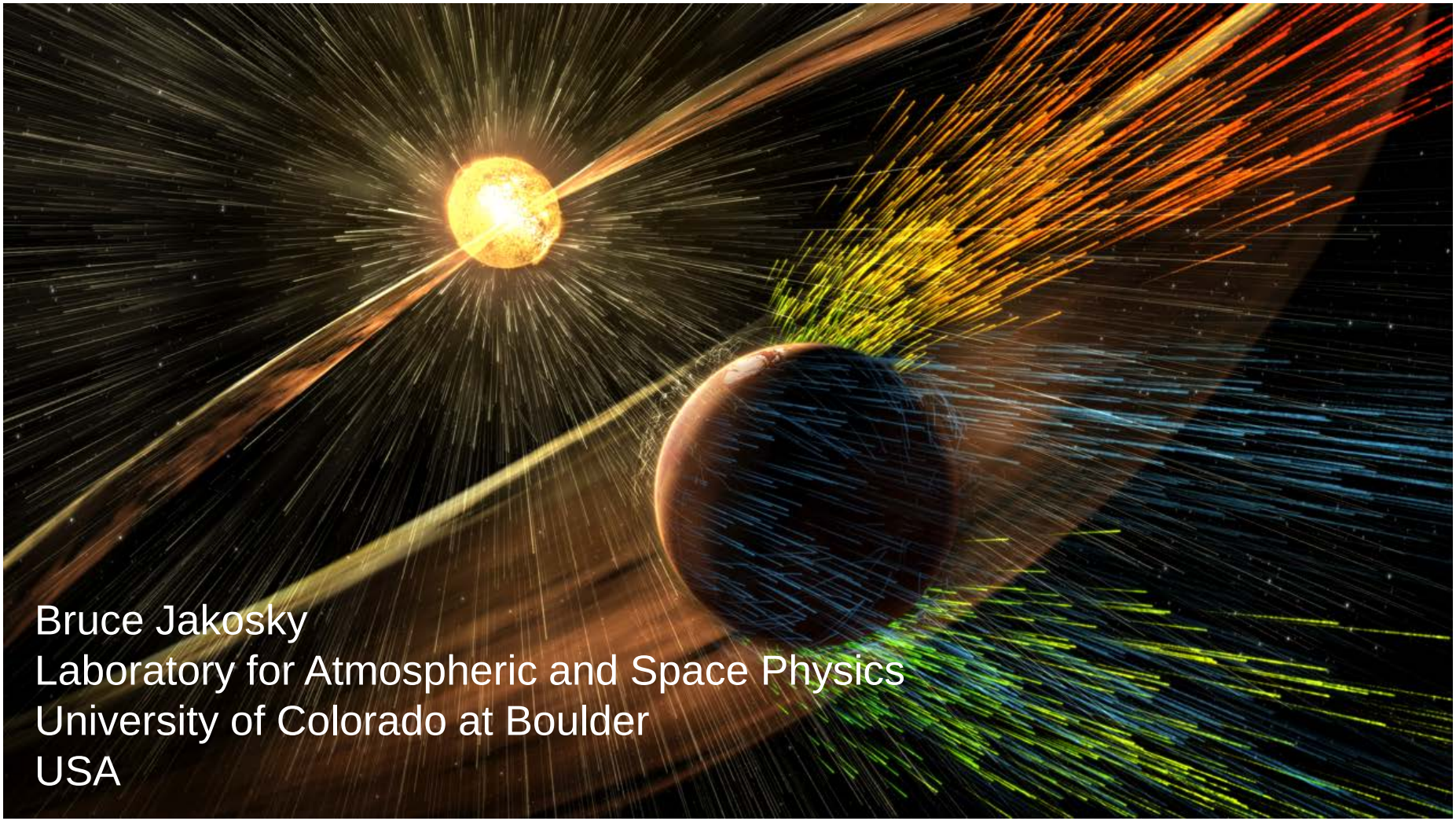
Mars Atmosphere and Volatile Evolution Mission (MAVEN)

Status of the MAVEN Mission at Mars
18 May 2018



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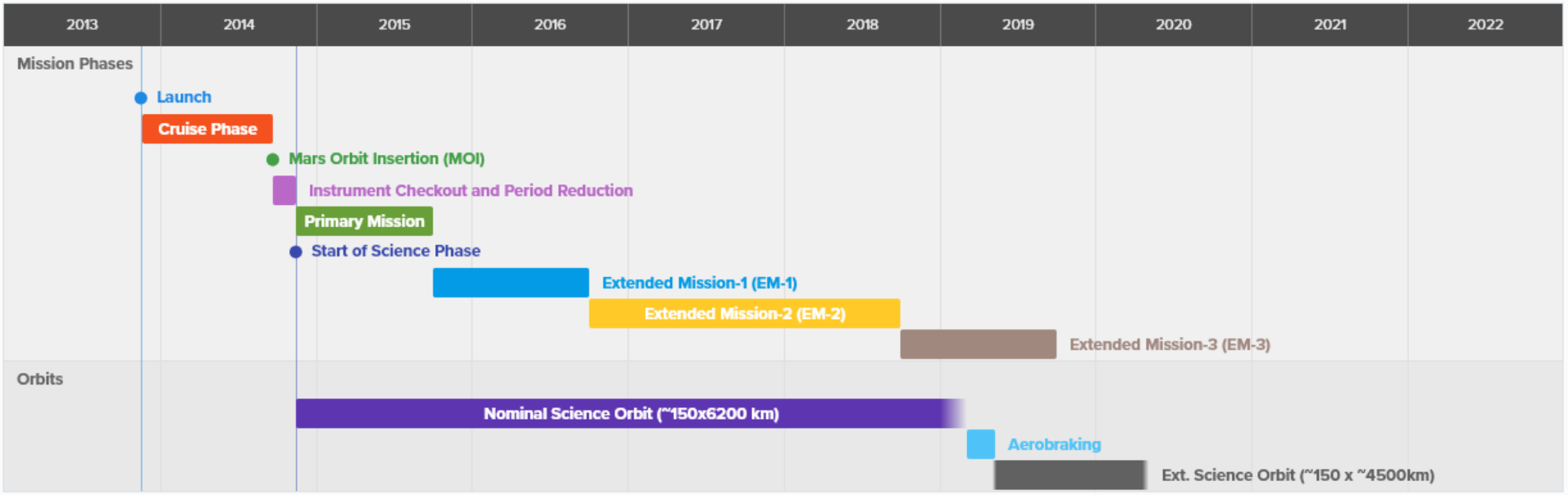
MAVEN Status Summary

