MAVEN

Mars Atmosphere and Volatile EvolutioN (MAVEN) Mission

Mission Spacecraft and Operations Overview
MAVEN Science Community Workshop
December 2, 2012

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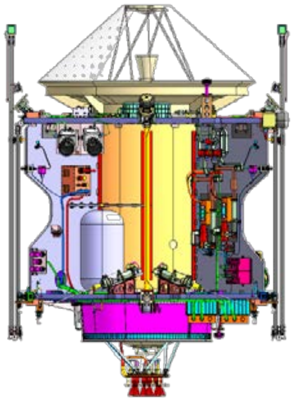
Spacecraft Design Lead
Lockheed Martin

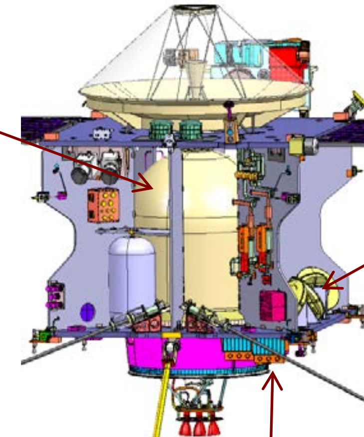
Spacecraft Overview

MAVEN
Mars Atmosphere and Volatile Evolution Mission
CU/LASP • GSFC • UCB/SSL • LM • JPL

Launch Configuration



Monoprop Propulsion System
1640 kg capacity N_2H_4 tank
Regulated during MOI
Blowdown during mission

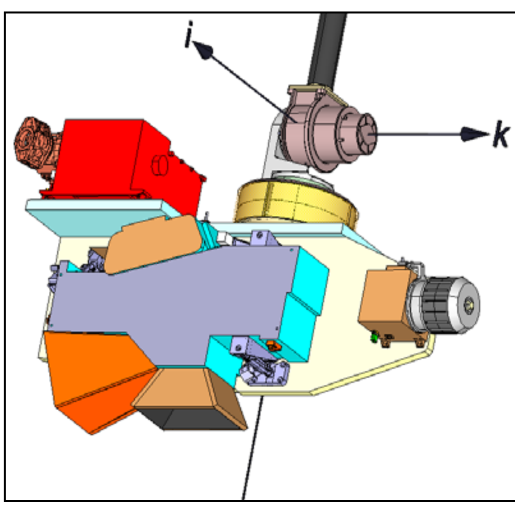


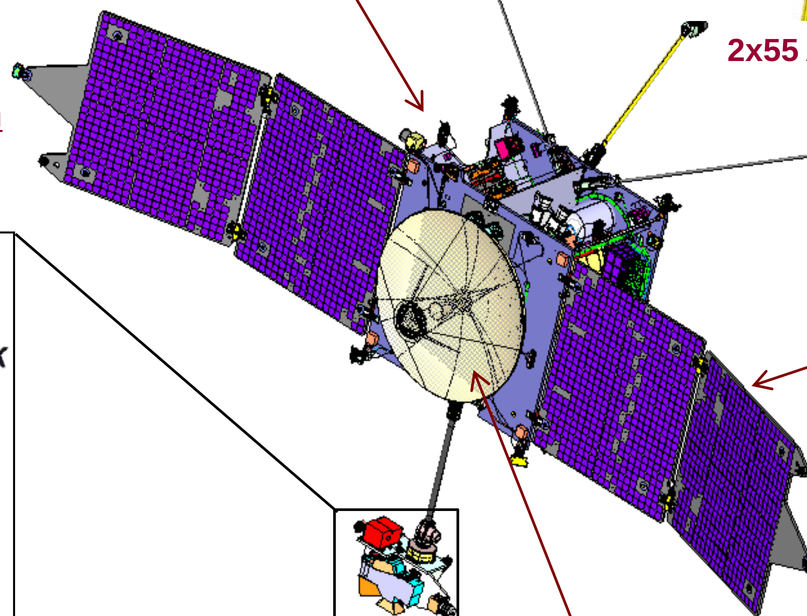
RWA Pyramid

2x55 A-hr Li Ion Batteries

3-Axis Stabilized Platform
Reaction wheel control,
Nominally sun-pointed
during operations

Articulated Payload Platform
+/- 90° elevation travel (inner)
+/- 177.5° azimuth travel (outer)





Fixed Solar Arrays
~1200W power generation,
20° gull wing angle
provides aerostability during
atmospheric encounters

