# LRO Mission Design Topics

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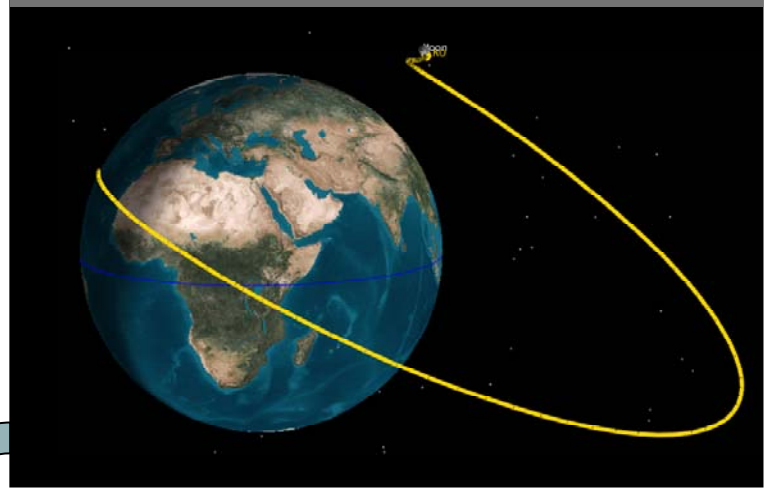
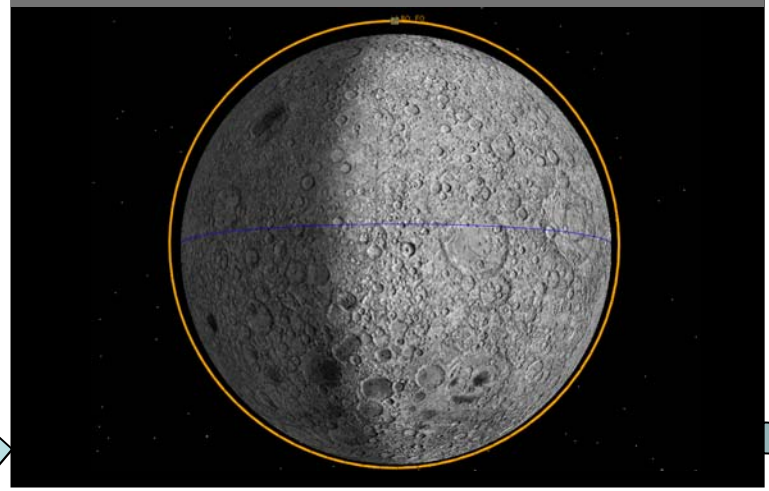
November 29, 2006

# LRO Mission Profile

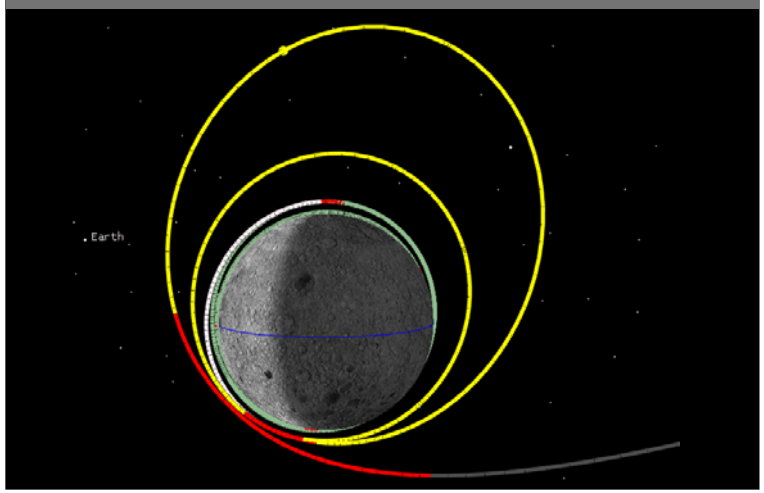
Minimum Energy Lunar Transfer: 4-5 days



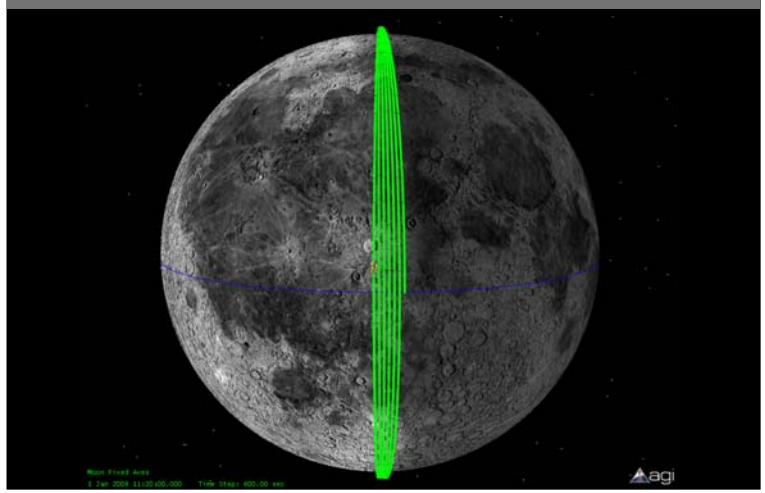

30 x 216 km Quasi-frozen Orbit: up to 60 days



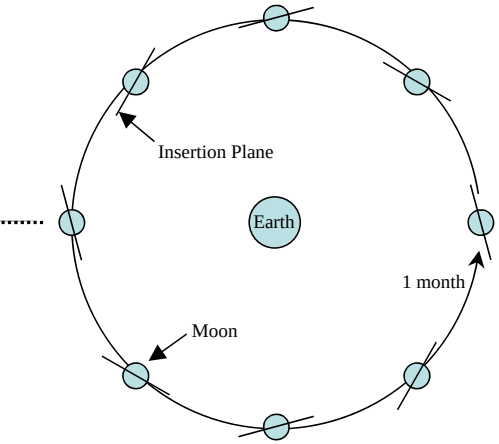
Lunar Orbit Insertion Sequence (4): 4-6 days



