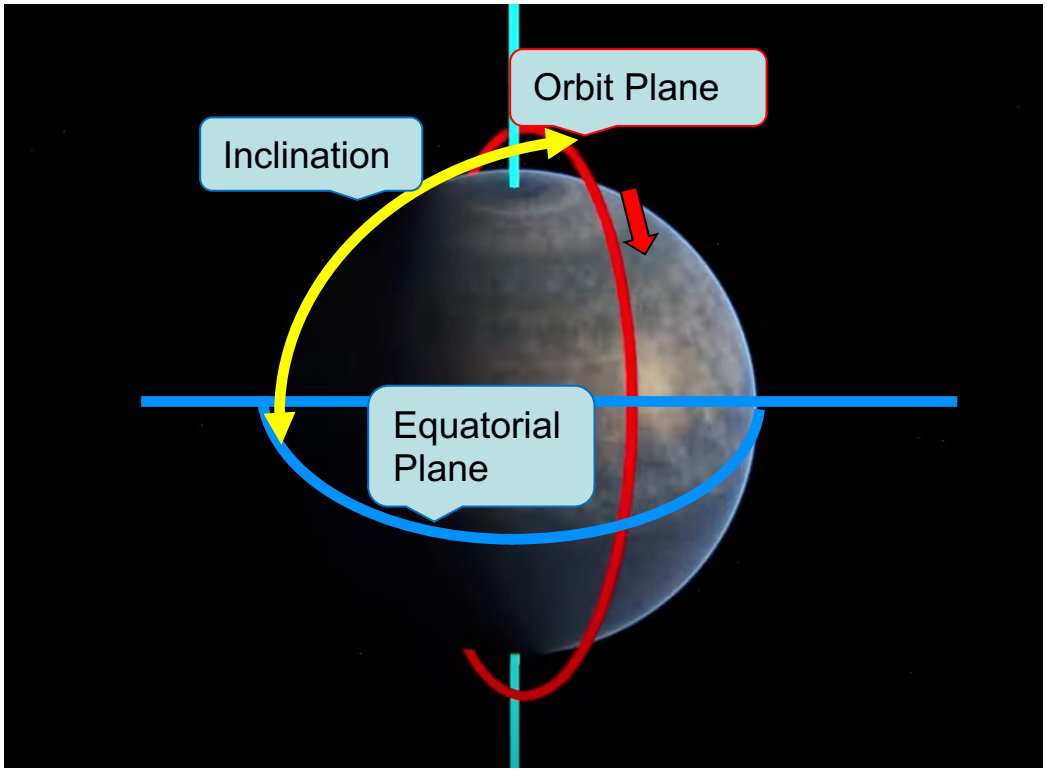
Polar LEO Parameters – Mean Altitude

- Measured above Earth surface datum
- Elliptical - your altitude may vary
- Circular orbits are good: apoapsis ~= periapsis