Fixed High Gain Antenna
2m dual reflector X-band
downlink rates up to 550 kbps

Instruments and Payloads

Particles and Fields Package ***(SSL)***

STATIC

SEP

SupraThermal And Thermal Ion Composition; Jim McFadden, SSL

Solar Energetic Particles; Davin Larson, SSL

SWEA

SWIA

Solar Wind Electron Analyzer; David Mitchell, SSL

Solar Wind Ion Analyzer; Jasper Halekas, SSL

LPW

MAG

Langmuir Probe and Waves
Bob Ergun,
LASP
Magnetometer; Jack Connerney, GSFC

Mass Spectrometry Instrument ***(GSFC)***

NGIMS

Neutral Gas and Ion Mass Spectrometer; Paul Mahaffy, GSFC

Remote-Sensing Package ***(LASP)***

IUVS

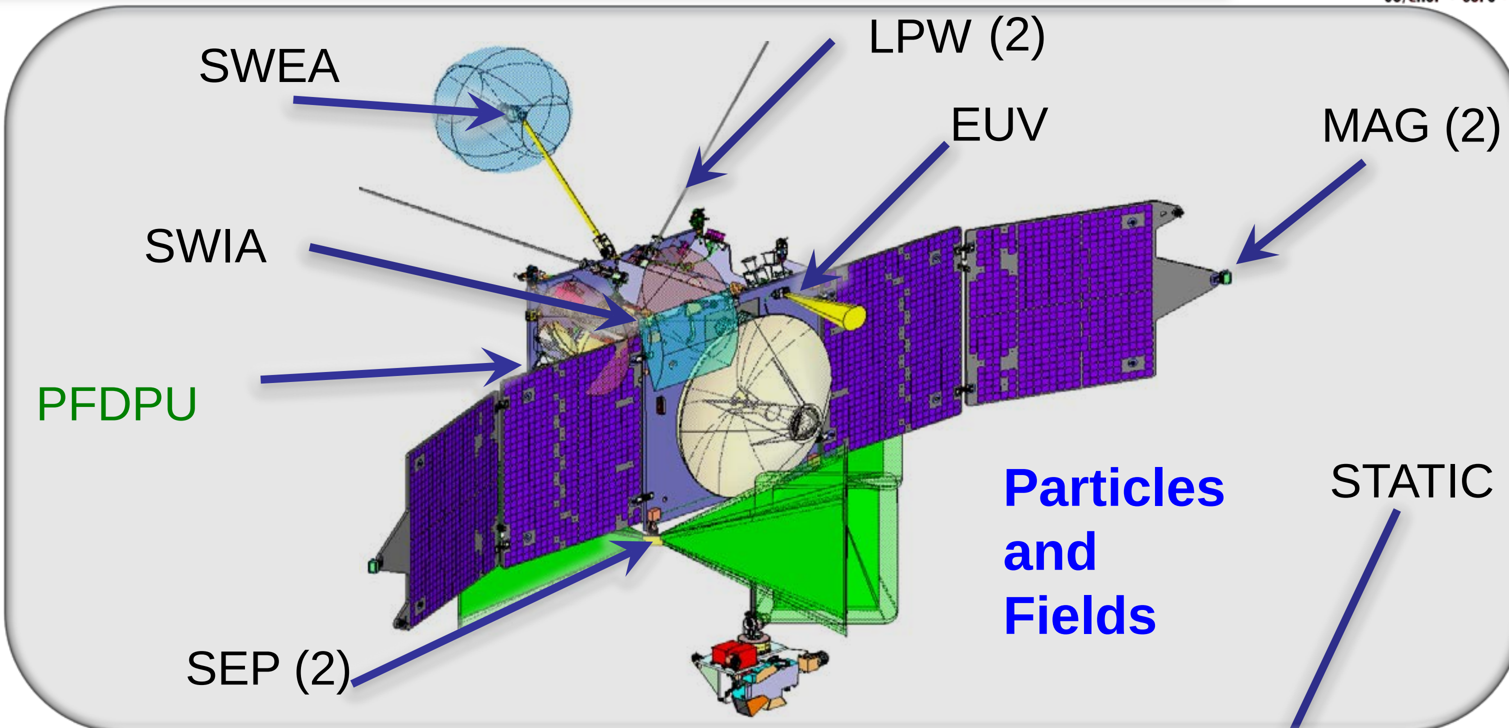
Imaging Ultraviolet Spectrometer; Nick Schneider, LASP

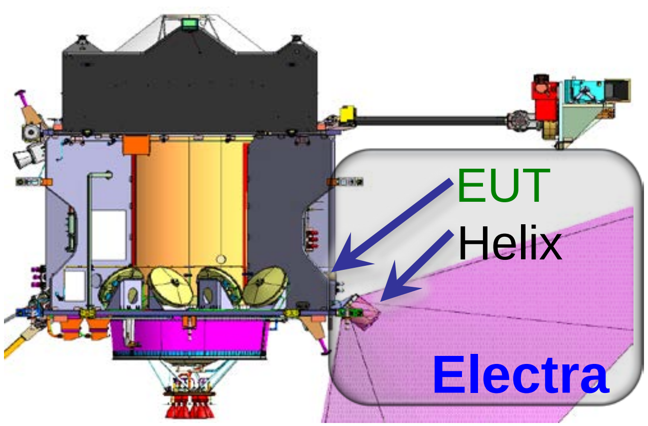
Electra Relay Package (JPL)

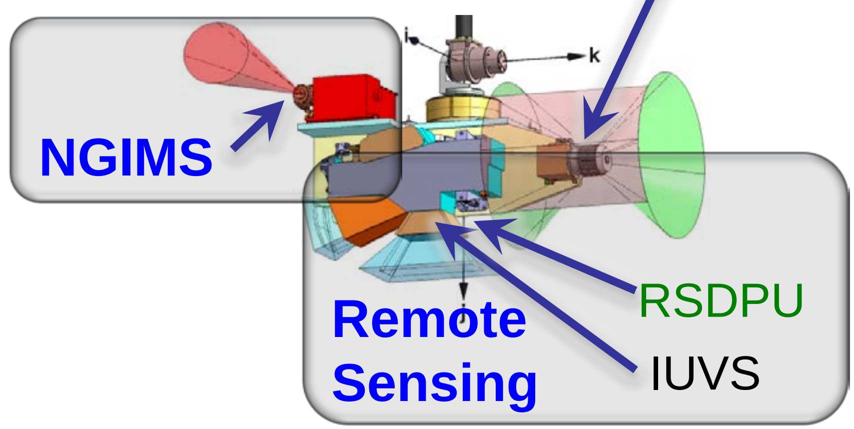
Electra

Electra UHF Transceiver and Helix Antenna;
Larry Epp, JPL

Instrument and Payload Locations





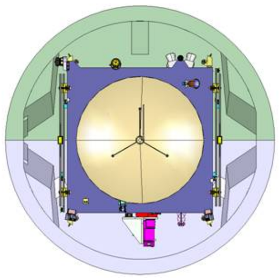


Mission Architecture

20-Day Launch Period

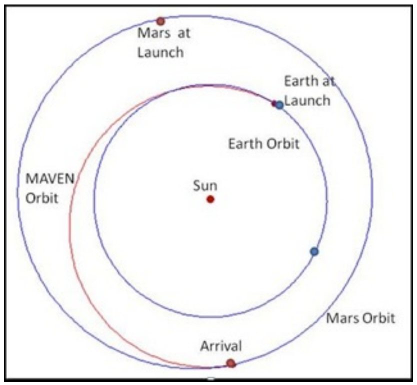
18 Nov 2013 (Open)
7 Dec 2013 (Close)

