

InSight End of Mission

Sol 1211

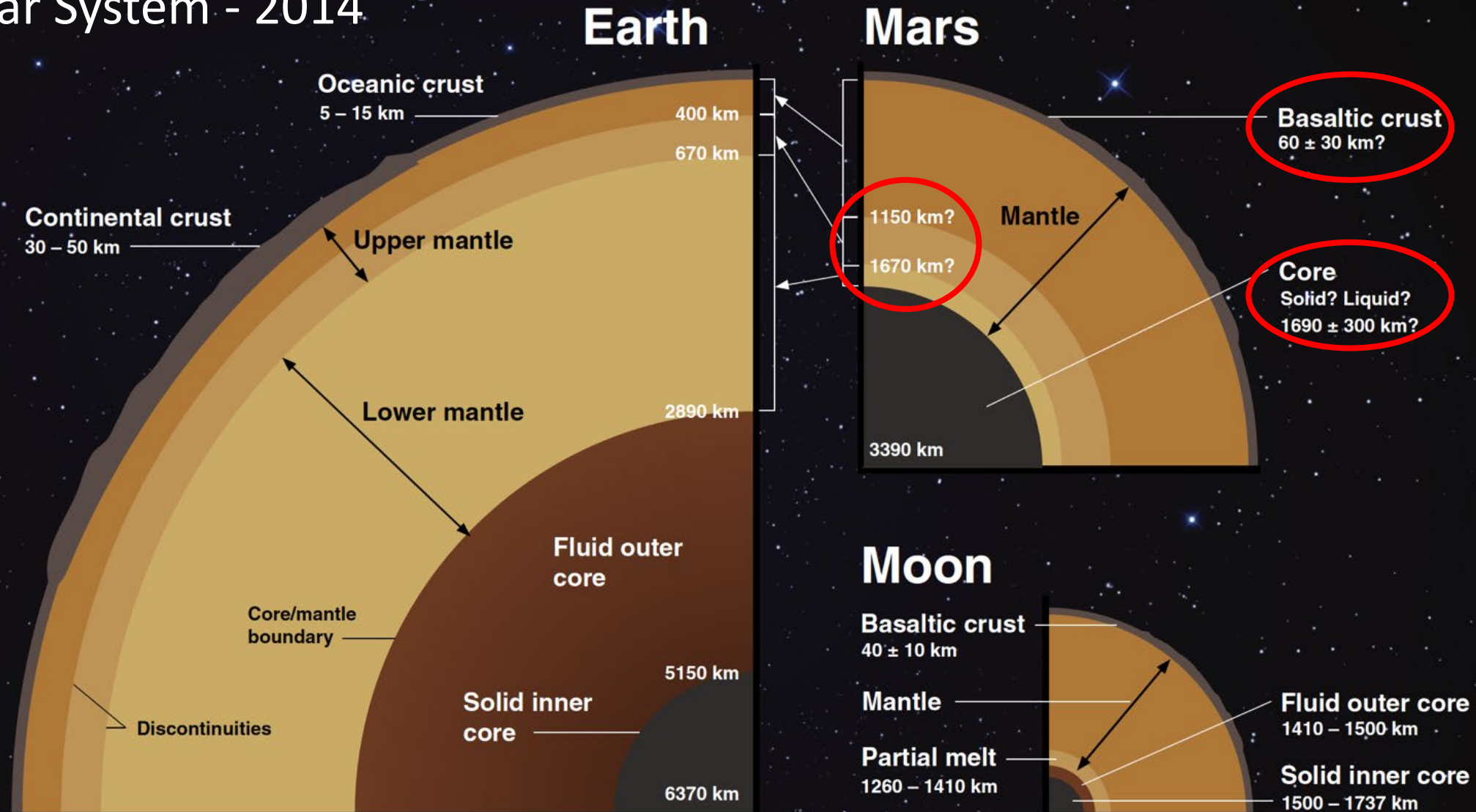
Bruce Banerdt
Jet Propulsion Laboratory, California Institute of Technology
27 February, 2023

- Last Transmission: December 15, 2022, 03:07 PST (Sol 1440, 15:05:30 LMST)
- Estimated DBR entry: December 16, 2022 (Sol 1442, ~01:00 LMST)
- Declared End of Mission: December 20, 2022
- Time on Mars: 4 years, 19 days
- Prime Mission: 720 sols
- Extended Mission: 680 sols
- DBR = Dead Bus Recovery Mode