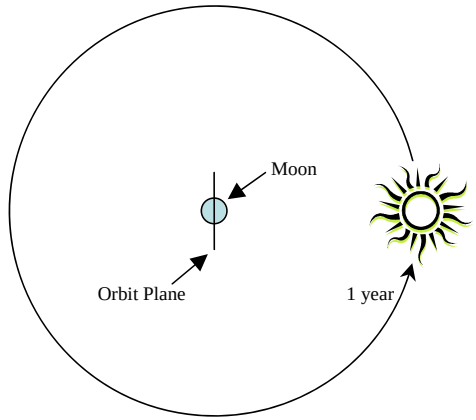

50 km Polar Mapping Orbit: at least 1 year

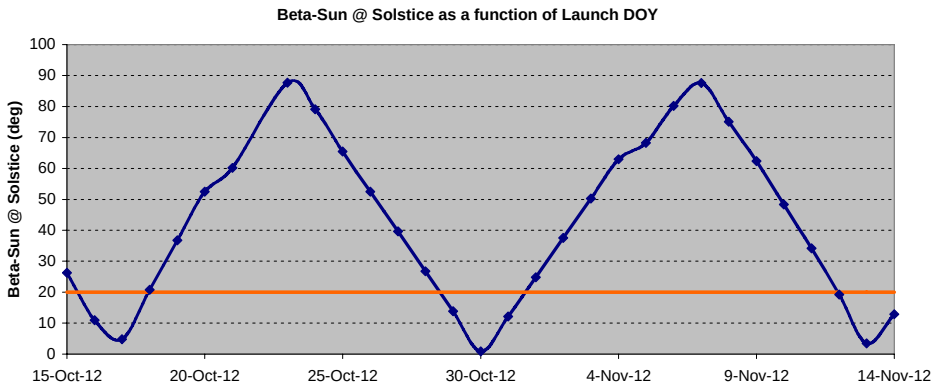


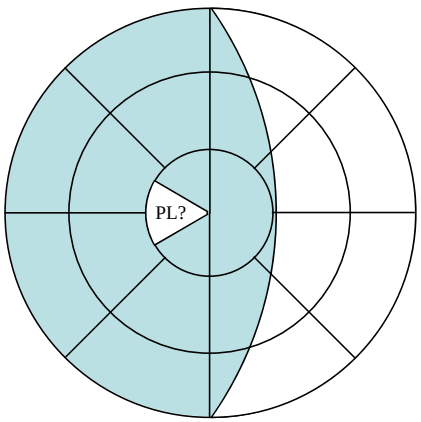
# Beta-angle Phasing




- Beta-earth at insertion is relatively fixed (~80 deg)
- Beta-sun at insertion is function of insertion DOY
- Sun circles moon system once/year after insertion
- Two (2) extreme lighting conditions (the solstices)
- Prime opportunities for looking at PL/PS regions
- Need to be near beta-sun-0 at each of the solstices
- 2-3 days, every 2 weeks, beta-sun @ solstice < 20°

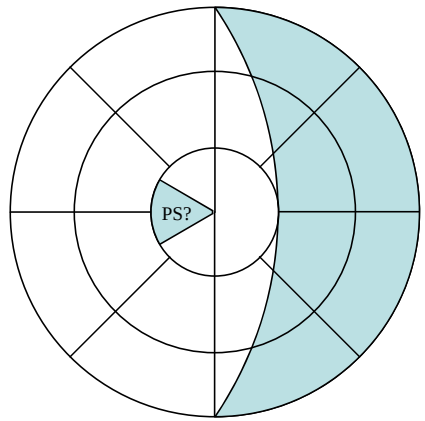



Sun @ Summer Solstice
1.4 deg "above" equator

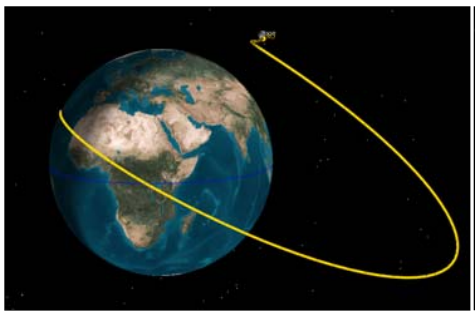
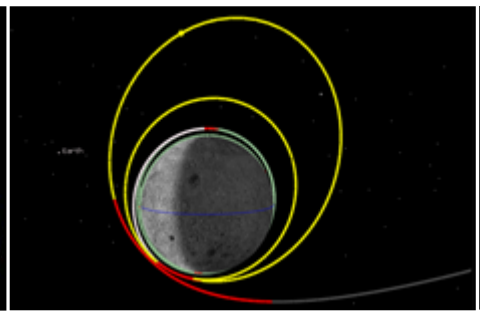
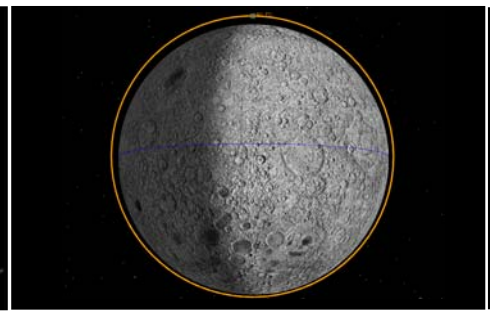
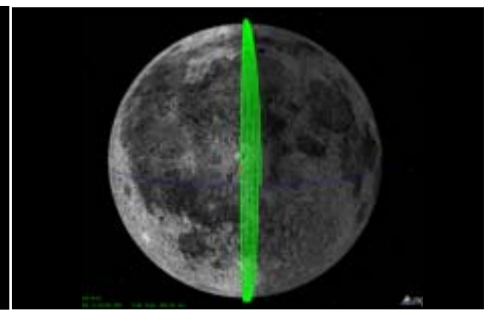
Sun @ Winter Solstice
1.4 deg "below" equator