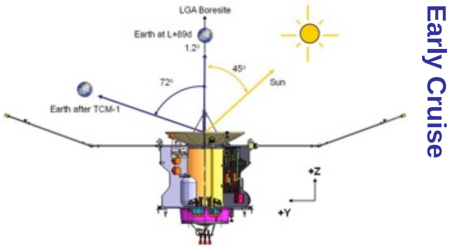
LV: Atlas V 401

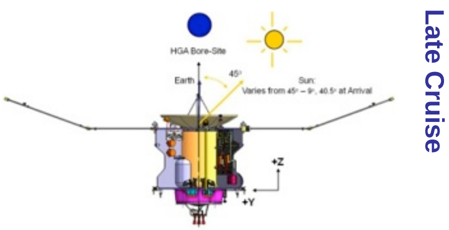


Ten Month Ballistic Cruise to Mars

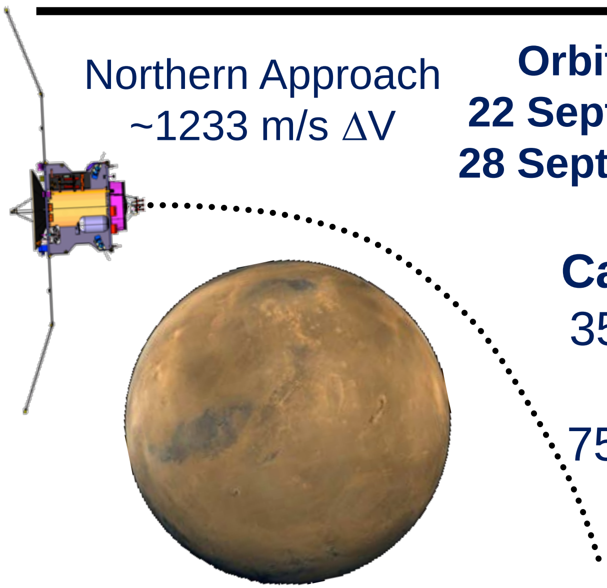
Type-II Trajectory





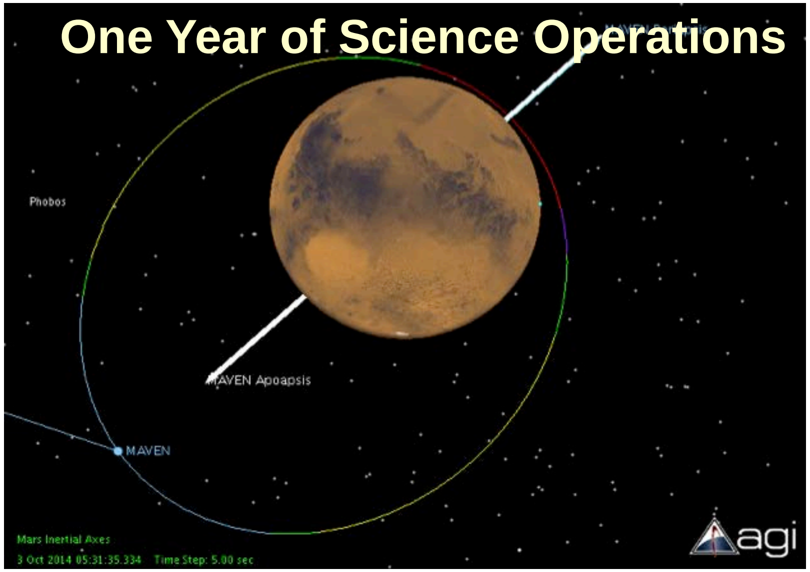


Northern Approach
~1233 m/s ΔV

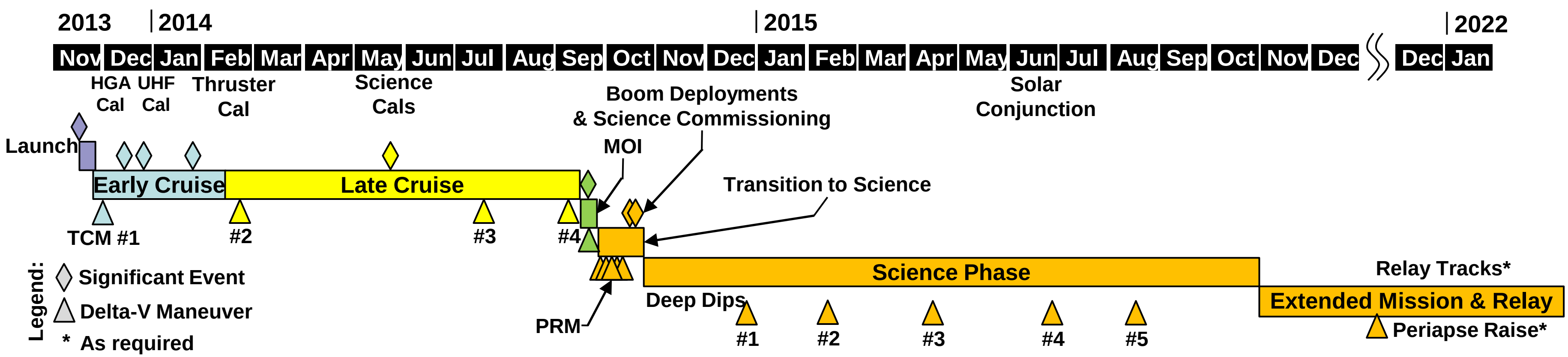


Orbit Insertion:
22 Sept 2014 (Open)
28 Sept 2014 (Close)