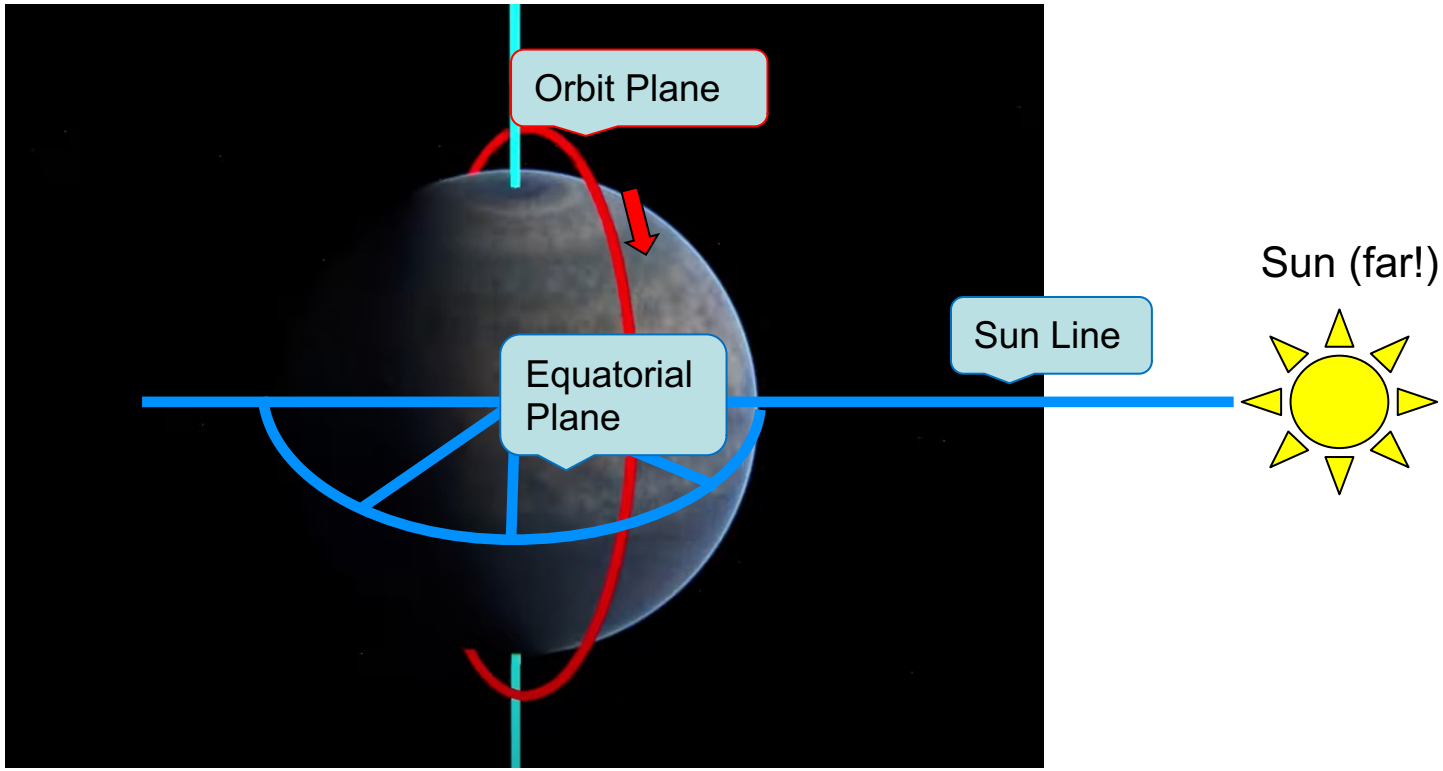
Polar LEO Parameters - Inclination

- Angle between Orbit Plane and Equatorial Plane
  - Angles around 98 degrees result in stable (ish) Sun Synchronous orbit



Polar LEO Parameters - MLTDN

- What time is it where the Orbit Plane crosses the equatorial plane (node) going North to South (descending)?
  - That's the MLTDN (mean local time of descending node)
  - Remains fixed regardless of what longitude of Earth happens to be under that point
  - Assumes true local times! Every point on the equator has its own conversion to UTC.



Visualization

- Source: https://youtu.be/ylvgxNF3C0c (Eumetsat)

Aging Orbits

- Factors that perturb orbit over time
  - Drag
  - Non-spherical Earth (magnetic and gravitational affects)
  - Solar Flux (or 'wind')
- These are mitigated by carefully planned impulsive maneuvers which consume a limited resource: fuel
- What happens if these maneuvers are not performed?
  - MLTDN will tend towards 6AM (orbit normal to the Sun) but will oscillate.
  - Beta angle will change (that's the angle between the orbit plane and the Sun vector) – some instruments have Beta angle limits
  - Orbit will lower
    - lower orbit has shorter period (flight dynamics is weird)

im·pul·sive

[imˈpəlsiv]