- MAVEN spacecraft and all science instruments continue to operate nominally
- MAVEN has been in orbit since September 2014 and in science operations since November 2014
  - 3 years 8 months in orbit
  - Will complete 2nd Mars year of science observations in August 2018
- Minor spacecraft and instrument issues do not affect operations or science return
- Mission extension past current September 2018 end date:
  - Approval expected for one-year mission extension, through September of 2019
  - Expect full three-year “senior review” proposal to be due in early 2019
- Planning to aerobrake in ~ Feb-April 2019 to enhance relay communications
  - Current 6020-km apoapsis will be reduced to between 4000-4500 km
  - Subsequent operations will combine relay and science
- Current fuel-exhaustion date of 2030

MAVEN Post-Launch Mission Timeline

- Launch, 18 November 2013
- Mars Orbit Insertion, 21 September 2014
- Start of Primary Science Mission, 16 November 2014
- Mission extension proposed here, termed EM-3, covers the period 1 Oct 2018 – 30 Sep 2019



MAVEN Overarching Science Goals

MAVEN's high-level science goals have not changed since the Primary Mission:

- Determine the behavior, variability, and driving processes controlling the Mars upper-atmosphere (which includes the thermosphere, ionosphere, exosphere, and magnetosphere)
- Determine the rate of escape of atmospheric gases to space at the present and their driving processes
- Determine properties that allow us to extrapolate back in time to determine the integrated atmospheric loss to space and its importance in the changing climate through time

- *Driving processes include*
  - *internal drivers (dust behavior, water cycle, atmospheric waves/coupling, crustal magnetic field)*
  - *external drivers (solar EUV, solar wind, solar-storm events).*
- *Extrapolation back in time starts with understanding how current loss is controlled through the seasonal cycle, year-to-year variability, and the eleven-year solar cycle.*

EM-3 Science Questions

During EM-3, we'll focus on observations to address specific, focused questions about the behavior of the Mars upper atmosphere:

- How does coupling between the lower atmosphere, the upper atmosphere, and the ionosphere affect escape to space?
- How do interactions between the solar wind and the crustal magnetic fields affect the upper atmosphere and escape to space?
- How does the approaching solar minimum affect interactions between the Sun and Mars, upper-atmospheric processes, and escape to space?
- *What are the implications for H escape, evolution of D/H, and the history of water?*

Measurements during EM-3 will focus specifically on addressing these science questions.

Observations/Implementation to Address EM-3 Science Questions

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- Observe behavior of upper atmosphere and driving processes during the important time period encompassed by EM-3 (L_s ~ 260 - 86°):
  - Lower-atmosphere dust-storm and dusty-atmosphere seasons
  - Southern-summer and northern-spring water-vapor pulses into the atmosphere
  - Declining solar activity moving into solar minimum (our best chance to observe quiescent conditions in detail prior to ramping up of relay)
- Observe the entire upper atmosphere during a three-month-long deep-dip campaign (a.k.a. aerobraking)
  - Obtain unprecedented time record of behavior through entire upper atmosphere
  - Investigate a wide range of unexplored local times and solar zenith angles (SZA)
  - Characterize behavior in/near both the strongest crustal magnetic fields and much-weaker magnetic fields at the same observing geometry
- Couple *MAVEN* observations to *Trace Gas Orbiter*, *InSight*, and ongoing *Mars Reconnaissance Orbiter*, *Mars Express* and *MSL* observations for exceptional atmospheric, magnetic-field, and radiation characterization

Observational goal is to observe under as wide a range of driving conditions as possible, in order to determine the range of atmospheric responses, to understand behavior at this epoch and constrain extrapolation to other epochs