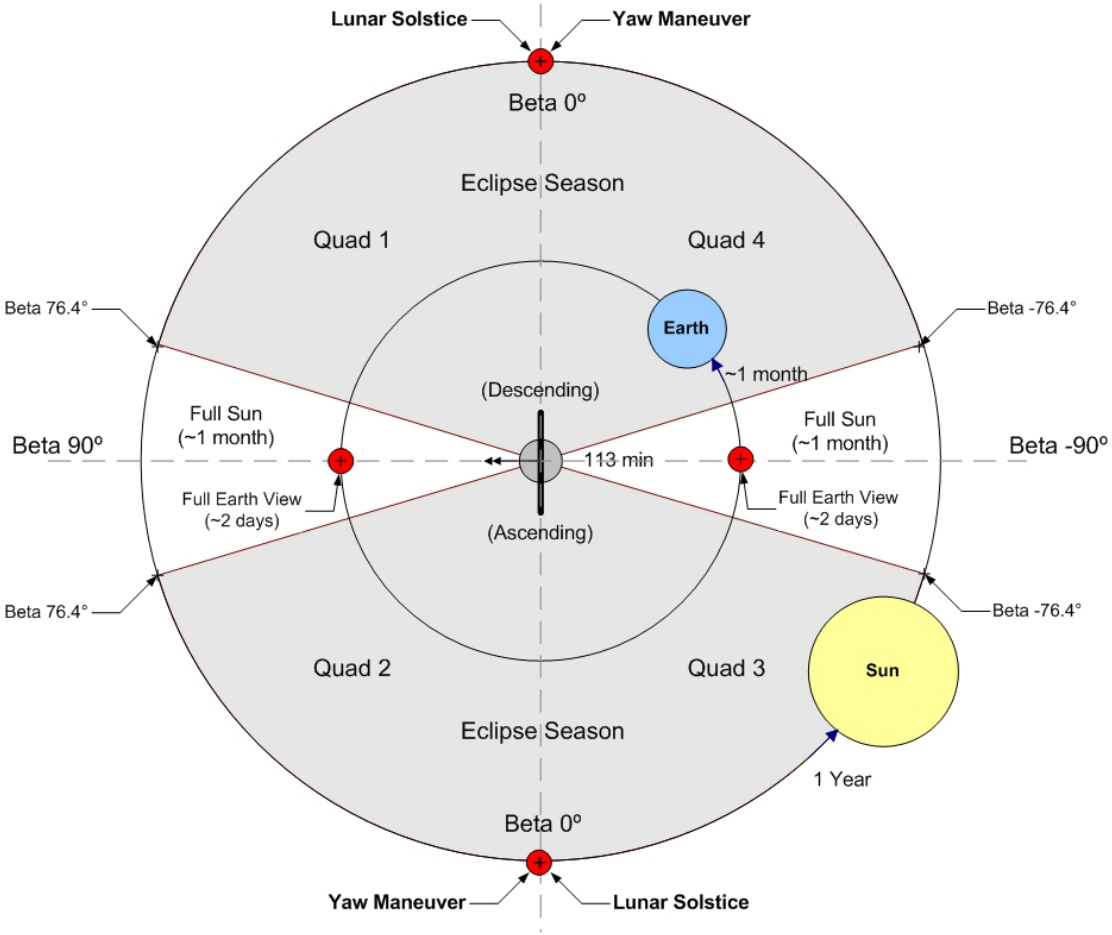

(South Pole Views)

# Launch Opportunities: Fall 2008

| Day (GMT) | Time (GMT) | Day (ET) | Time (ET) | Solution | TLI (min) | Eclipse (min) | AOS (min) | LOI (m/sec) | Beta (deg) |
|---|---|---|---|---|---|---|---|---|---|
| 10/28/08 | 8:51 | 10/28/08 | 4:51 | Short | 92.34 | 2.67 | 0.00 | 507.18 | 17.31 |
| 10/29/08 | 10:28 | 10/29/08 | 6:28 | Short | 89.84 | 1.20 | 0.00 | 512.41 | 4.31 |
| 10/30/08 | 12:06 | 10/30/08 | 8:06 | Short | 86.99 | 0.00 | 1.44 | 521.00 | 8.58 |
| 10/31/08 | 13:42 | 10/31/08 | 9:42 | Short | 84.02 | 281.07 | 3.02 | 531.51 | 21.34 |
| 11/11/08 | 8:11 | 11/11/08 | 3:11 | Short | 46.47 | 124.13 | 2.45 | 549.68 | 23.69 |
| 11/12/08 | 9:44 | 11/12/08 | 4:44 | Short | 44.81 | 0.00 | 3.31 | 552.81 | 7.83 |
| 11/13/08 | 11:37 | 11/13/08 | 6:37 | Short | 41.90 | 0.00 | 4.61 | 557.81 | 8.47 |
| 11/14/08 | 13:34 | 11/14/08 | 8:34 | Short | 38.41 | 0.00 | 6.48 | 561.46 | 25.14 |
| 11/24/08 | 6:42 | 11/24/08 | 1:42 | Short | 92.58 | 6.56 | 0.00 | 506.91 | 21.70 |
| 11/25/08 | 8:11 | 11/25/08 | 3:11 | Short | 90.51 | 5.18 | 0.00 | 511.62 | 8.67 |
| 11/26/08 | 9:47 | 11/26/08 | 4:47 | Short | 87.84 | 3.92 | 0.86 | 519.36 | 4.18 |
| 11/27/08 | 11:22 | 11/27/08 | 6:22 | Short | 84.99 | 2.63 | 2.45 | 528.68 | 16.95 |
| 12/09/08 | 3:12 | 12/08/08 | 22:12 | Long | 58.07 | 0.00 | 10.80 | 550.35 | 18.03 |
| 12/10/08 | 3:33 | 12/09/08 | 22:33 | Long | 60.29 | 0.00 | 9.36 | 547.90 | 3.02 |
| 12/11/08 | 10:44 | 12/11/08 | 5:44 | Short | 40.22 | 0.00 | 5.47 | 569.82 | 16.47 |
| 12/12/08 | 12:40 | 12/12/08 | 7:40 | Short | 36.59 | 0.00 | 7.34 | 572.12 | 33.34 |
| 12/22/08 | 5:57 | 12/22/08 | 0:57 | Short | 91.11 | 9.32 | 0.00 | 508.62 | 12.87 |
| 12/23/08 | 7:32 | 12/23/08 | 2:32 | Short | 88.57 | 7.82 | 0.43 | 516.82 | 0.08 |
| 12/24/08 | 9:06 | 12/24/08 | 4:06 | Short | 85.81 | 6.57 | 2.02 | 526.76 | 12.87 |
| 12/25/08 | 10:38 | 12/25/08 | 5:38 | Short | 82.93 | 5.40 | 3.46 | 536.77 | 25.60 |

# The Moon-Centered Universe

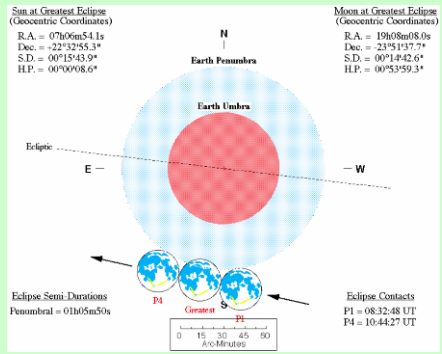



- Twice a month, LRO's orbit will be in full view of the Earth for roughly 2 days.
- Twice a month, LRO will perform a momentum management maneuver while the ground has complete coverage.
- Once a month, LRO will perform a station-keeping (SK) maneuver while the ground has complete coverage.
- Twice a year, LRO's orbit will be in full view of the Sun for roughly one month.
- During the eclipse season, LRO will have a maximum lunar occultation of 48 minutes.
- LRO's orbit will be targeted such that lunar solstice occurs near maximum occultation.
- Twice a year, LRO will perform a 180° yaw maneuver.
- Twice a year, the Moon will pass through the Earth's shadow (Lunar Eclipse).