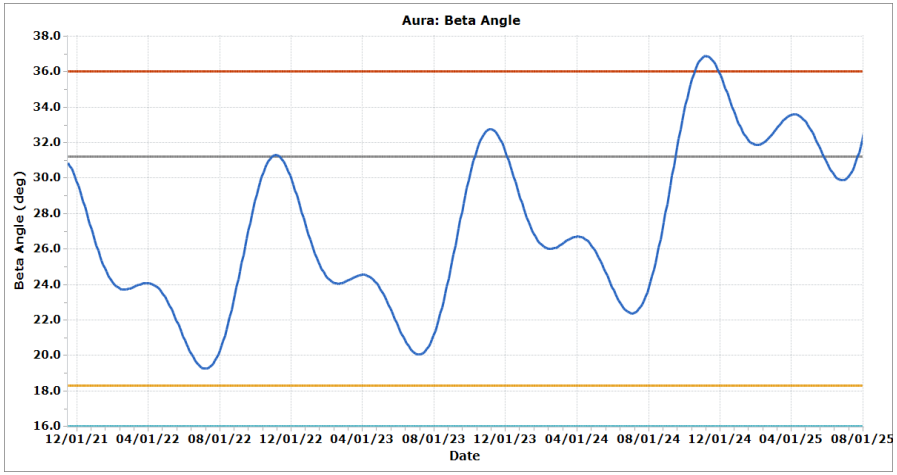
ADJECTIVE

impulsive (adjective)

1. acting or done without forethought:
   "they had married as young impulsive teenagers" · "perhaps he's regretting his impulsive offer"
   synonyms: impetuous · spontaneous · hasty · passionate · emotional · uninhibited · unrepressed · abandoned · rash · reckless · foolhardy · madcap · devil-may-care · daredevil · hotheaded · wild · daring · adventurous · impromptu · snap · unpremeditated · spur-of-the-moment · extemporaneous · precipitate · headlong · incautious · imprudent · injudicious · sudden · quick · ill-considered · ill-thought-out · unplanned · thoughtless · unthinking
   antonyms: cautious · premeditated
2. *physics*
   acting as an impulse:
   "the approaching waves contain an impulsive component"