PM And EM-1 Orbit Trace In Areocentric Coordinates, 16 Nov 2014 – 30 Sep 2016

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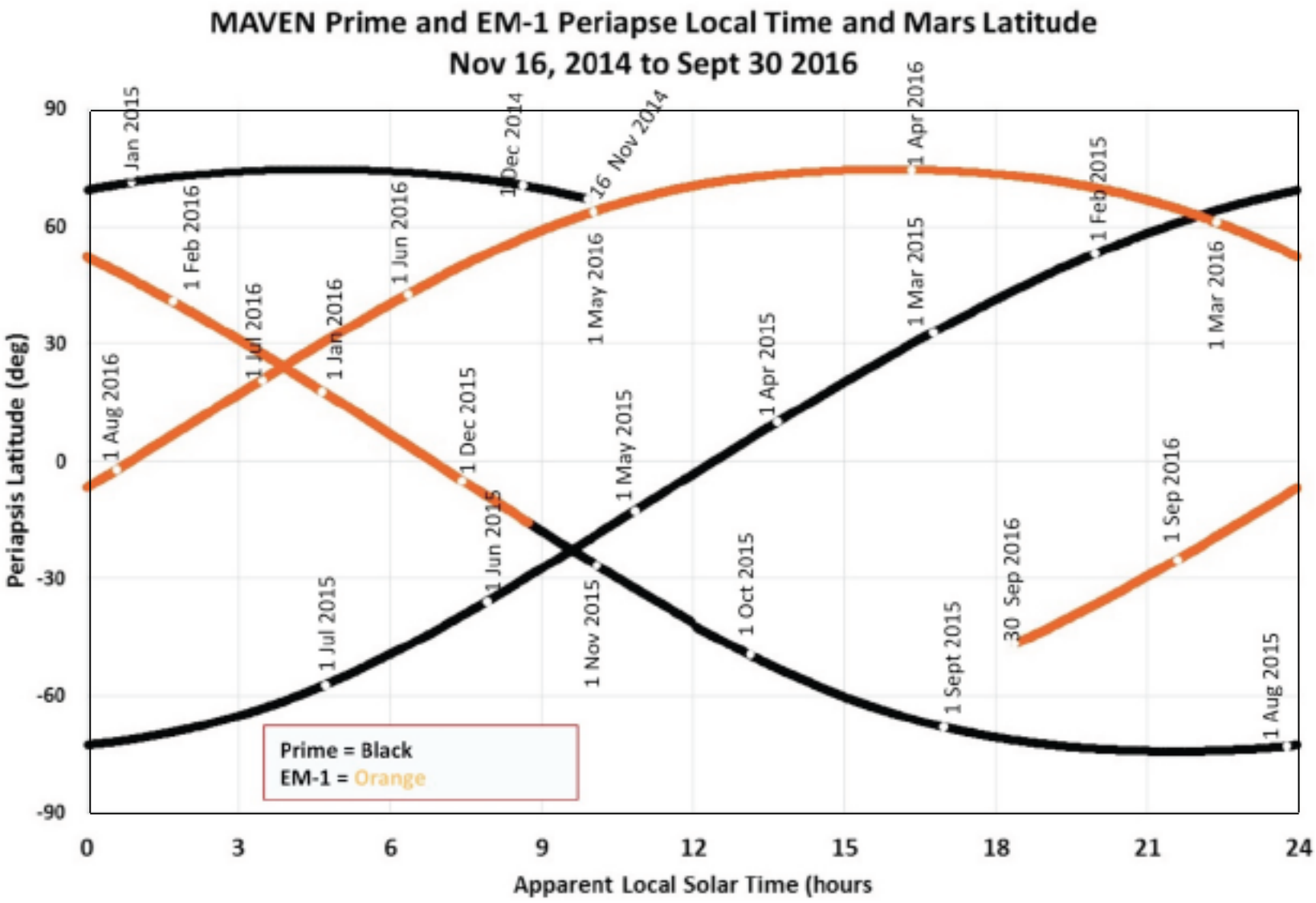
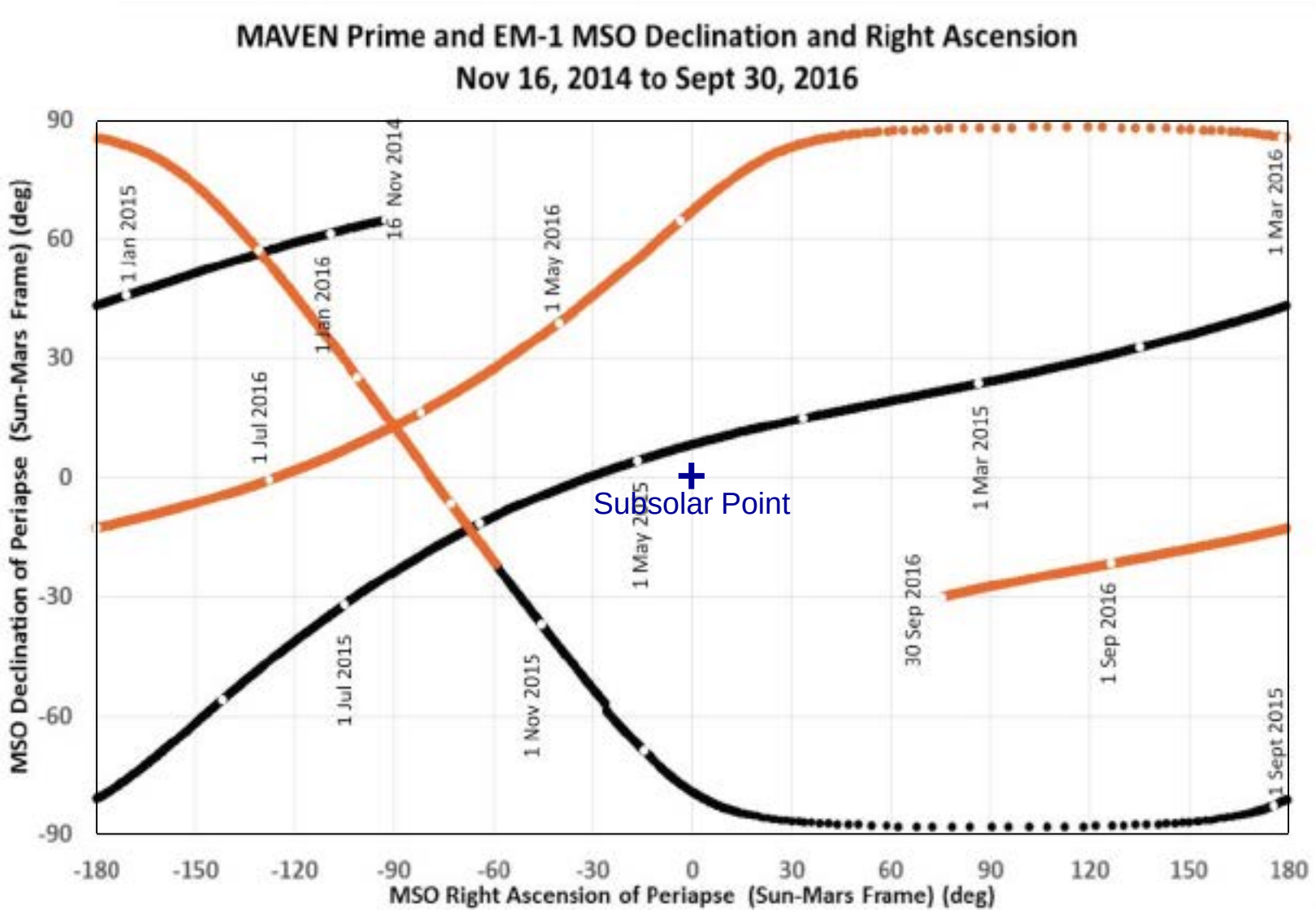
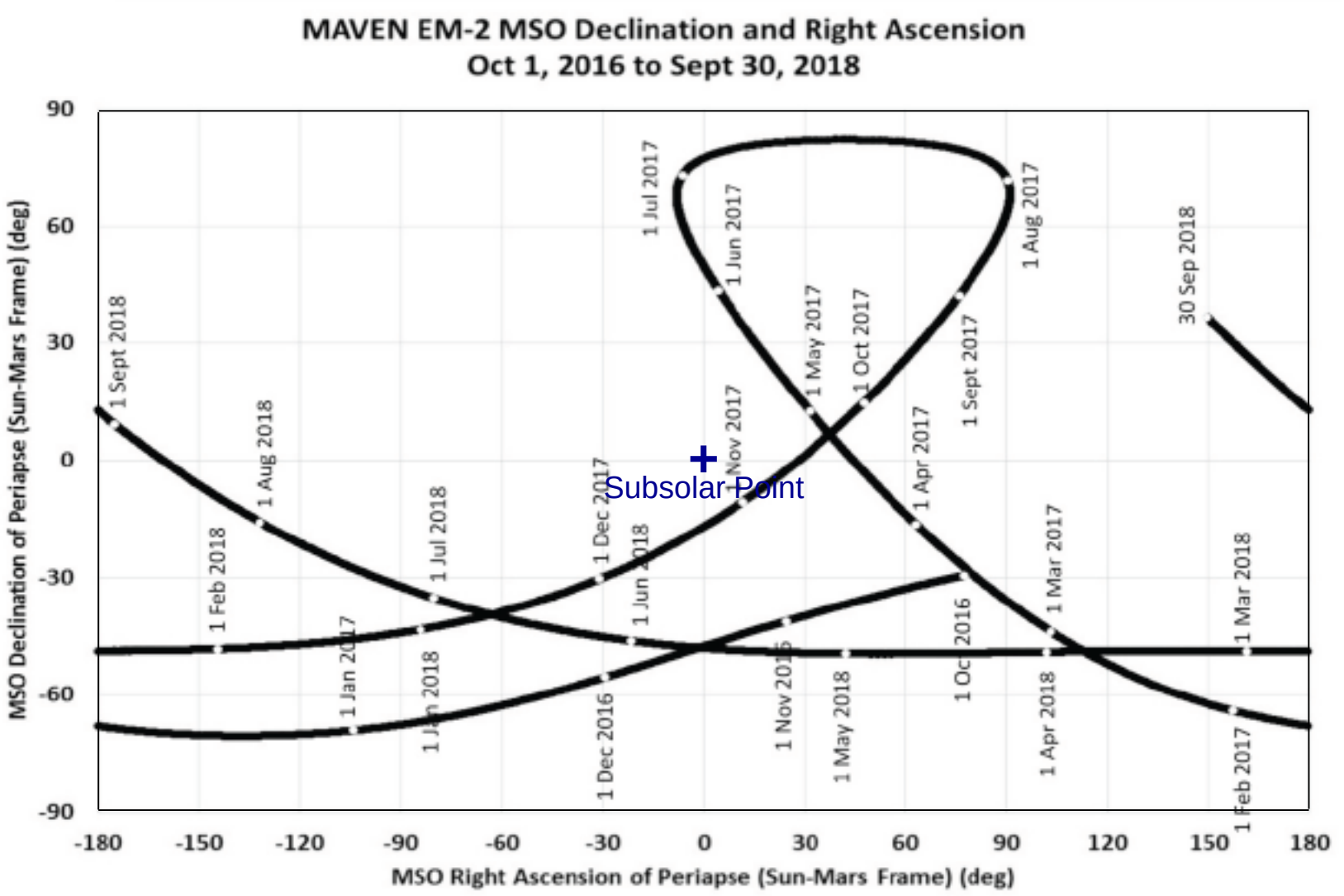