Capture Orbit:
35 hour period
380 km P2
75° inclination



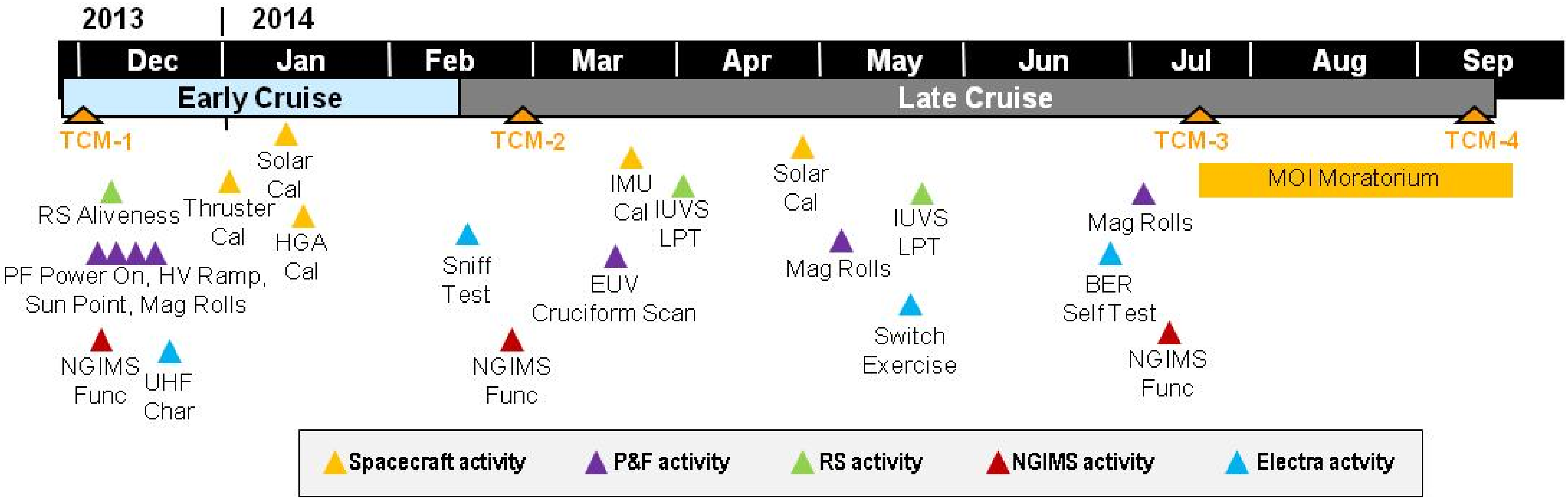
Mission Phases/Timeline

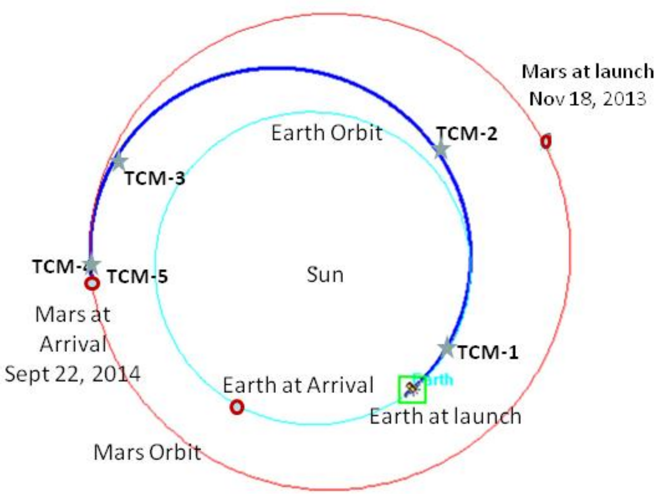


Flight Software Phase	Mission Operations Phase	Phase Boundary Definition
Prelaunch	Launch	Launch-1 day (power on) to Transfer to internal power on the pad (not part of Mission Operations Plan)
Launch		Transfer to internal power to Launch+1 day (approximately, depends on SPK/ephemeris availability)
Early Cruise	Cruise	Operators configure for cruise, and set Mission Phase to “Early Cruise” (approximately L+1 day)
Late Cruise		Slew to HGA Earth point (approximately L+90 days)
MOI	MOI	MOI sequence load (approximately MOI-3 days)
Science	Transition	Immediately following confirmation of successful MOI (approximately MOI+3 hours)
	Science	
	Extended	
Lost In Time (LIT)	N/A	Used for “default” safe mode state if spacecraft cannot autonomously resolve the mission phase

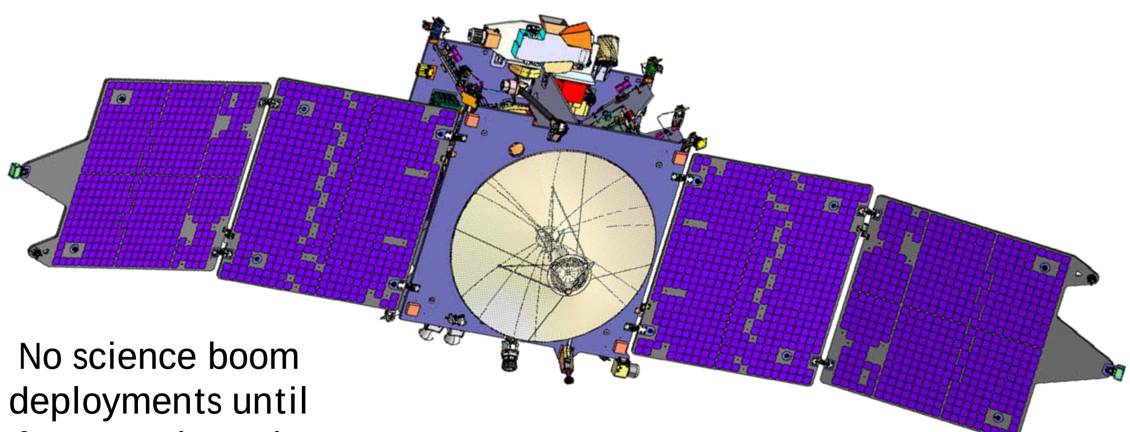
- Launch window: 11/18-12/7/2013
- Ten month ballistic cruise
- Mars Arrival/MOI: 9/22-28/2014
- Five week transition period
- One Earth-year nominal mission
- Extended science and/or relay
  - Best estimate supports 29 additional months in the nominal orbit, plus 6 years in a raised orbit (~200 km periapse)