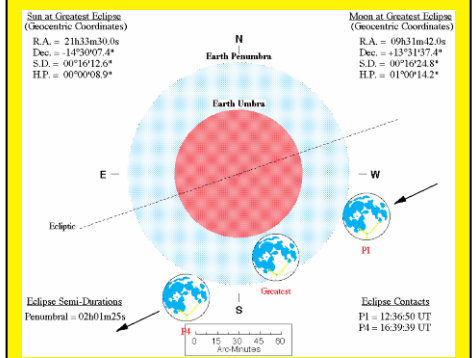
# Lunar Eclipses

| Lunar Eclipses: 2009-2013 | | | | |
|---|---|---|---|---|
| **Date** | **Type** | **Penum.** | **Partial** | **Total** |
| 2009 Feb 09 | **(2)** | 4:03 | – | – |
| 2009 Jul 07 | **(1)** | 2:12 | – | – |
| 2009 Aug 06 | **(1)** | 3:16 | – | – |
| 2009 Dec 31 | **(2)** | 4:15 | 1:02 | – |
| 2010 Jun 26 | **(3)** | 5:26 | 2:44 | – |
| 2010 Dec 21 | **(4)** | 5:38 | 3:29 | 1:13 |
| 2011 Jun 15 | **(4)** | 5:39 | 3:40 | 1:41 |
| 2011 Dec 10 | **(4)** | 6:00 | 3:33 | 0:52 |
| 2012 Jun 04 | **(3)** | 4:33 | 2:08 | – |
| 2012 Nov 28 | **(2)** | 4:41 | – | – |
| 2013 Apr 25 | **(2)** | 4:12 | 0:32 | – |
| 2013 May 25 | **(1)** | 0:54 | – | – |
| 2013 Oct 18 | **(2)** | 4:04 | – | – |