PM And EM-1 Orbit Trace In MSO Coordinates
16 Nov 2014 – 30 Sep 2016



EM-2 Orbit Trace In MSO Coordinates
1 Oct 2016 – 30 Sep 2018



EM-3 Orbit Trace In MSO Coordinates
1 Oct 2018 – 30 Sep 2019

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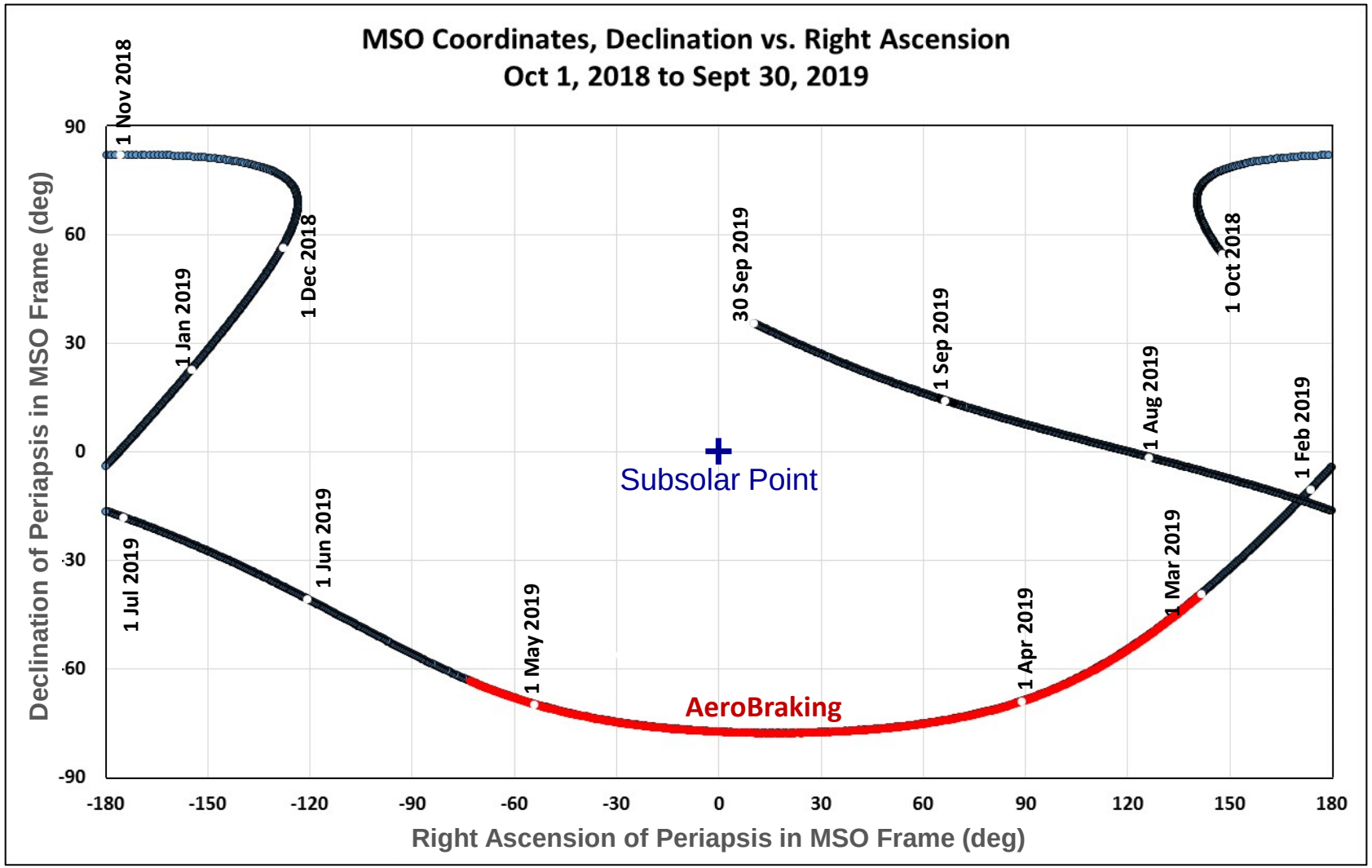

EM-3 Orbit Trace: Apparent Local Time vs. Latitude (In Areocentric Coordinates)