ORIGIN

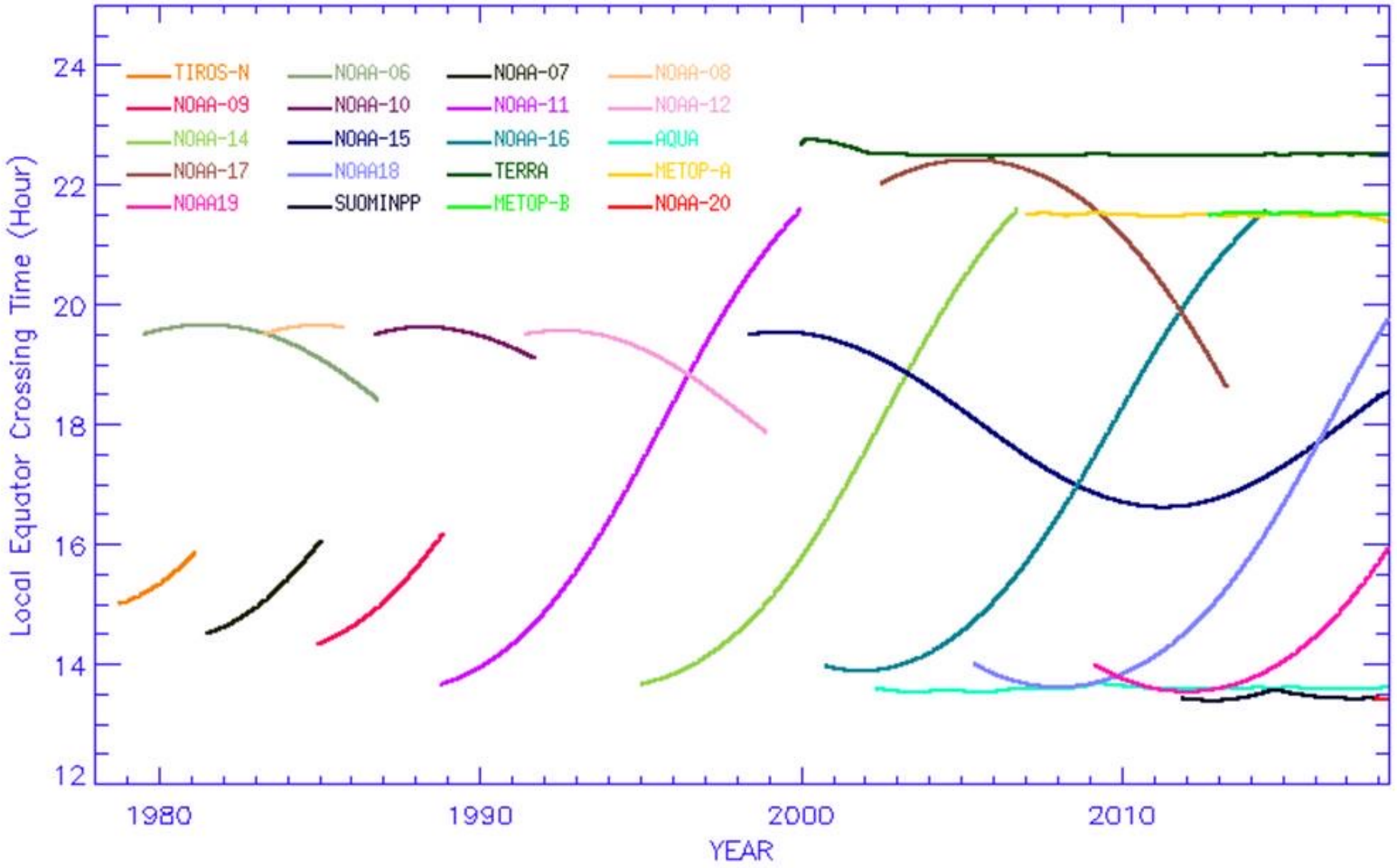
late Middle English (in the sense 'tending to impel'): from French impulsif, -ive or late Latin impulsivus, from Latin impuls- 'driven onwards' (see impulse). impulsive dates from the mid 18th century.



- For science data this means:
  - Lighting conditions and re-visit pattern change
- Eventually, spacecraft will re-enter Earth atmosphere and burn up.
  - This is required within 25 years of mission end for orbital debris mitigation.
- Specific information on Terra: https://terra.nasa.gov/about/terra-orbital-drift-information

Aging Orbits – LEO Weather

- Here's MLTAN for the entire fleet
- Source: https://www.star.nesdis.noaa.gov/jpss/orbit_drift.php



Aging Satellites

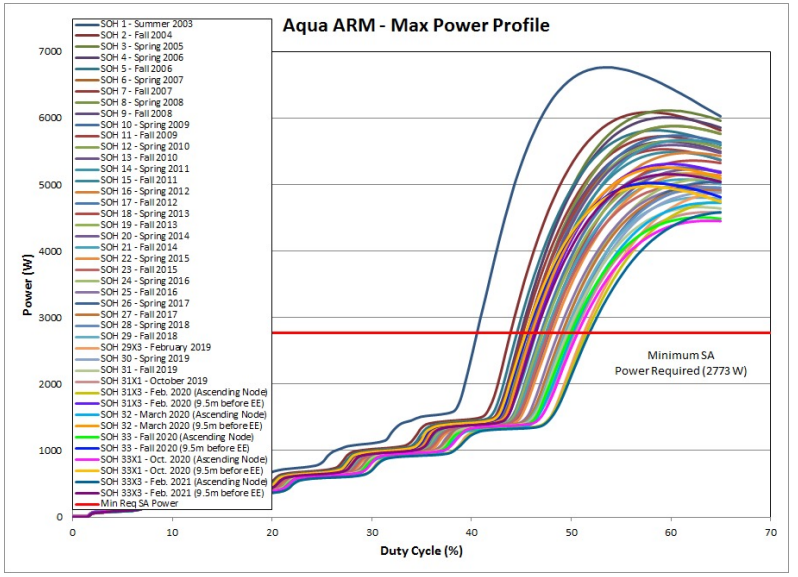
Fuel is not the only life limiting factor