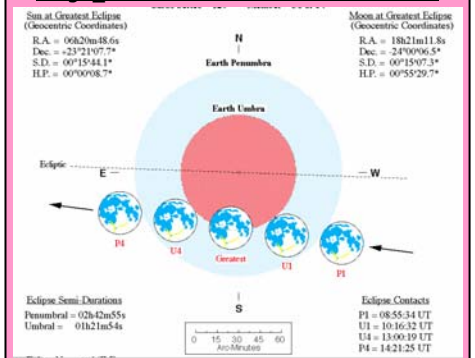
**Type 1:** 2009 Jul 07



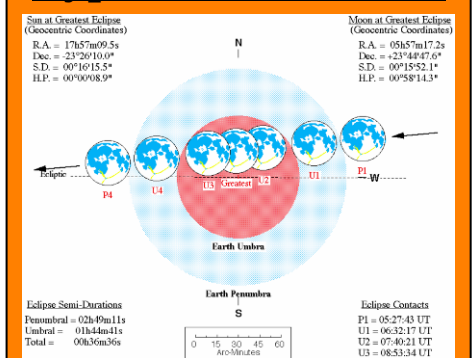

**Type 2:** 2009 Feb 09




**Type 3:** 2010 Jun 26

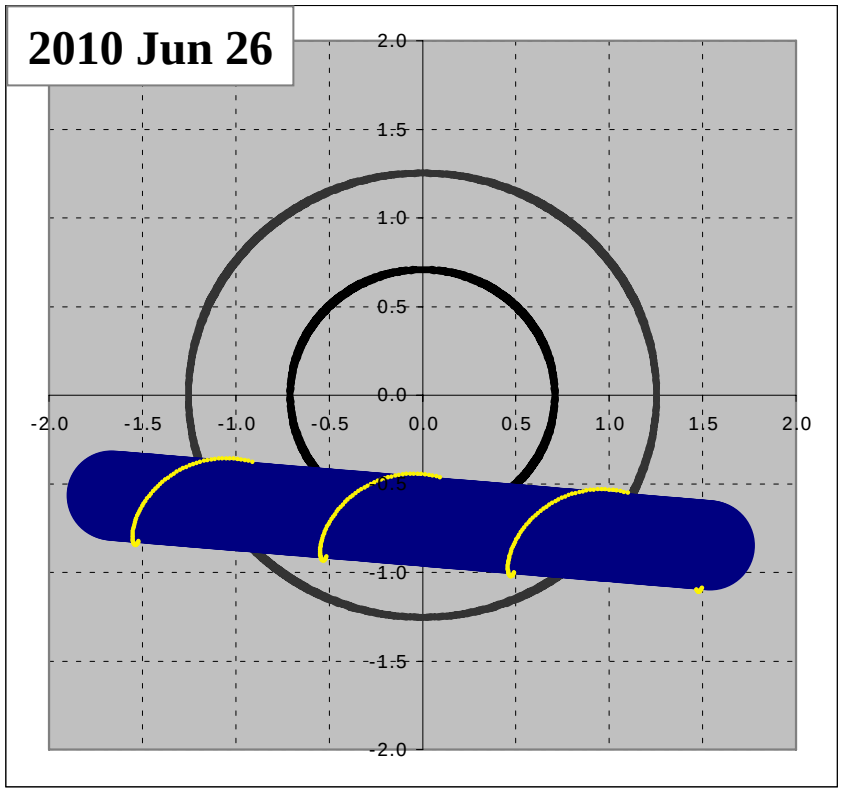


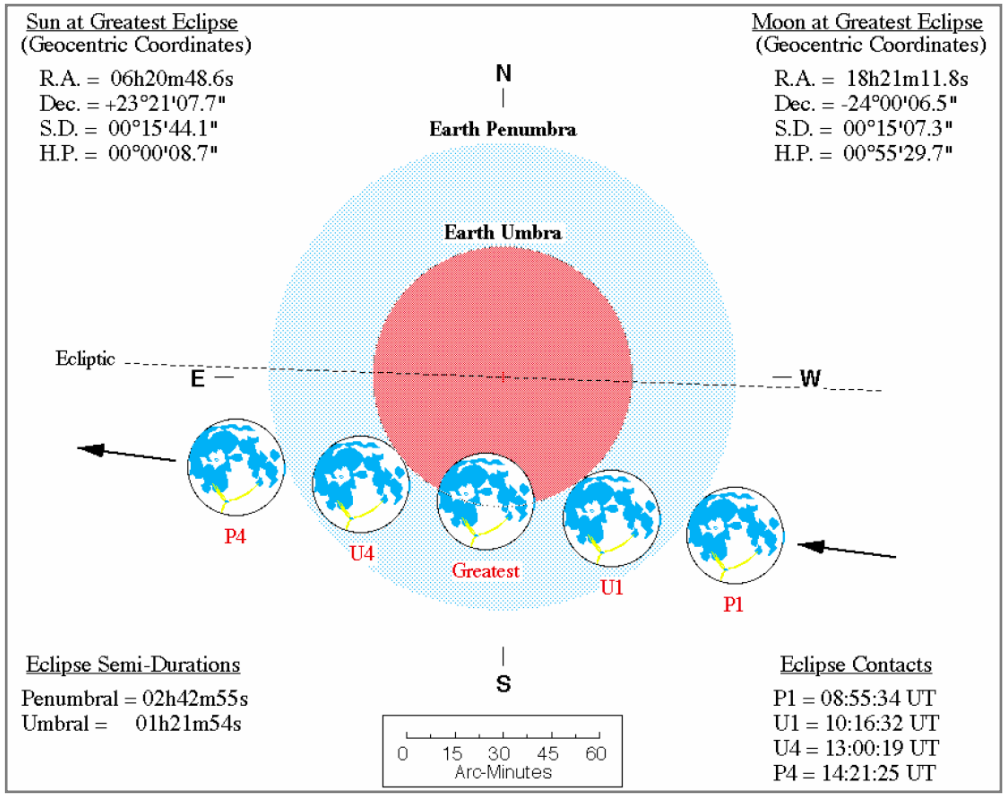

**Type 4:** 2010 Dec 21

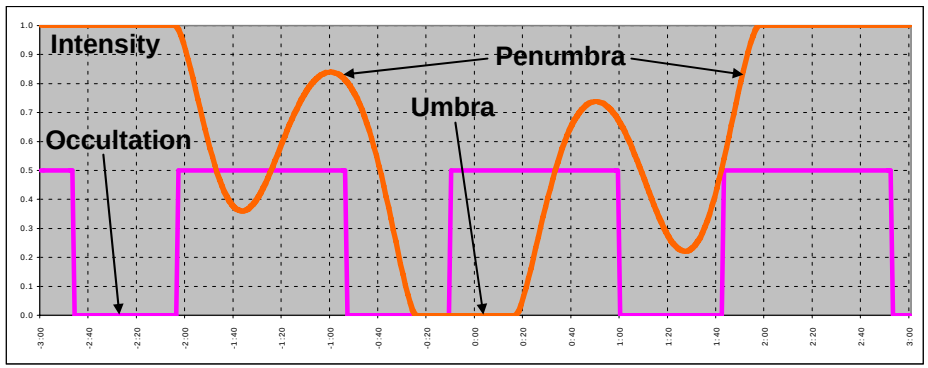


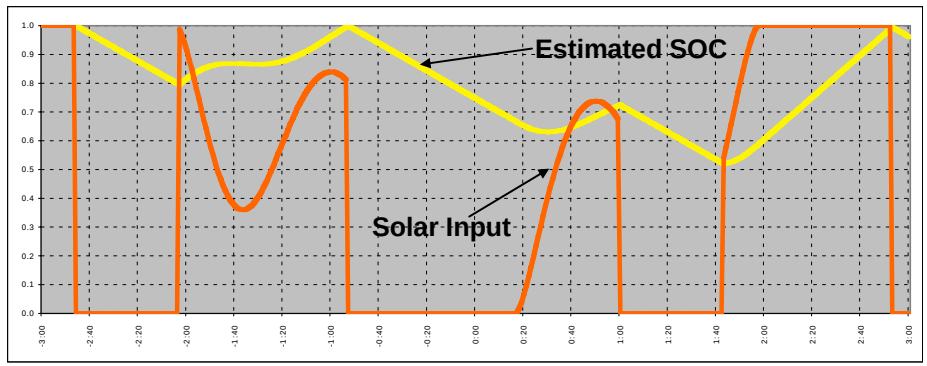

***Lunar Eclipses are "seasonal" w/ ~ 4 year severity cycle***

# Lunar Eclipse Modeling



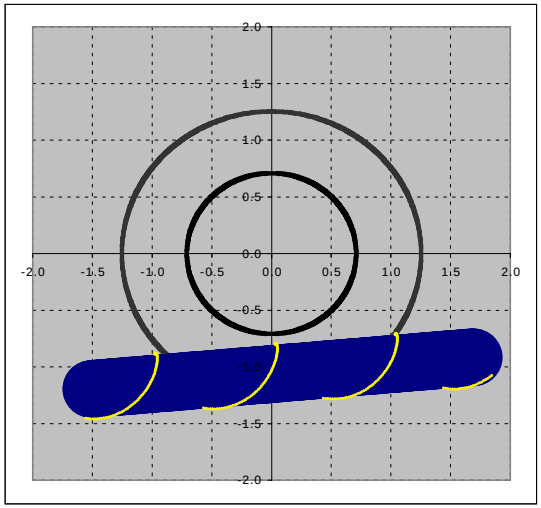