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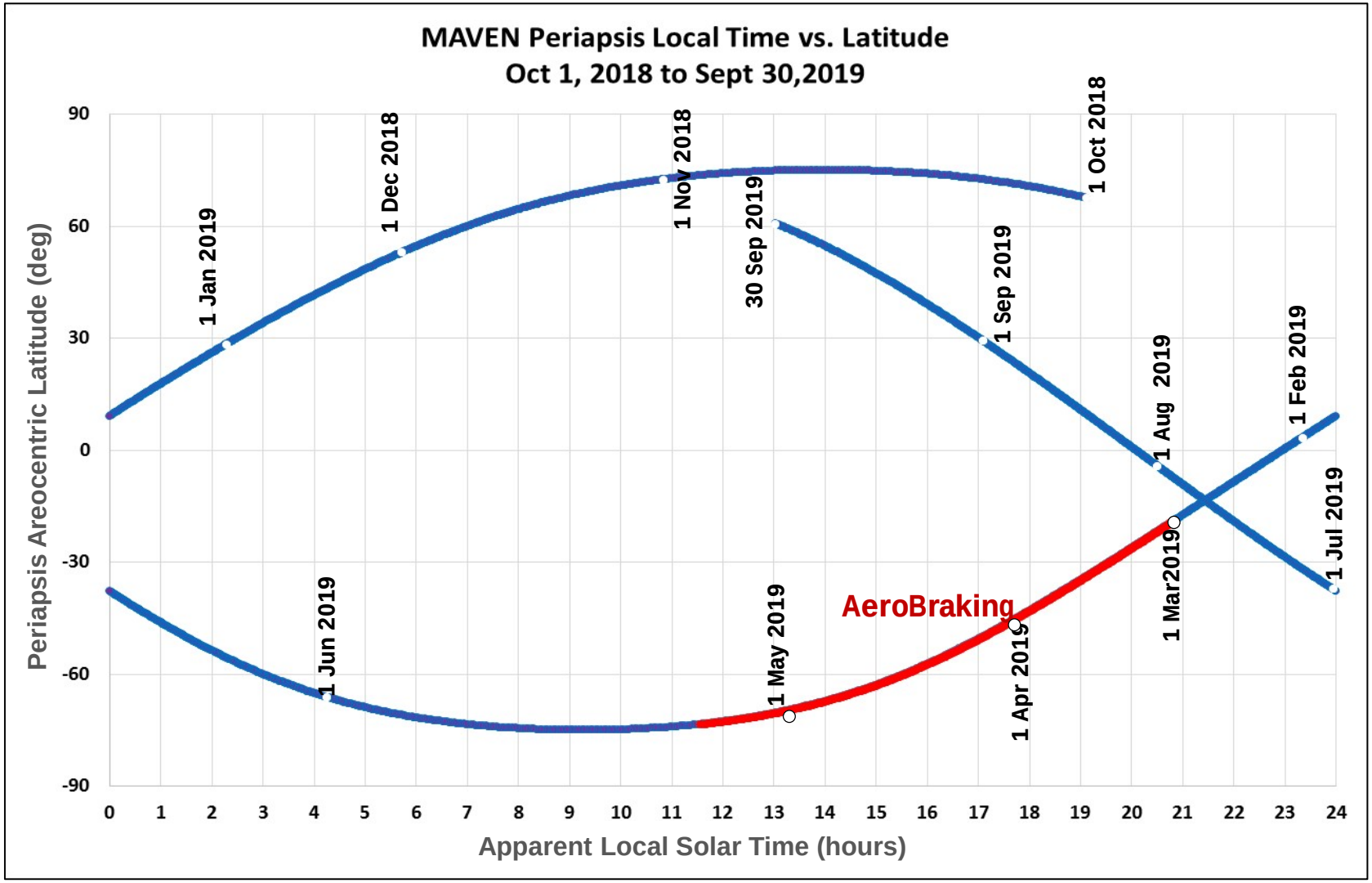
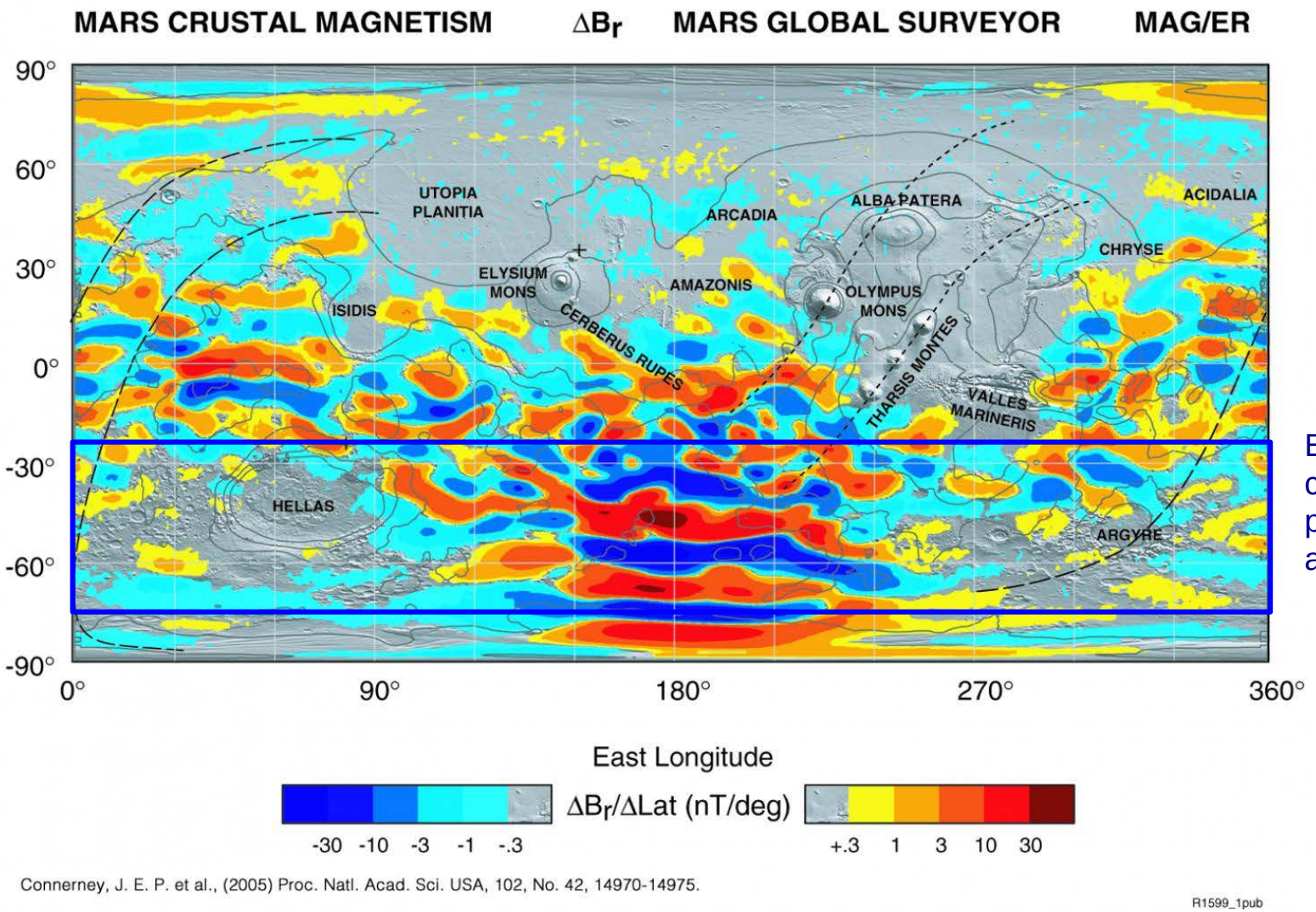
Ref: trj_orb_180205-190319_targetM2020EDL-nso_180223.bsp, and trj_orb_190301-200507_targetM2020EDL-ab4550_180223.bsp



Science Value Of 3-Month Deep-Dip Campaign

- Deep-dip campaigns involve lowering periapsis from ~150 to 125 km
  - 30x change in density over ~3 atmospheric scale heights
- Provides coverage of essentially entire column of upper atmosphere
- Aerobraking provides a 3-month-long campaign at deep-dip periapsis altitude
  - Unprecedented continuous coverage, “deep-dip” science measurements planned
  - At key latitude band that allows detailed coverage of regions of both magnetic anomalies and unmagnetized crust
  - Detailed coverage across dusk terminator region, providing details on ionospheric loss and transport