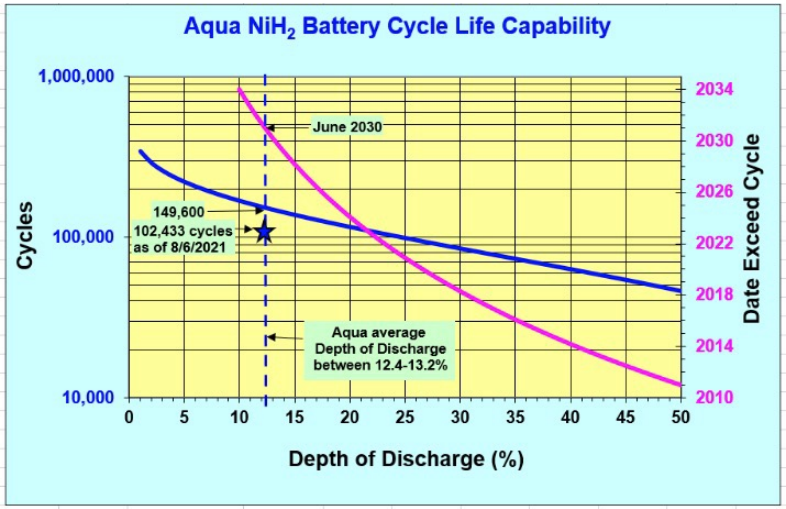
- Electrical power generation gradually decays as solar arrays age
- Batteries lose efficiency over time
  - this is critical for operations when spacecraft transit Earth's shadow for part of each orbit
  - Aqua performed a discharge test recently and cell capacity was much better than predicted for this age
- Equipment fails and is not repaired
  - instruments lose channels or data storage capacity mainly due to ionizing radiation (charged particles)
  - thruster components lose efficiency with use
  - attitude control via reaction wheels and magnetic torque bars can fail
  - onboard redundancy is eventually used up

Mission Managers perform complex trades

- When to cease Inclination Adjustment Maneuvers?
- When to perform orbit lowering to exit EOS constellation orbit and ensure the required < 25 year re-entry?
- When to cease science operations?

"Aging Gracefully" requires creativity and skill





Life Extension

- On-Orbit Servicing, Assembly and Manufacturing 1 (OSAM-1) is in development to refuel and orbit-raise the Landsat 7 spacecraft
  - Formerly “Restore-L”, renamed after addition of “SPIDER” assembly and manufacturing payload
- Mission is planned to launch February 2026
- Mission sequence includes:
  - Rendezvous with passive client (i.e. not actively guiding or controlling)
  - Berthing by clamping to Marmon ring used as launch attachment
  - Accessing and opening fuel valves used for fueling and closed out ‘permanently’ with safety wiring and thermal blanketing
  - Transfer of propellant to Landsat’s internal tanks
  - Boost towards operational orbit
- Technology demonstration to develop and test concepts that can be enhanced by pre-mission preparation of future science spacecraft
  - Cooperative servicing valves for fuel
  - Reflectors and reference markings for docking
  - Modular designs for on-orbit unit replacement

Contact

Web Links

- DRL: https://directreadout.sci.gsfc.nasa.gov/?id=home
- OSAM-1: https://nexis.gsfc.nasa.gov/osam-1.html
- Cooperative Servicing: https://nexis.gsfc.nasa.gov/cooperative_servicing_aids.html

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