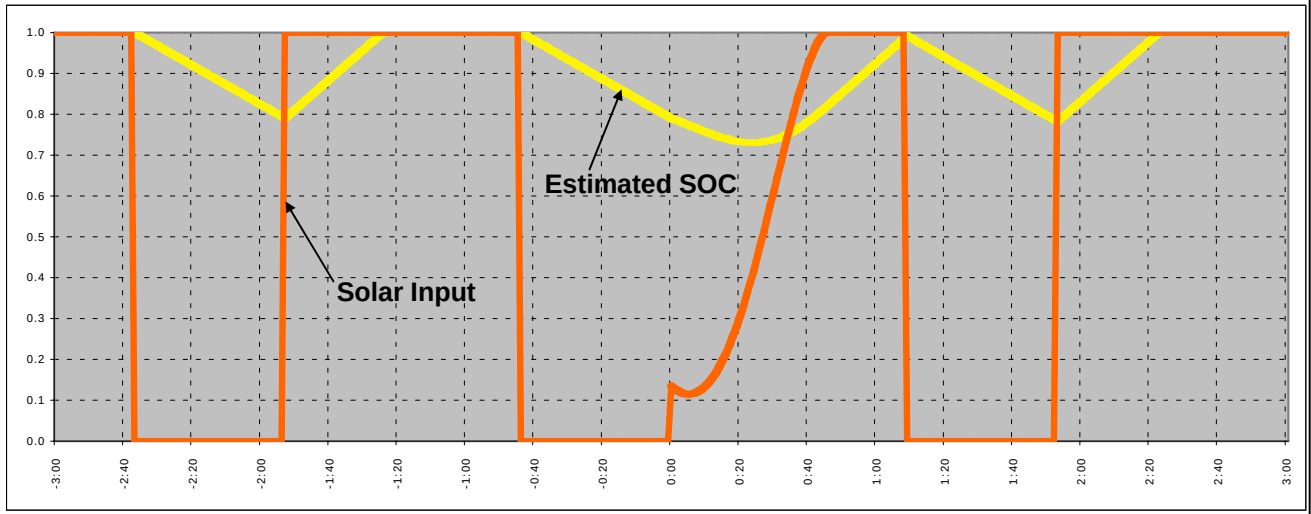



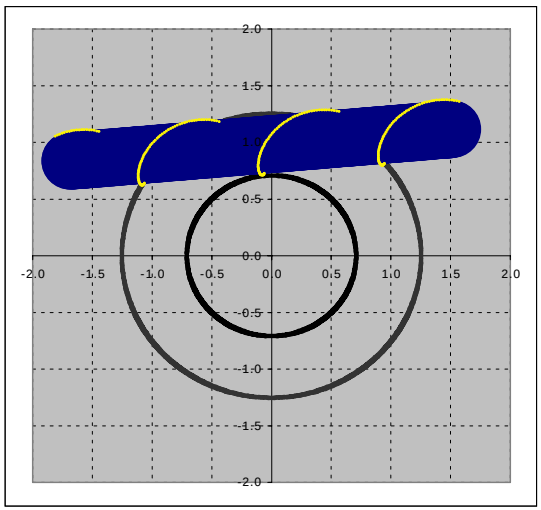
# Lunar Eclipses in Nominal Mission

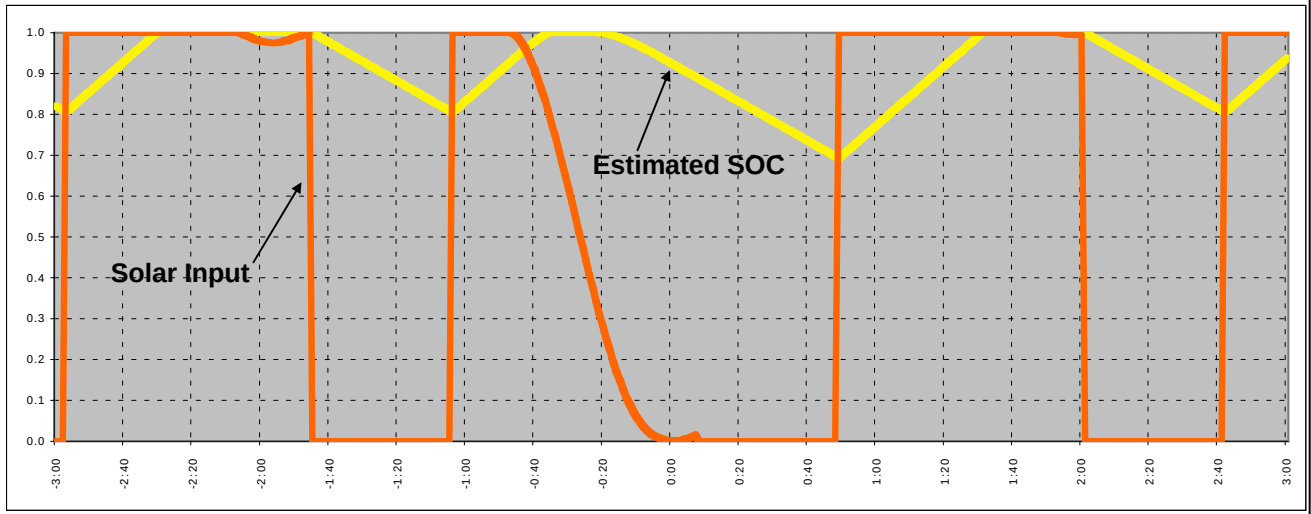
## First: 2009 Feb 09 — DOD: ~30%



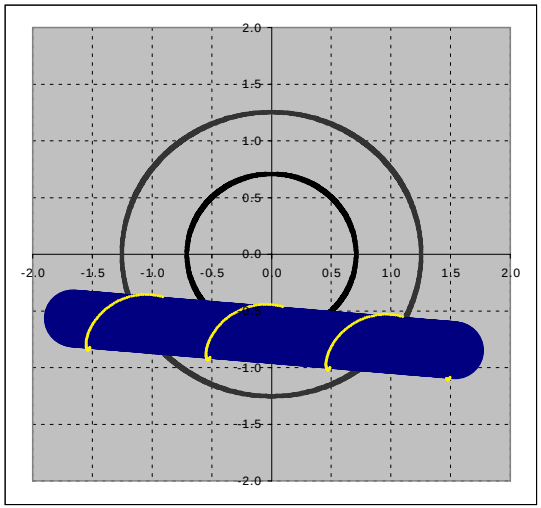

## Worst: 2009 Dec 31 — DOD: ~30%

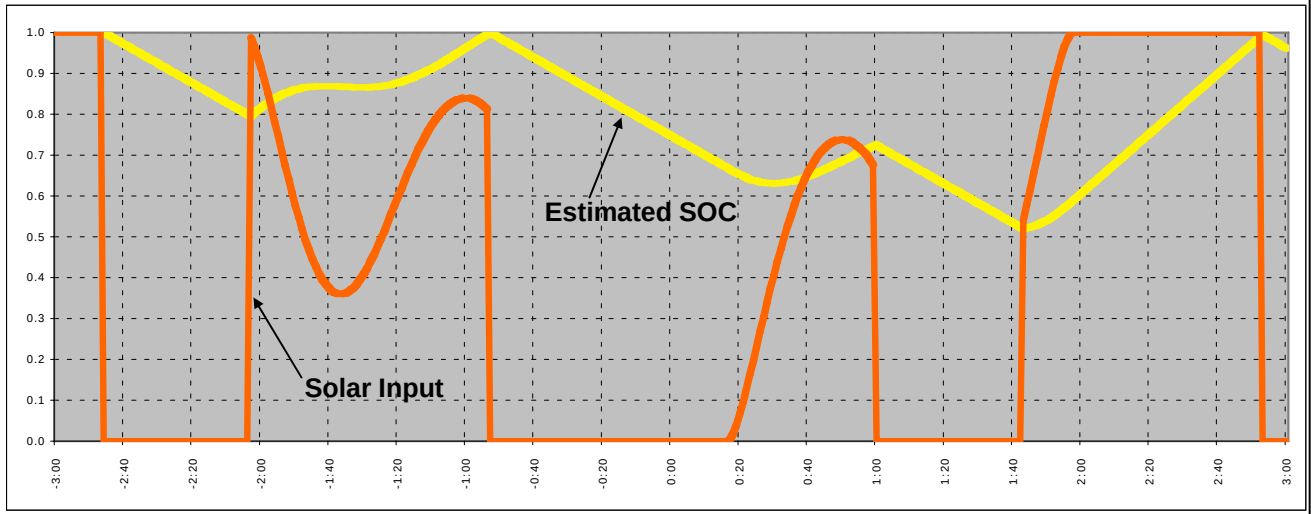


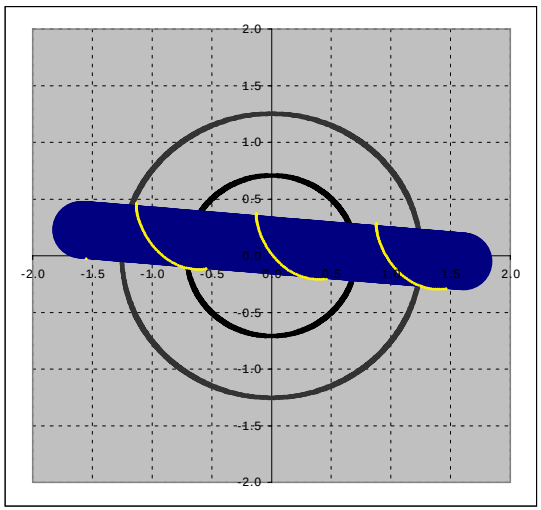
# Lunar Eclipses in Extended Mission

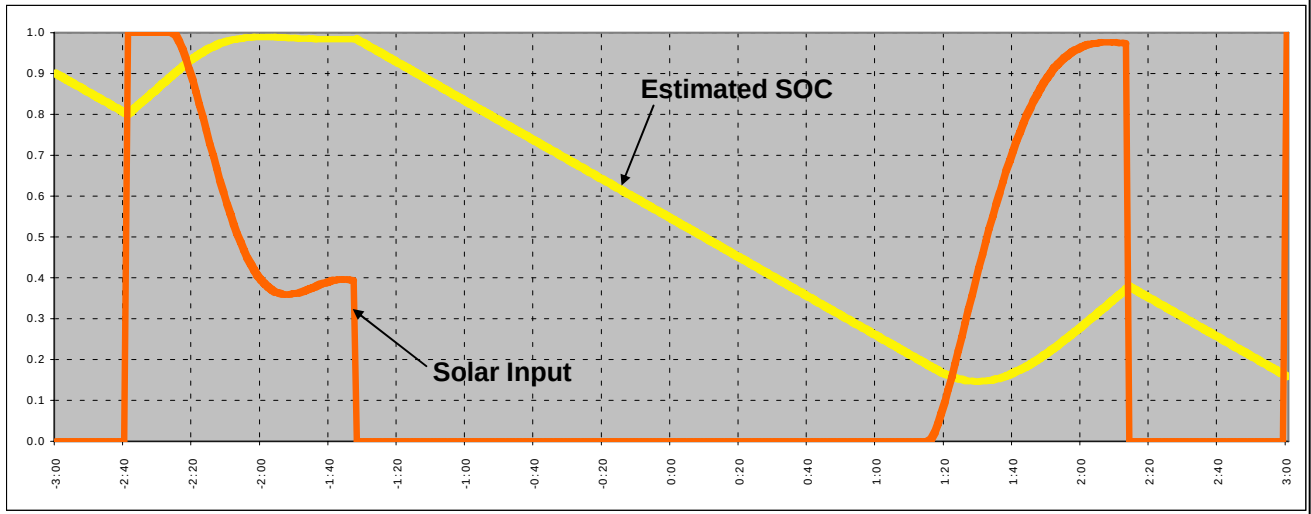