Mars Crustal Magnetic Field Measurements For EM-3



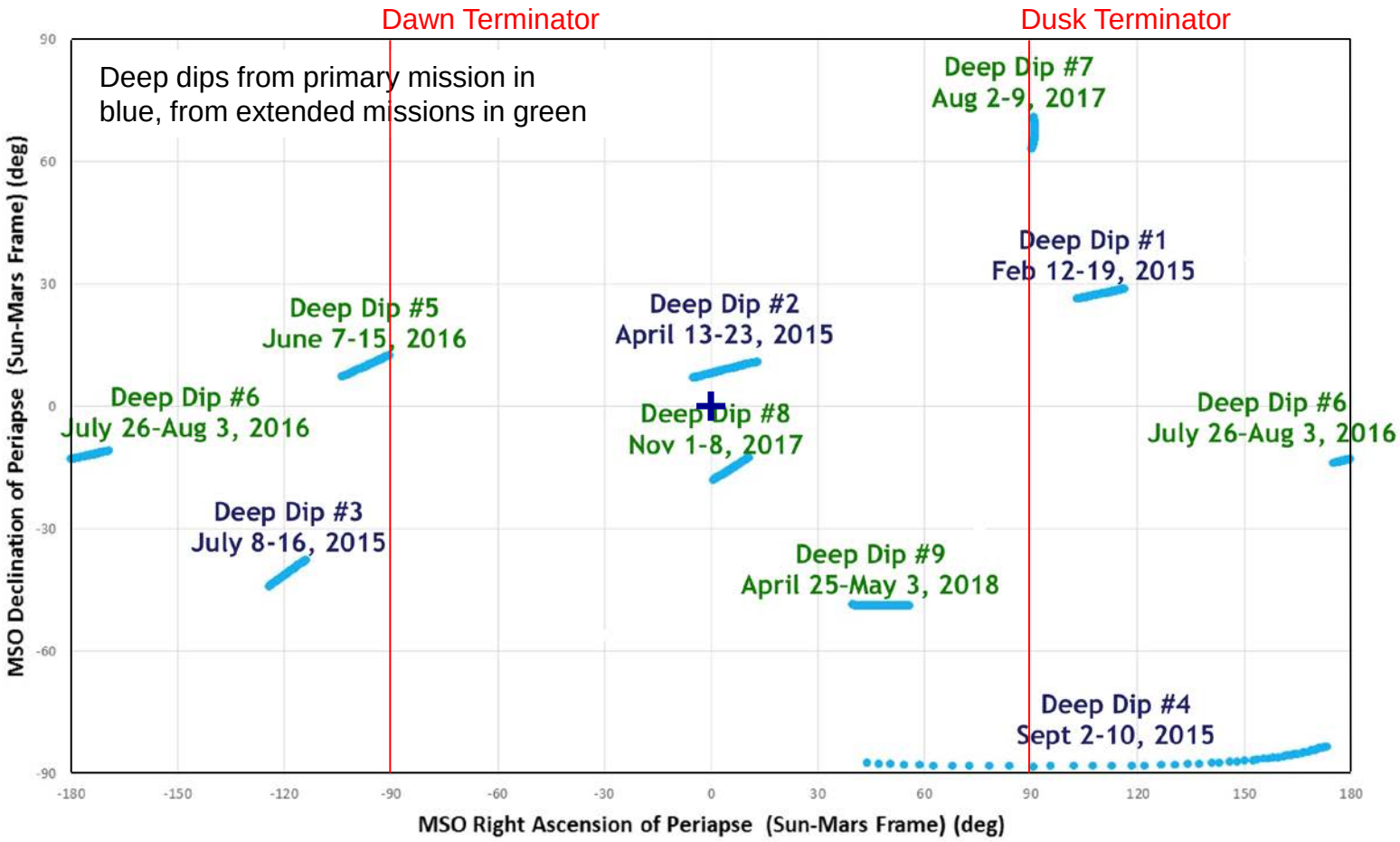
Blue = latitudes covered at periapsis during aerobraking

Connerney, J. E. P. et al., (2005) Proc. Natl. Acad. Sci. USA, 102, No. 42, 14970-14975.