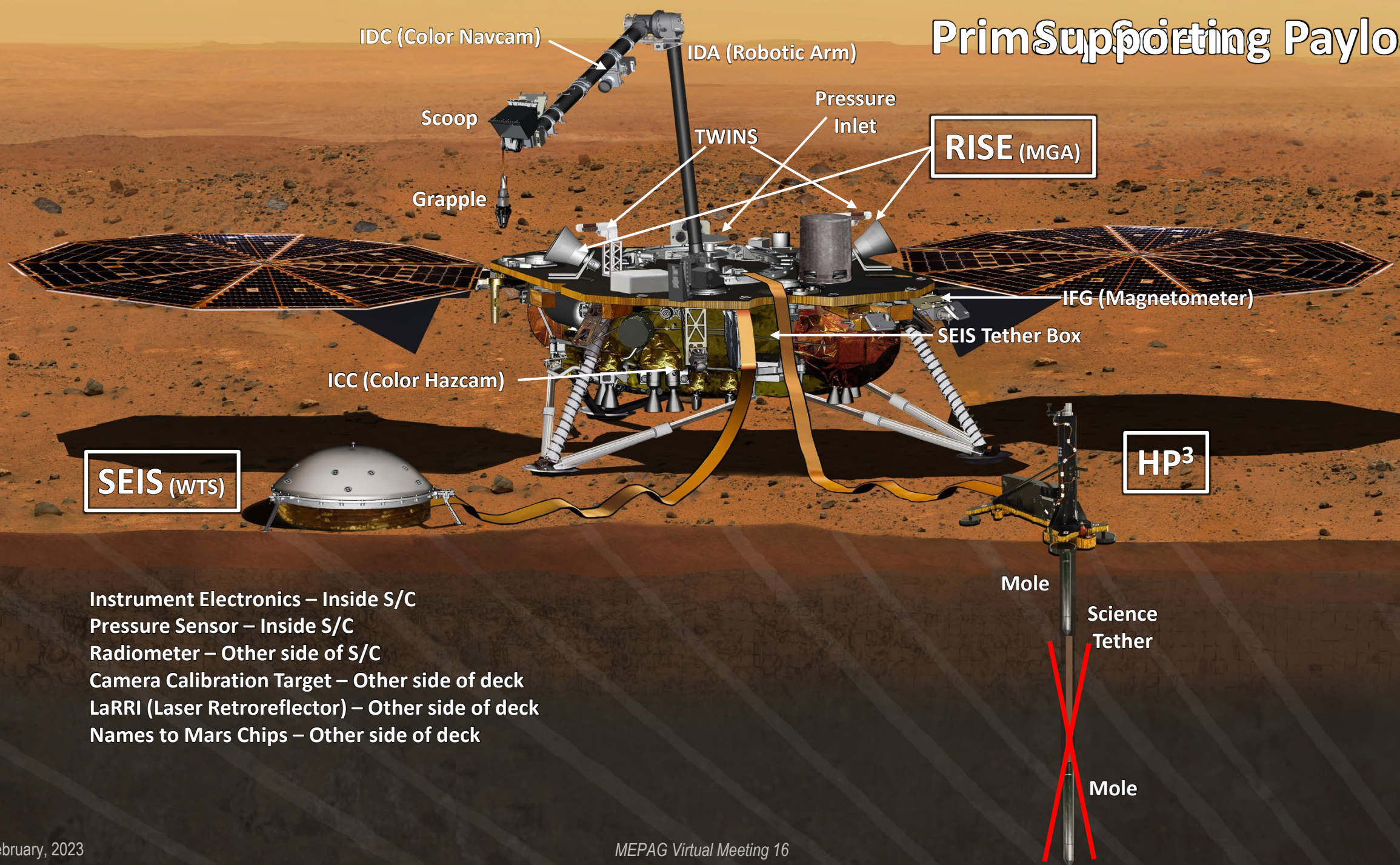
Scientific Results

Mars Structure Compared to Earth and Moon

From the Encyclopedia of the
Solar System - 2014



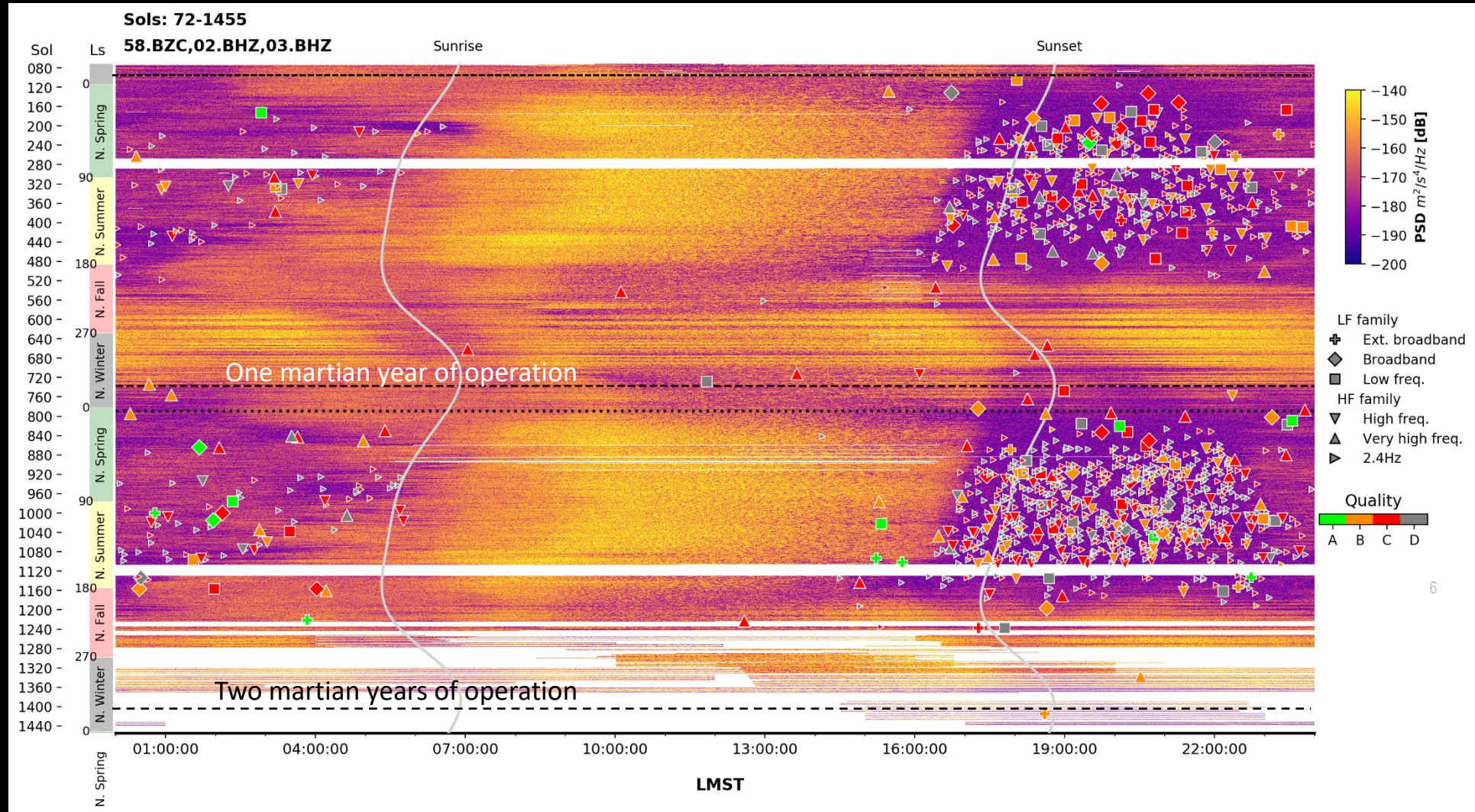
Primary Supporting Payload



Instrument Electronics – Inside S/C
Pressure Sensor – Inside S/C
Radiometer – Other side of S/C
Camera Calibration Target – Other side of deck
LaRRI (Laser Retroreflector) – Other side of deck
Names to Mars Chips – Other side of deck

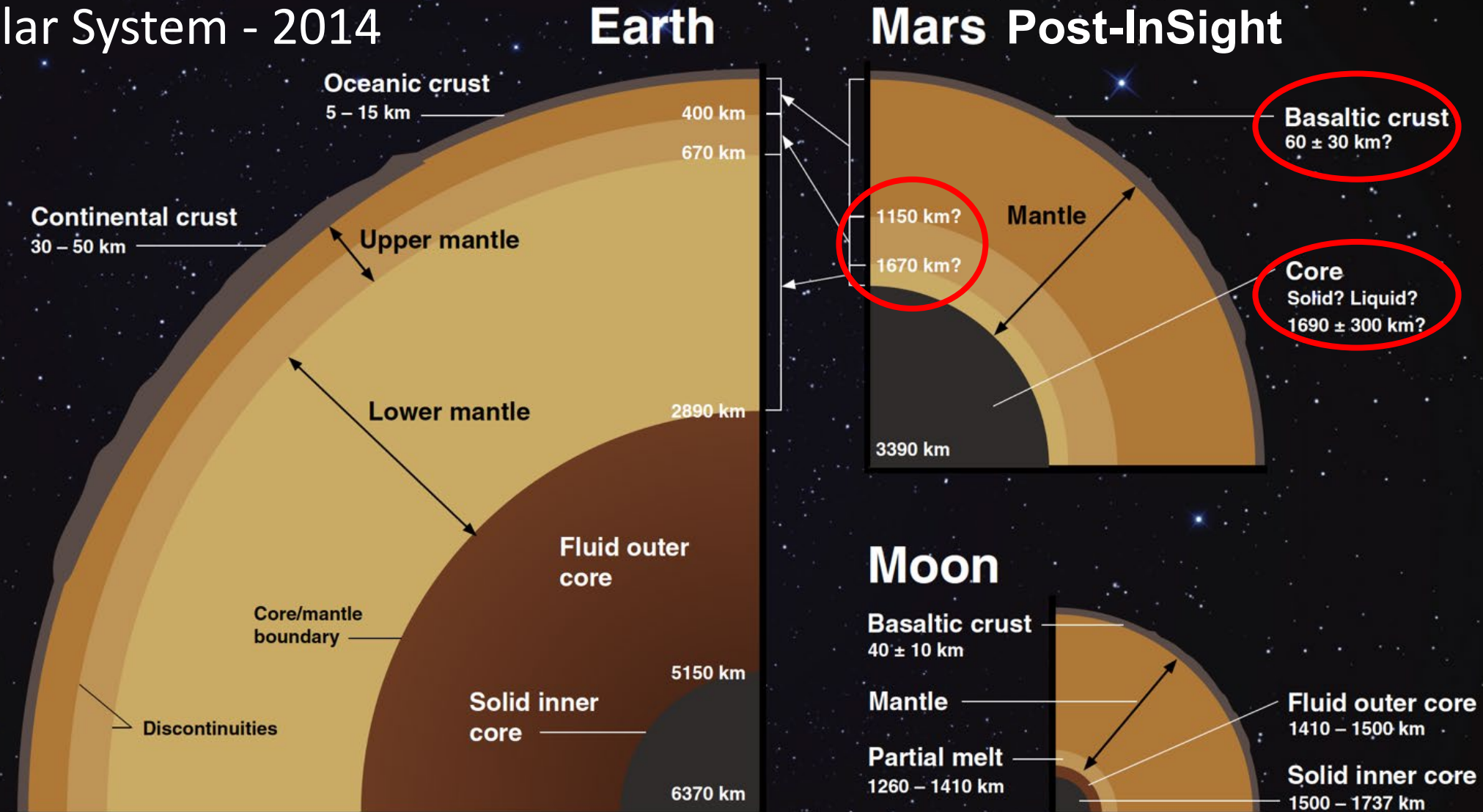
Req. #	Title	L1 Requirement	Instrument
Threshold			
L1-SCI-41 ✓	Crust Thickness	Determine the depth of the crust-mantle boundary to ± 10 km.	SEIS
L1-SCI-42 ✓	Crust Layering	Detect velocity contrast ≥ 0.5 km/sec over depth interval ≥ 5 km within the crust, if it exists.	SEIS
L1-SCI-43 ✓	Mantle Structure	Determine seismic velocities in the upper 600 km of the mantle to within ± 0.25 km/sec.	SEIS
L1-SCI-45 ✓	Core State	Distinguish between liquid and solid core to 90% confidence.	SEIS + RISE
L1-SCI-46 ✓	Core Radius	Determine the radius of core to within ± 200 km.	SEIS + RISE
L1-SCI-47 ✓	Core Density	Determine the average core density to within ± 450 kg/m ³ .	SEIS + RISE
Baseline			
L1-SCI-49 ✗	Heat Flux	Determine the heat flux at landing site to within ± 5 mW/m ² .	HP ³
L1-SCI-50 ✓	Seismic Activity	Determine the rate of seismic activity to within a factor of 2.	SEIS
L1-SCI-51 ✓	Event Locations	Determine epicenter distance to ± 25 % and azimuth to $\pm 20^\circ$.	SEIS
L1-SCI-52 ✓	Impact Rate	Determine the rate of meteorite impacts to within a factor of 2.	SEIS