## First: 2010 Jun 26 — DOD: ~50%




## Worst: 2011 Jun 15 — DOD: <90%

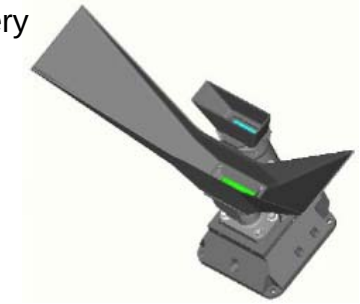


# Orbiter Instrumentation

### LROC/WAC: Wide-Angle Camera

- Global Imagery
- Lighting
- Resources



Day Side
Autonomous

### LROC/NACs: Narrow-Angle Cameras

- Targeted Imagery
- Hazards
- Topography

Day Side
Timeline Driven

### LOLA: Lunar Orbiter Laser Altimeter

- Topography
- Slopes
- Roughness

Full Orbit
Autonomous

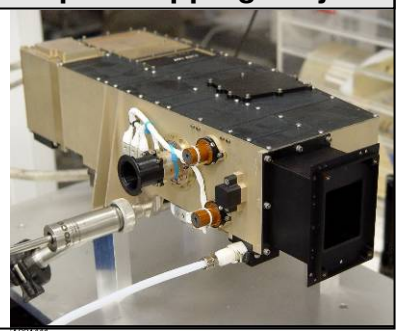
### DLRE: Diviner Lunar Radiometer Exp.