R1599_1pub

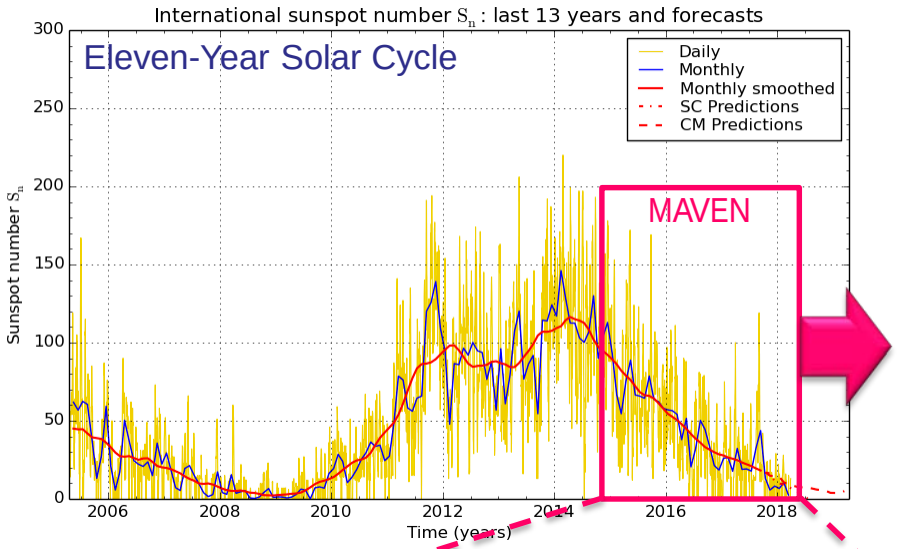
Deep-Dip Campaign Geometries

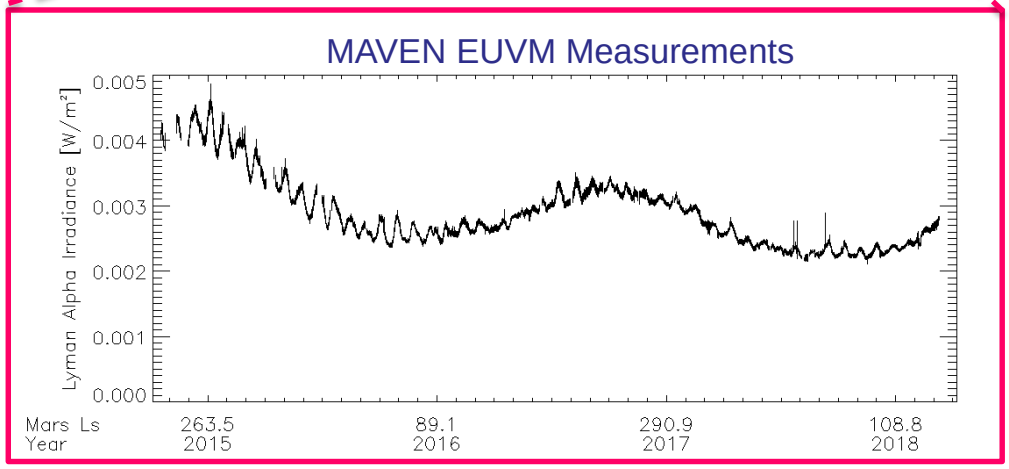
- Nine deep-dip campaigns carried out to date through entire mission
- Each one provided five consecutive days of measurements, 20-25 orbits



Points are shown in MSO coordinates, with the subsolar point at (0, 0)

MAVEN EM-3 Will Occur Near Minimum In The Eleven-Year Solar Cycle





- MAVEN arrived just after the peak in the current solar cycle, and we are approaching solar minimum
- EUV shows variation on timescales of solar rotation, orbit around the Sun (with R varying from 1.38-1.67 A.U.), and solar cycle
- Next solar maximum is expected to occur around 2023-2025

Aerobraking Into Lower-Apoapsis Orbit To Support Mars 2020 Relay

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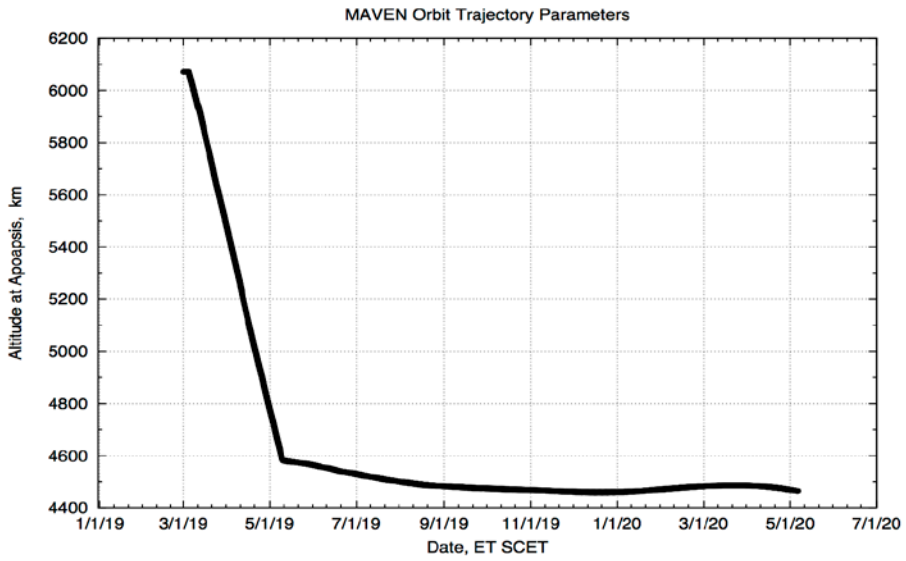
- MAVEN is planning an aerobraking campaign to reduce apoapsis from the current 6200 km to an altitude of 4000-4500 km
  - Orbit reduction will occur by lowering the periapse altitude to Deep Dip density range for a period of ~2.2 months in early 2019.
  - The date and duration of the campaign are constrained by eclipse periods, *Insight* commissioning period, and solar conjunction.
  - The Navigation team designs a “glideslope” to which MAVEN will fly
- MAVEN will support the *Mars 2020* EDL in early 2021
  - Planned +0.6 deg Inclination Change Maneuver (ICM-1) for summer 2018.
  - Phasing accomplished during aerobraking campaign.
- Increase the periapsis altitude to increase MAVEN’s mission lifetime
  - Planned periapsis raise maneuver after EM-3, as required by fuel usage and relay timing requirements
  - Final periapsis altitude TBD
- Post-aerobraking ops will include both science and relay
  - Up to 5 science orbits/day post-a/b
  - 1-3 science orbits/day in era of *Mars 2020* mission



Mission Summary Assessment

System		Status
Science		• Exciting science that fully addresses planned objectives and includes significant discoveries about the Mars system
Spacecraft		• Spacecraft continues nominal performance • Evaluating potential mitigations to power and thermal constraints to support relay during eclipse seasons
Instruments		• All instruments continue nominal performance
Operations		• Planning for execution of aerobraking campaign in Spring 2019 • Final deep-dip campaign, DD#9, completed 23 Apr – 1 May
Programmatic		• Funding augmentation expected to cover cost of planning for aerobraking during the remainder of FY18 • Concerns over funding in FY19 due to cost of implementing aerobraking

MAVEN is anticipating a scientifically exciting and productive FY18-19, inclusive of extended aerobraking campaign to reduce apoapsis altitude and improve relay support