1319 Marsquakes



Mars Structure Compared to Earth and Moon – After InSight

From the Encyclopedia of the Solar System - 2014



Mapping the internal structure of Mars, its crust, mantle and core

Additional significant results in geology, meteorology, magnetics, spin dynamics

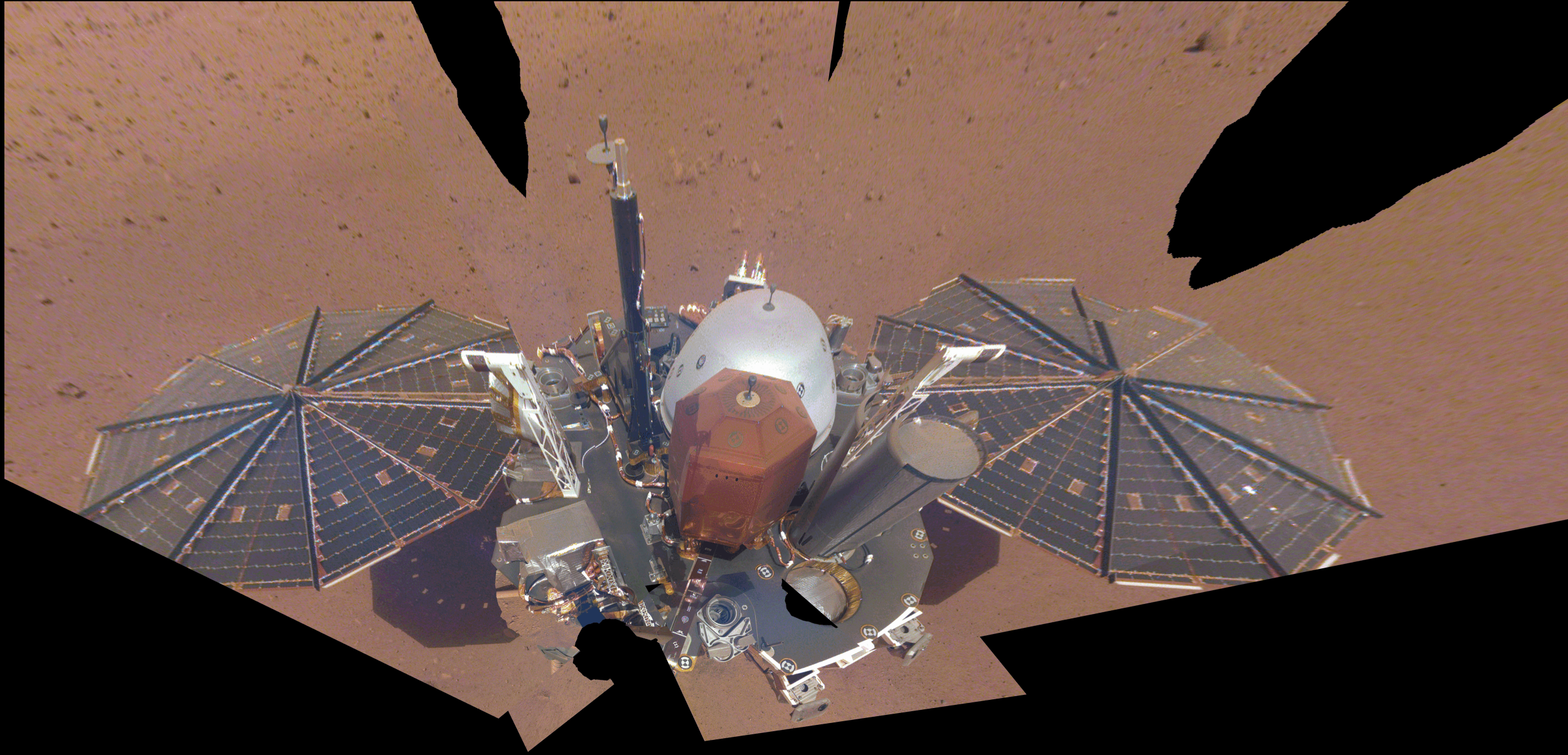
- First seismometer on the surface of Mars
- First detection of a marsquake
- First seismic measurement of the impact event for an identified crater
- Lowest seismic noise level ever measured on any planet
- First infrasound measurements on Mars
- First measurement of the nutation of a planet other than the Earth
- First magnetic measurements at the surface of Mars
- The most comprehensive and highest resolution weather data ever obtained on Mars
- The detection and characterization of more than 20,000 vortices (dust devils)
- First laser retroreflector at the surface of Mars
- First robotic deployment of an instrument to the surface of another planet
- First programming of a Frank Zappa wake-up song on a planet other than the Earth