- Temperature
- Hazards
- Resources

Full Orbit
Autonomous

### LAMP: Lyman-Alpha Mapping Project

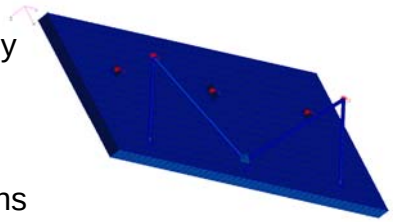
- Water-Frost
- PSR Maps



Night Side
Autonomous

### Mini-RF: Synthetic Aperture Radar

- Tech Demonstration
- Resources
- Topography



Polar Regions
Timeline Driven

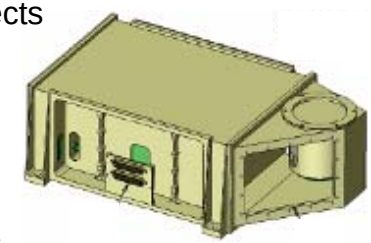
### LEND: Lunar Explr. Neutron Detector

- Neutron Albedo
- Hydrogen Maps

Full Orbit
Autonomous

### CRaTER: Cosmic Ray Telescope…

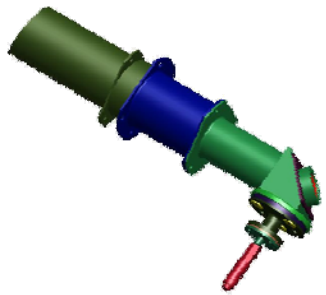
- Radiation Spectra
- Tissue Effects



Full Orbit
Autonomous

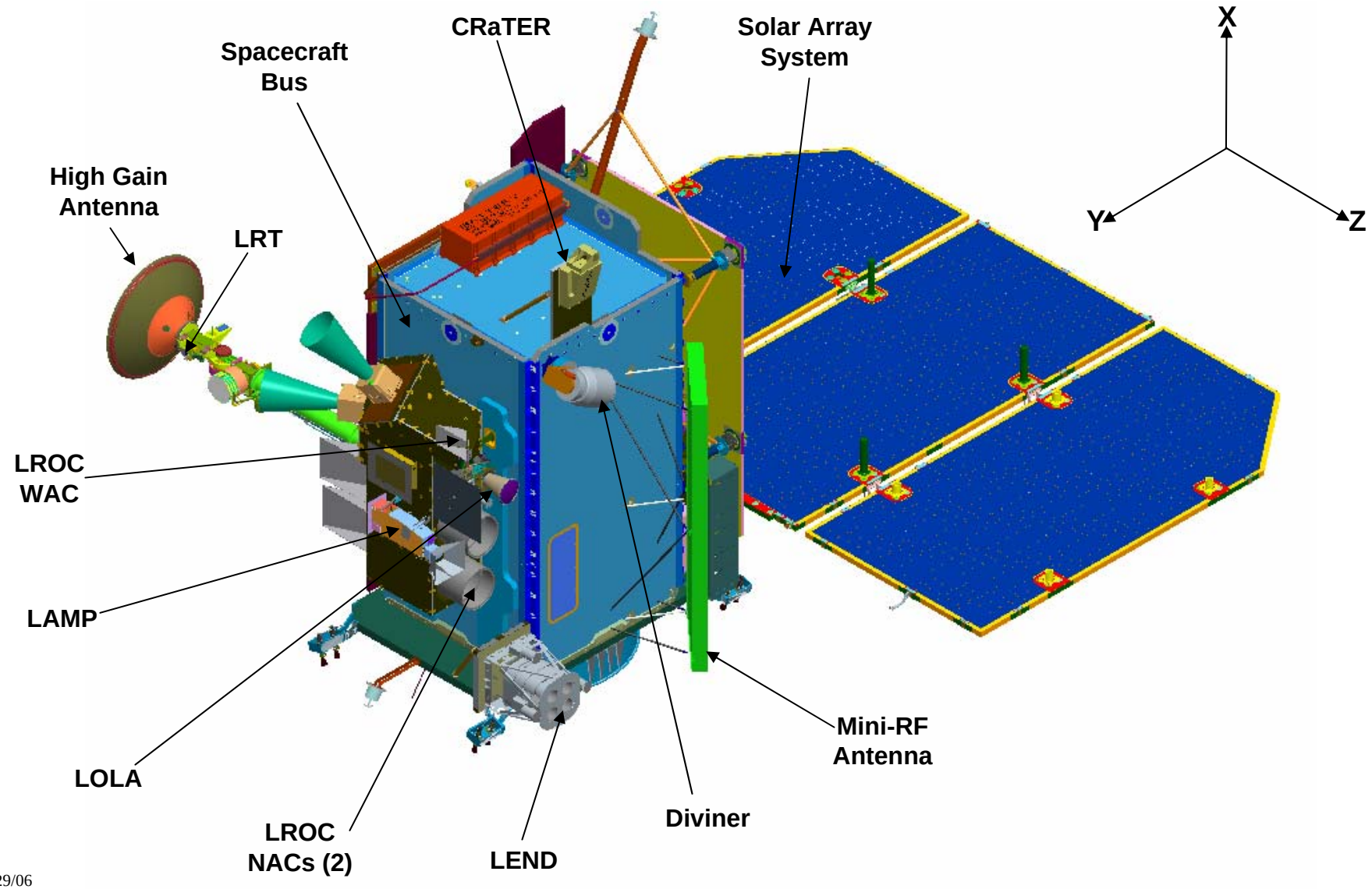
### LRT: Laser Ranging Telescope

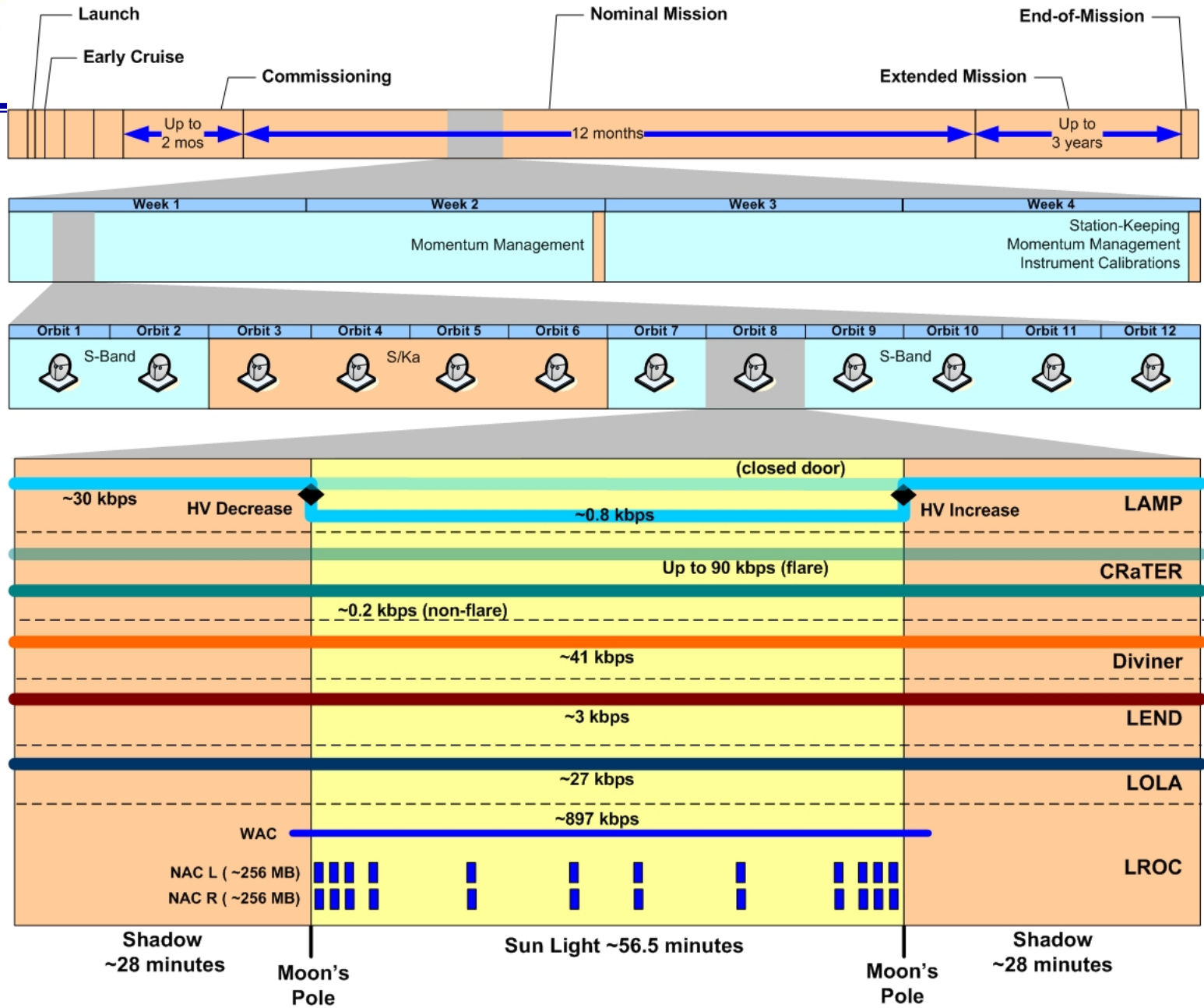
- Topography
- Gravity



LRGS LOS
Autonomous

# Orbiter Layout




Launch
Early Cruise
Commissioning
Nominal Mission
Extended Mission
Up to 2 mos
12 months
Up to 3 years
Week 1
Week 2
Week 3
Week 4
Momentum Management
Station-Keeping
Momentum Management
Instrument Calibrations
Orbit 1
Orbit 2
Orbit 3
Orbit 4
Orbit 5
Orbit 6
Orbit 7
Orbit 8
Orbit 9
Orbit 10
Orbit 11
Orbit 12
S-Band
S/Ka
S-Band
(closed door)
~30 kbps
HV Decrease
~0.8 kbps
HV Increase
LAMP
Up to 90 kbps (flare)
CRaTER
~0.2 kbps (non-flare)
~41 kbps
Diviner
~3 kbps
LEND
~27 kbps
LOLA
~897 kbps
WAC
NAC L ( ~256 MB)
NAC R ( ~256 MB)
LROC
Shadow ~28 minutes
Moon's Pole
Sun Light ~56.5 minutes
Moon's Pole
Shadow ~28 minutes