Cruise





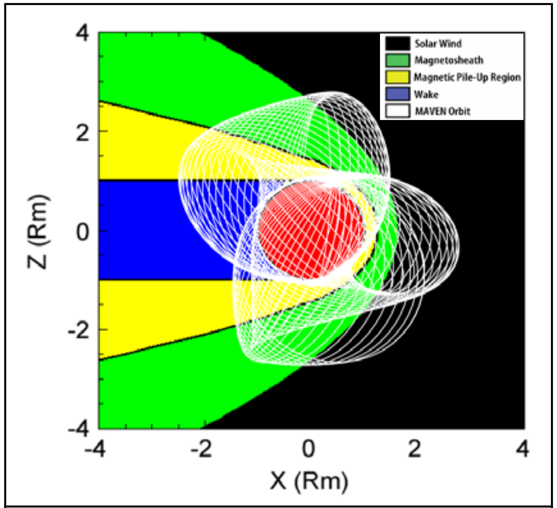
Cruise Configuration

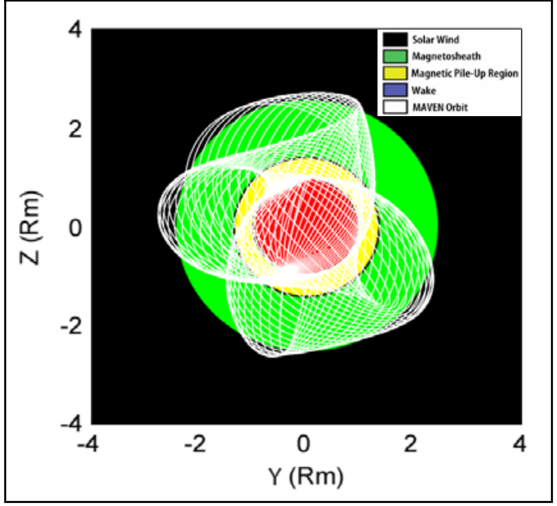


No science boom deployments until after Mars insertion

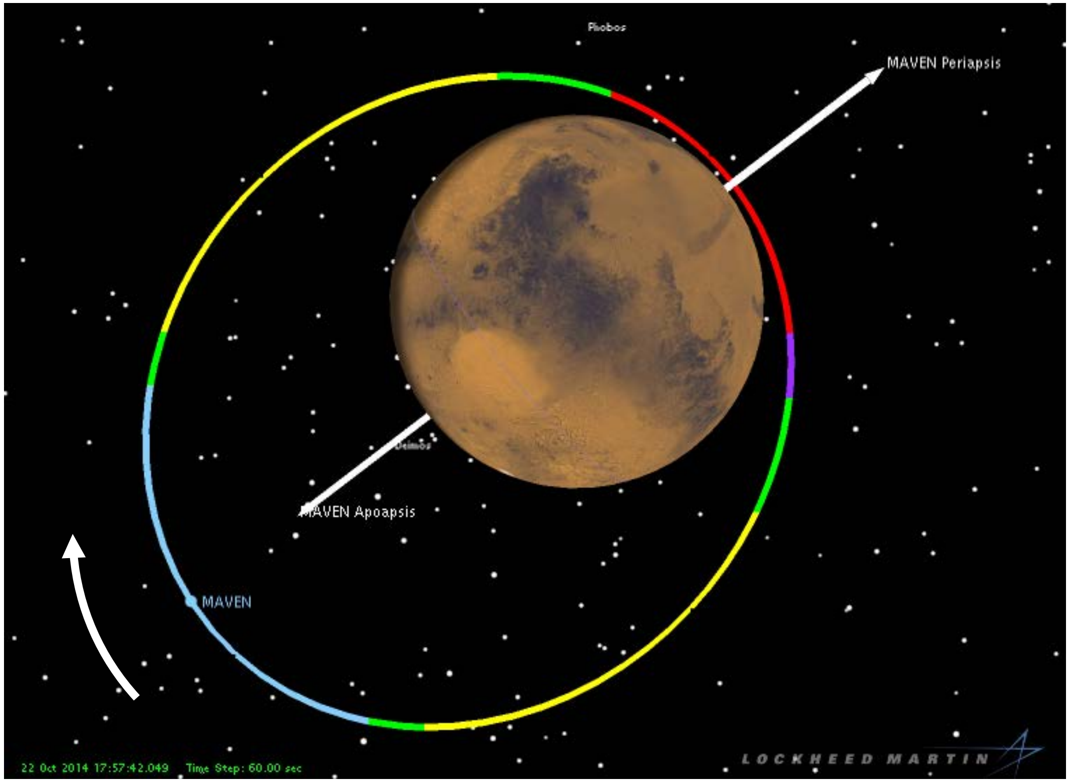
Science Operations Overview

- Orbit chosen to observe a wide range of geometries
  - Right Ascension and Ascending Node precession rate ~ -0.6 deg/day
  - Argument of Periapsis precession rate ~ -0.8 deg/day
- Two atmospheric regimes, defined by periapsis density
  - Nominal (0.05 – 0.15 kg/km^3)
  - Deep Dips (2.0 – 3.5 kg/km^3) – 5 "one week" campaigns
- Numerous operational constraints to be managed
  - Pointing control mode singularities
  - Sun in FOV constraints
  - Solar eclipses and Earth occultation
  - Instrument high voltage management due to corona effects
- Limited Earth communications
  - Daily ranging contacts (unattended)
  - Two 5-hr DSN contacts per week for downlink of recorded science and engineering data and for S/C and instrument command uplinks
  - Necessitates significant autonomy in S/C and instrument commanding
  - Continuous DSN coverage for deep dip campaigns
- Limited tracking data for Navigation
  - Requires autonomous Periapsis Timing Estimator (PTE) to meet orbit timing requirements