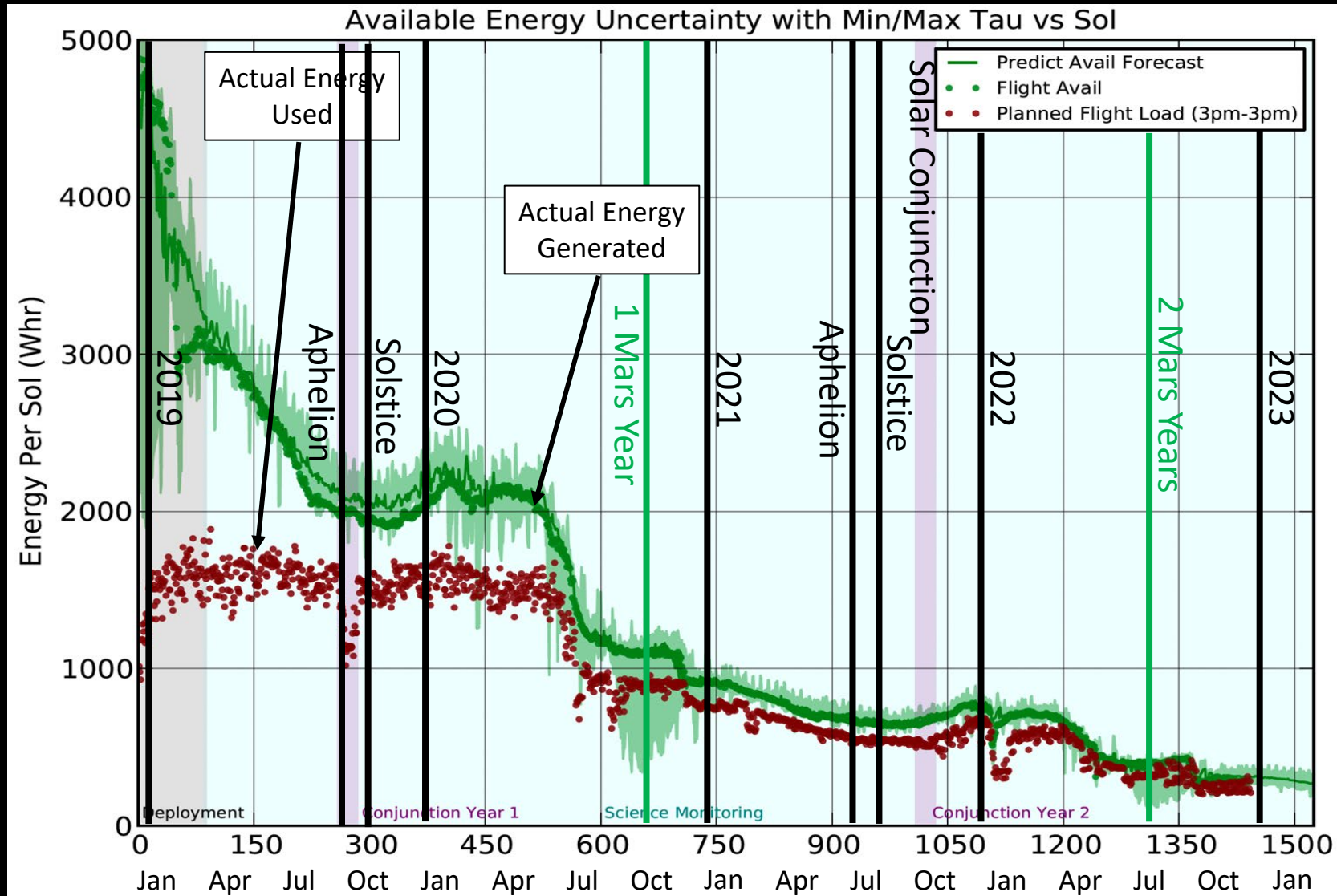
- The InSight Science Team has published over 225 peer-review papers thus far.
 - InSight papers have been featured in a number of high-impact journals, including *Science*, *Nature*, *Journal of Geophysical Research*, and *Proceedings of the National Academy of Sciences*.
- The paper by Stähler et al., “Seismic detection of the Martian core”, has been awarded the AAAS Newcomb Cleveland Prize for outstanding paper of 2022 in the journal *Science*.
- There are more than 50 additional team papers that are submitted or in active preparation, including a *Geophysical Research Letters* special collection focused on the large S1222a event.
- Dozens of papers from outside the team have been published using InSight data, and more are coming out every month.



- Throughout the mission, InSight has consistently released it's data on schedule, within 6 months of acquisition.
- There is one remaining scheduled PDS data release on Mar. 31, which will contain the final batch of science data acquired from Oct. 1 – Dec. 15, 2022.
- A final reprocessed archive data set will be released on Jun. 31
- In addition to the instrument data, the InSight project provides higher-level, derived data products to PDS. These include reference interior models and marsquake catalogs.
- The process for generating these products is iterative, and includes peer-review and publication.
- This process is expected to take up to an additional year.

What Happened?

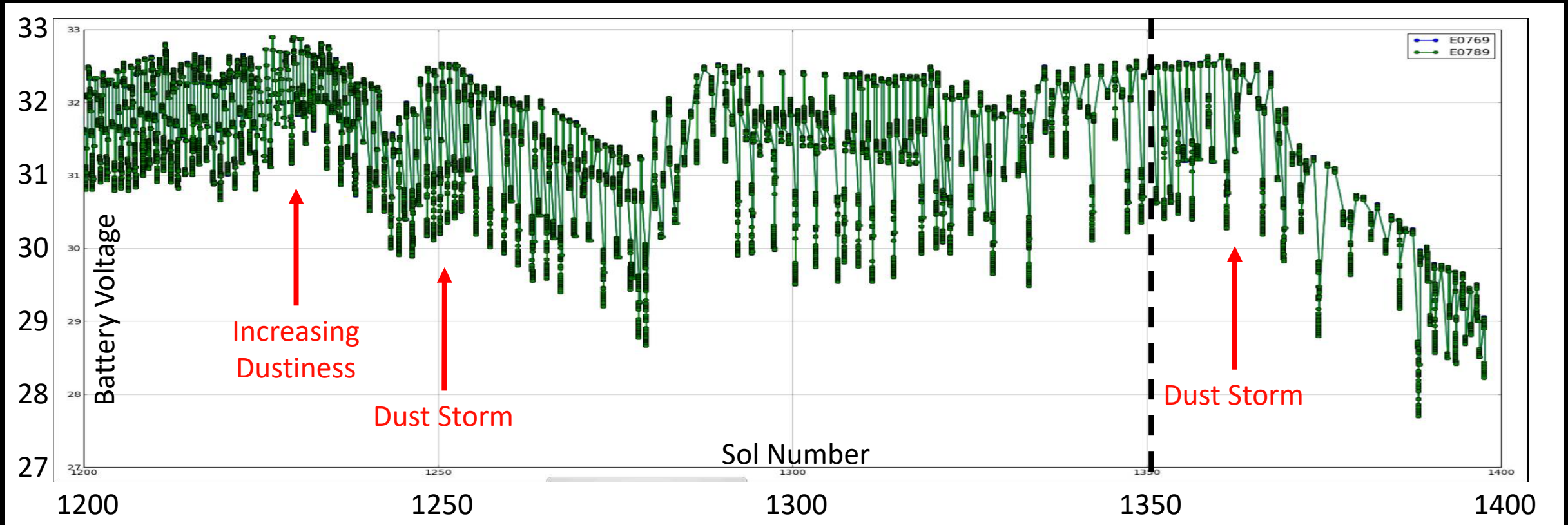


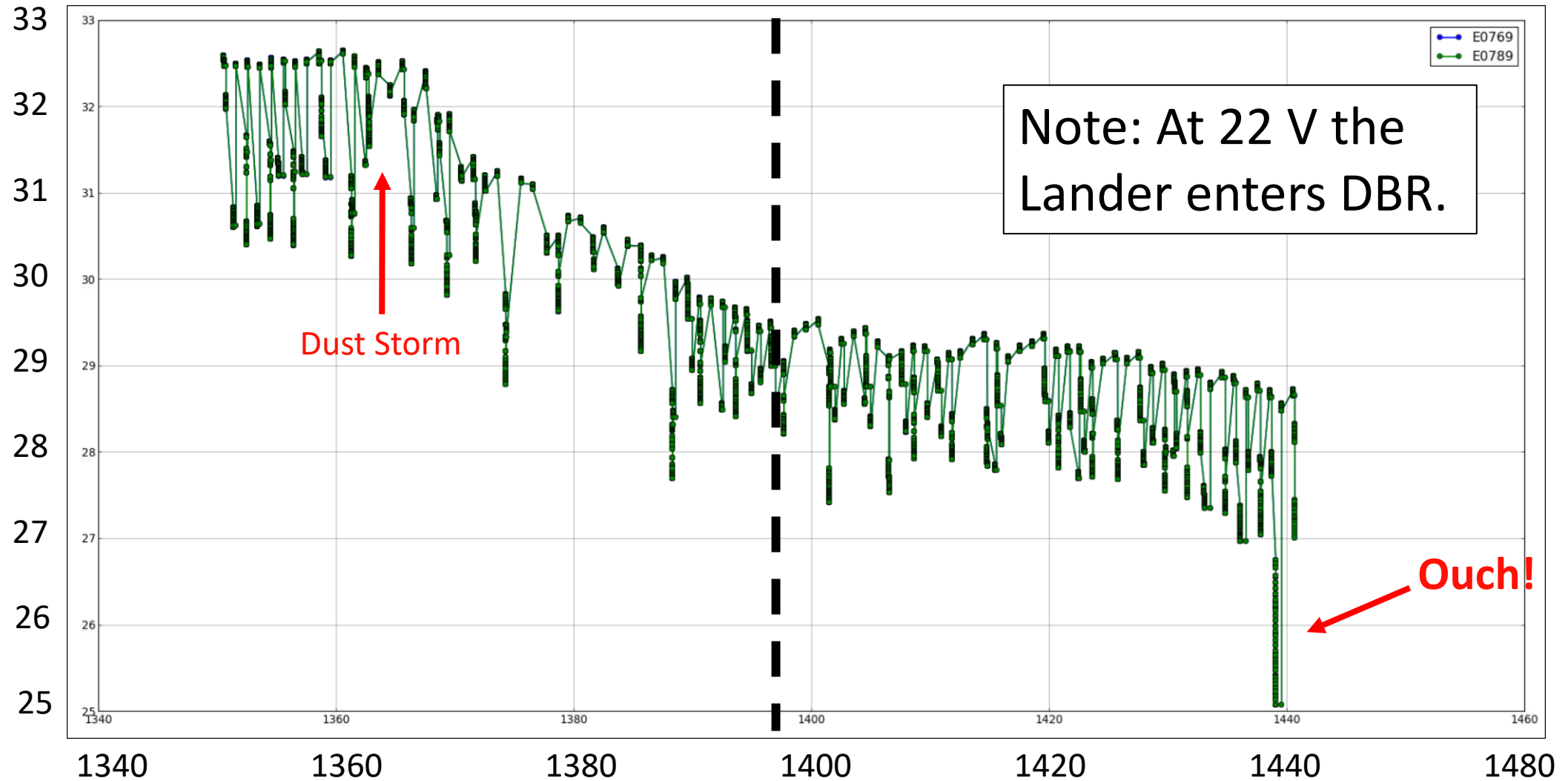


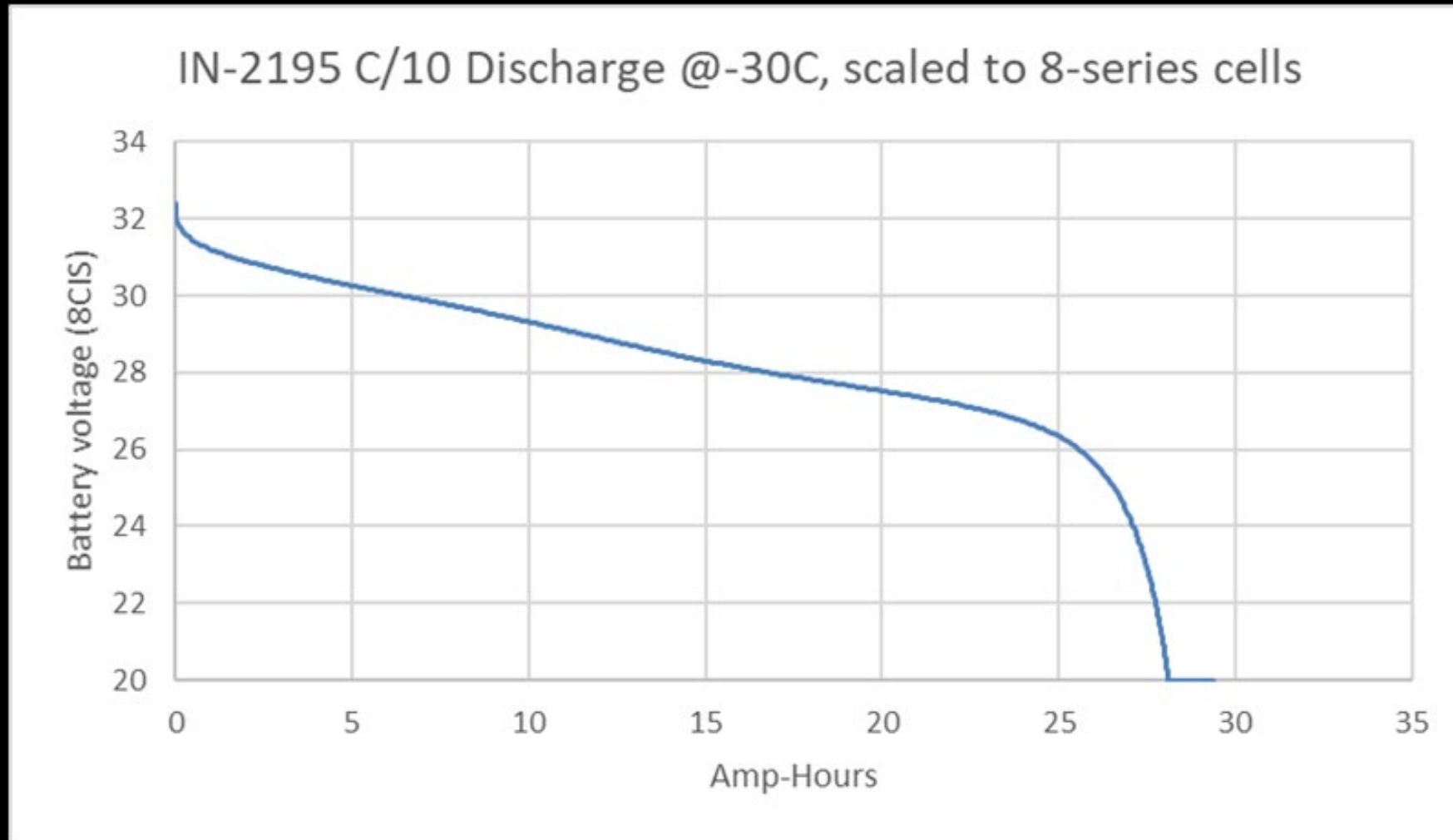
By late last year our 4-Sol operational routine was:

Sol 1: Run SEIS 8 hr. Sol 2: Transmit data. Sol 3: Sleep/recharge. Sol 4: Sleep/recharge.

This allowed us to continue to obtain seismic data, but was slowly depleting the batteries.