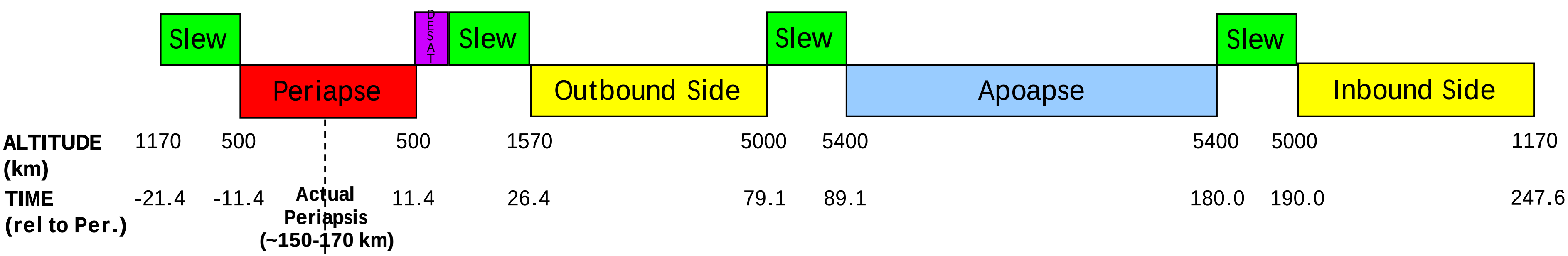




Science Orbit Timing and Geometry



- S/C generally sun-pointed for the body mounted instruments
- Orbit broken into 3 segments to accommodate APP pointing
  - Apoapse (IUVS Disk Mapping)
  - Mid-altitude sides -inbound and outbound (STATIC and IUVS)
  - Periapse (NGIMS, STATIC, IUVS sharing)
- Small set of weekly ops scenarios
  - Balance conflicting instrument requirements
  - Account for S/C and instrument pointing constraints
- A "nominal" scenario used for the majority of the science phase
  - "Constraint" scenarios used to accommodate various spacecraft and instrument constraints



Nominal Science Operations

Science Scenarios Definitions

		1	1a	2	2a	2b	3	4	4a	4b	5	SC
Orbit 1	Apoapse	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	Sun-Nadir
	Sides	IUVS Coronal Scan	IUVS Coronal Scan	IUVS Coronal Scan	IUVS Coronal Scan	IUVS Coronal Scan	IUVS Coronal Scan	IUVS Coronal Scan	IUVS Coronal Scan	IUVS Coronal Scan	IUVS Coronal Scan	Sun-Nadir
	Periapse	Fly-Y	Fly-Y	Fly-Y	Fly-Y	Fly-Z	Sun-Velocity	Fly-Y	Fly-Y	Fly-Z	Sun-Velocity	Sun-Nadir
	APP@peri	Ram-Nadir	*Ram-Horizontal*	Ram-Nadir	Ram-Nadir	Ram-Nadir	Ram-Track	Ram-Nadir	Ram-Nadir	Ram-Nadir	Ram-Track	Sun-Safe
Orbit 2	Apoapse	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	IUVS Disc Scan	Sun-Nadir
	Sides	STATIC Sun-Nadir	STATIC Sun-Nadir	STATIC Sun-Nadir	STATIC Sun-Nadir	STATIC Sun-Nadir	STATIC Sun-Nadir	IUVS Coronal Scan	IUVS Coronal Scan	IUVS Coronal Scan	IUVS Coronal Scan	Sun-Nadir
	Periapse	Sun-Velocity	Sun-Velocity	Fly-Y	Fly-Y	Fly-Z	Sun-Velocity	Fly-Y	Fly-Y	Fly-Z	Sun-Velocity	Sun-Nadir
	APP@peri	Ram-Track	Ram-Track	Ram-Nadir	*Ram-Horizontal*	Ram-Nadir	Ram-Track	Ram-Nadir	*Ram-Horizontal*	Ram-Nadir	Ram-Track	Sun-Safe