The InSight Mission was Designed to Die

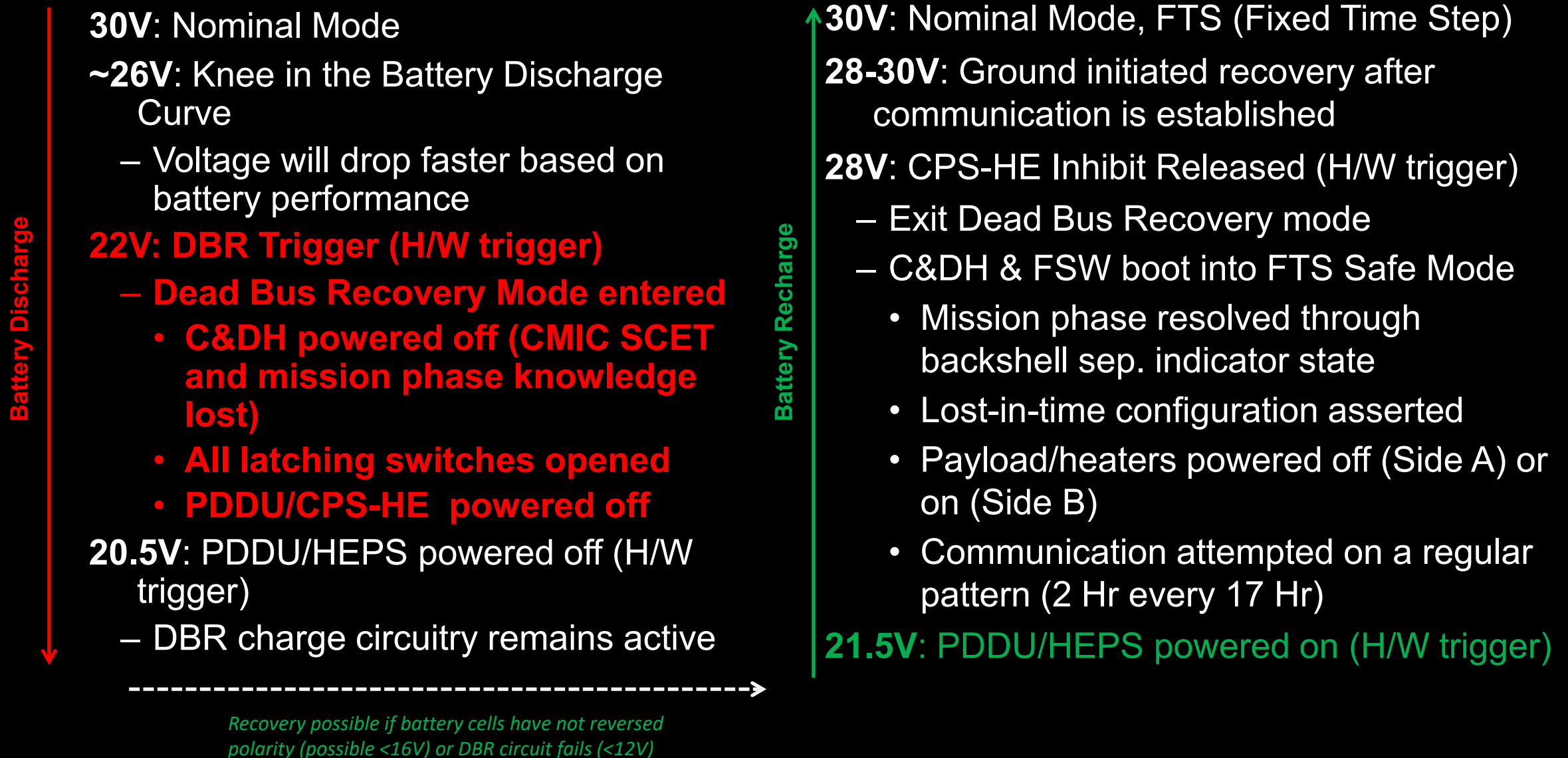
- InSight is a cost-capped Discovery Program mission.
- It was designed to accomplish ten specific scientific objectives (Level-1 Requirements).
- During development (i.e., proposal writing) the science team concluded that these objective could be met with one Mars year (~2 Earth years) of surface operations.
- Thus, we implemented a power system (based on the Phoenix system) that was affordable and would support operations for a Mars year (with margin).
- But not much more.
- Mission lifetime was pretty predictable:
 - We knew solar array efficiency, insolation as a function of orbital position, probabilistic tau as a function of season.
 - We also knew the rate of dust accumulation on Mars (Pathfinder, Spirit, Opportunity).
- There were no surprises on Mars with any of these.

Did We Think It Was Going to Die?

- Officially, yes. In our hearts, no.
- Both Spirit and Opportunity experienced multiple “cleaning events”, presumably from vortices. We had some expectation that this would happen for InSight as well.
- Why didn’t it?
- We believe that they are associated with wind events, and in particular atmospheric vortices (e.g., dust devils).
- There are many vortices at the InSight location, similar in number to Gusev Crater.
 - PS and SEIS detected more than 20,000 of them nearby over the course of the mission; none were seen in images.
- However, tracks as seen from orbit are much narrower and straighter than those near Spirit.
- Comparing the rate of area swept out by tracks, we should expect the rate of direct hits on the lander to be ~10X less frequent than in Gusev (which was ~1/200 sols).
- This implies a mean time between cleanings of ~7 years.

What's Next?

Dead Bus Recovery Sequence



- We have set up a program to listen for InSight's recovery within the existing Mars Network services.
 - X-band open loop recording during comm passes with other Mars assets (~daily)
 - UHF overflight passes on a non-interference basis (several times/week)
- Paid for with left-over InSight FY22 funds
- Responsibility handed over to Mars Exploration Program at InSight's End of Project, June 30, 2023.
- This phase is scheduled to last through the end of FY25

Sunset over Elysium Planitia, Sol 1198