Represents difference from Nominal Scenario 1

Nominal Scenarios

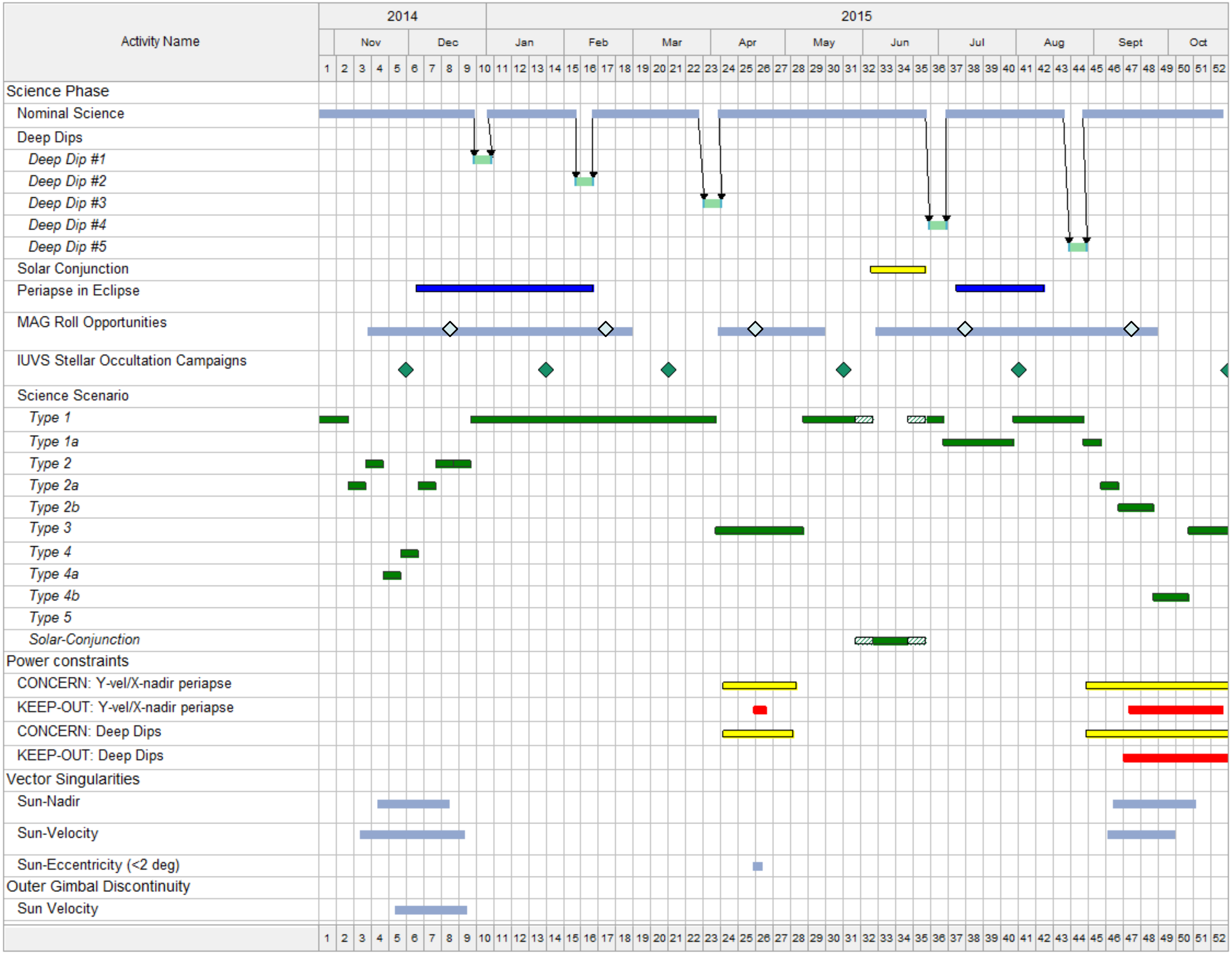
- **Scenario 1** – Primary scenario used for ~70% of mission
- **Scenario 1a** – Alternate Nominal Scenario to allow STATIC APP Ram-Horizontal (R-H) pointing during Periapsis

Constraint Scenarios

- **Scenario 2** – Used when attitude singularity precludes use of periapsis sun–velocity pointing mode
- **Scenario 2a** – Alternate Scenario 2 to allow STATIC APP R-H pointing during periapsis
- **Scenario 2b** – (Fly-Z) Alternate Scenario 2 for use when simultaneous constraints preclude use of Fly-Y and Sun-Velocity attitudes
- **Scenario 3** – Used during power constrained periods of mission (precludes Fly-Y attitude during periapsis which takes solar arrays off the sun
- **Scenario 4** – Used when attitude singularities preclude use of side segment sun-nadir and periapsis sun-velocity pointing modes
- **Scenario 4a** – Alternate Scenario 4 to allow STATIC APP R-H pointing during periapsis
- **Scenario 4b** – (Fly-Z) Alternate Scenario 4 for use when simultaneous constraints preclude use of Fly-Y and Sun-Velocity attitudes
- **Scenario 5** – Used during power constrained periods of mission and when attitude singularity prevents use of side segment sun-nadir mode
- **Solar Conjunction**– S/C Sun pointed with APP parked in sun-safe position

- **Communications:** 2x per week per DSN visibility constraints
- **Deep Dips:** executed with a selected scenario as the baseline, but when scheduled HGA comm is available, all non-periapse segments will be operated in Earth Point

Science Phase Timeline



Summary

- Relatively simple spacecraft design
  - Enabled low cost/risk development
  - Necessitates compromises between science optimization and operational complexity/cost

- Integrated plan to manage competing science desires
  - Menu of pre-canned operational "scenarios"
    - Default scenario balances pointing desires across instruments
    - Alternate scenarios to manage S/C and instrument constraints
  - Baseline operations defined for duration of primary mission
    - Five deep dip campaigns
    - One "special" event per month
      - Magnetometer calibrations, IUVS stellar occultation observations
    - Spacecraft and instrument constraints

BACK-UP MATERIAL

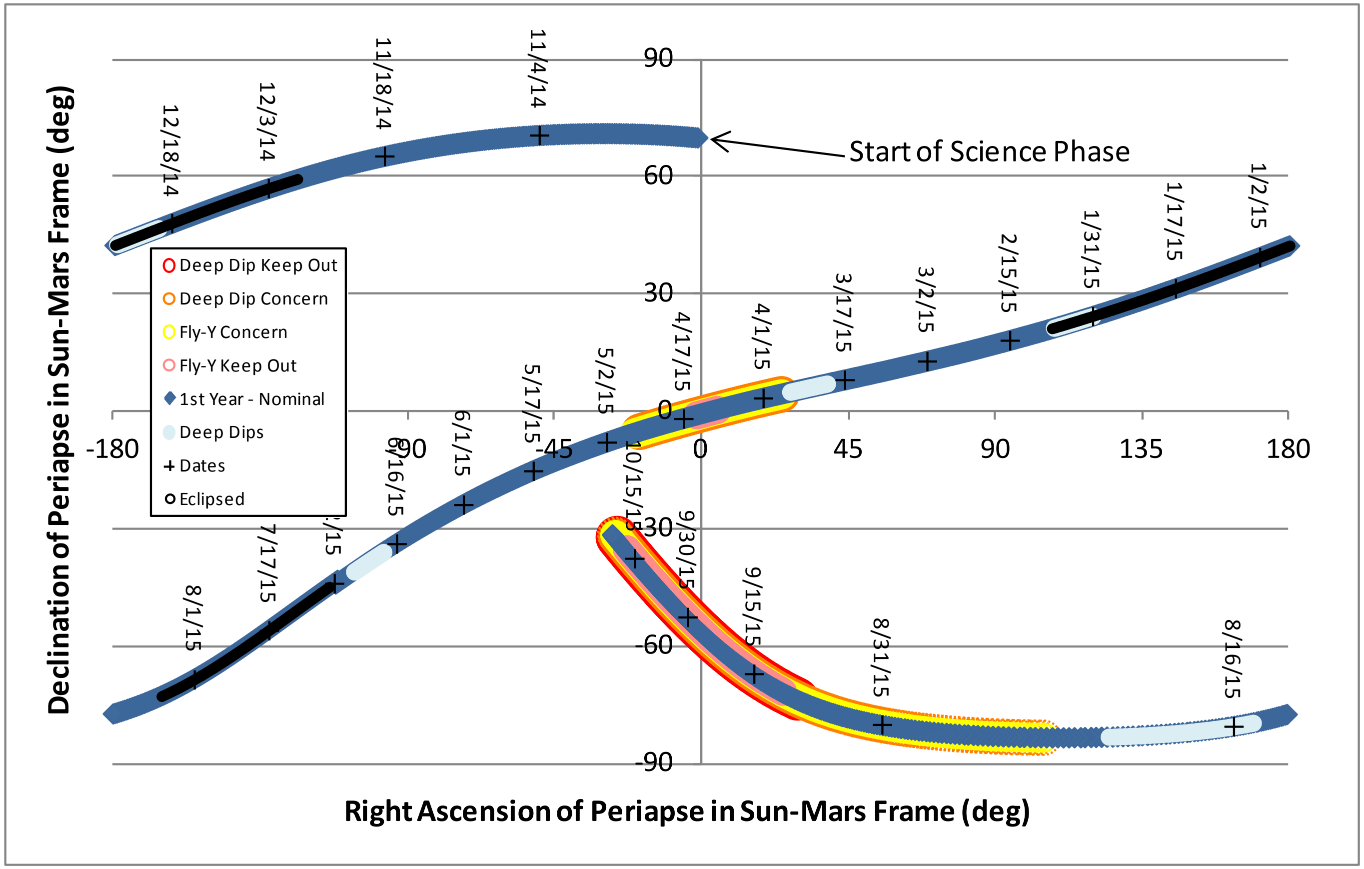
Science Observation Modes

Science Mode	ACS Mode	Slew Mode	APP Mode	Attitude
IUVS Disc Scan	Inertial Hold	Semi-major Target	Commanded Position	Aligns +Z to Sun, Constrains +X towards orbit semi-major axis; APP: +j aligned with orbit semi-major axis, -k towards orbit normal
IUVS Coronal Scan	Inertial Hold	Semi-minor Target	Commanded Position	Aligns +Z to Sun, Constrains +X towards orbit semi-minor axis; APP: +j aligned with orbit semi-minor axis, -k towards orbit normal
STATIC Sun-Nadir	Sun-Nadir	Sun-Nadir Target	Commanded Position	Aligns +Z to Sun, Constrains +X towards Nadir; APP: inner gimbal = 0, outer = 25 deg
Sun-Velocity	Sun-Velocity	Sun-Velocity Target	Velocity Track	Aligns +Z to Sun, Constrains +/-Y towards planet-relative velocity; APP: +i tracks planet-relative velocity
Fly-Y	Velocity-Nadir	Velocity Target	Commanded Position	Aligns +/-Y to planet-relative velocity, Constrains +X towards nadir; APP: ram-nadir: inner = 0, outer = -65/115 deg to align +i with planet-rel velocity; ram-horizontal: inner = +/-90, outer = -65/115 deg to align +i with planet-rel velocity and +k towards nadir
Fly-Z	Velocity-Nadir	Velocity Target	Commanded Position	Aligns -Z to planet-relative velocity, Constrains +X towards nadir; APP: ram-nadir: inner = 0, outer = 25 deg to align +i with planet-rel velocity; ram-horizontal not supported
Deep Dip	Velocity-Nadir	Velocity Target	Velocity Track	Damps rates to follow profile of planet-relative velocity vector around periapse; APP: +i tracks planet-relative velocity
Comm	Earth Point	Earth Target	Commanded Position	Aligns +Z to Earth, Constrains -Y towards Sun; APP: inner = 90, outer = -65 deg
Stellar Occultations	Inertial Hold	Sun Inertial	Commanded Position	Aligns +Z to Earth, +X generally towards selected star; APP: IUVS stellar occ FOV pointed at star, APP +i normal to horizon (up)

Deep-Dip Schedule

Deep Dip Number	Region	Start Date	Science Mission Day	Periapse Latitude (sun-rel) (deg)	Periapse Longitude (sun-rel) (deg)	Solar Zenith Angle (deg)	Eclipse Duration (min)	SPE (deg)	Sun Range (AU)
1	Anti-solar	12/26/2014	64	41	-178	139	31	28	1.38
2	Dusk Term	2/6/2015	107	18	108	108	20	21	1.41
3	Sub-solar	4/10/2015	170	-3	4	5	77	11	1.47
4	Dawn Term	6/26/2015	247	-44	-108	102	3	3	1.57
5	South Pole	8/21/2015	303	-81	91	91	28	13	1.63

Note: schedule may be adjusted during the science phase based on actual conditions



Science Phase Timeline w/ Inst Constraints