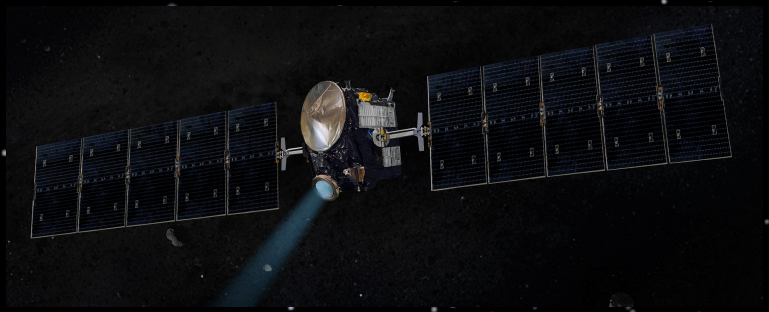
DAWN AT CERES



Ceres 2015

Vesta: 2011-2012

C. A. Raymond, C. T. Russell, C. A. Polanskey, S. Joy, M. Rayman

Presentation to the
9th Small Bodies Assessment Group Meeting
Washington, DC
11 July 2013

Ceres – A Unique Asteroid

…and a dwarf planet

- Twice the size of Enceladus (~475 km radius)
- Surface temperature > 200K
- Hydrostatic shape
- No craters > 100 km
- Density: 2088 kg/m^3
- Rock/Ice mass fraction: ~70/30
- Surface dominated by brucite [$Mg(OH)_2$] and carbonates (Milliken and Rivkin 2009)

There are no meteorites that are linked to Ceres

Only telescopic data are available to understand Ceres' composition

→ Ceres is the third solar system object after Earth and Mars, on which carbonates have been observed.

Planning Constraints

- Loss of second reaction wheel at the end of the Vesta mission
  - Resulted in the need for a plan that could achieve the science objectives using only jet control (hydrazine reaction control system)
  - Hybrid control using jets with remaining two wheels will be used to extend operational lifetime
  - Hydrazine and jet pulses became the limiting consumable
- Hydrazine conservation is key to maximizing science return
  - Studied and implemented hydrazine conservation measures resulting in increase in hydrazine available for science operations
    - Reduced number of turns, slower turns
    - Pointing control deadbands tuned for observing conditions
  - Performed analyses and simulations to ensure efficient safe operation under hybrid control

Ceres Planning Status

- Concept study completed in December
  - Demonstrated a viable Ceres mission concept that met L1 Requirements within initial first-order hydrazine constraints
- Science Orbit Requirements completed
  - Includes Survey, High-Altitude and Low-Altitude orbits similar to Vesta
  - Low-Altitude Mapping Orbit (LAMO) has equivalent geometry in terms of solid angle to Vesta
  - Detailed navigation studies are underway
- Science Plan is being elaborated
  - Initial draft of activity-level time-ordered listing have been generated consistent with the L1 requirements, science objectives and higher-fidelity hydrazine constraints

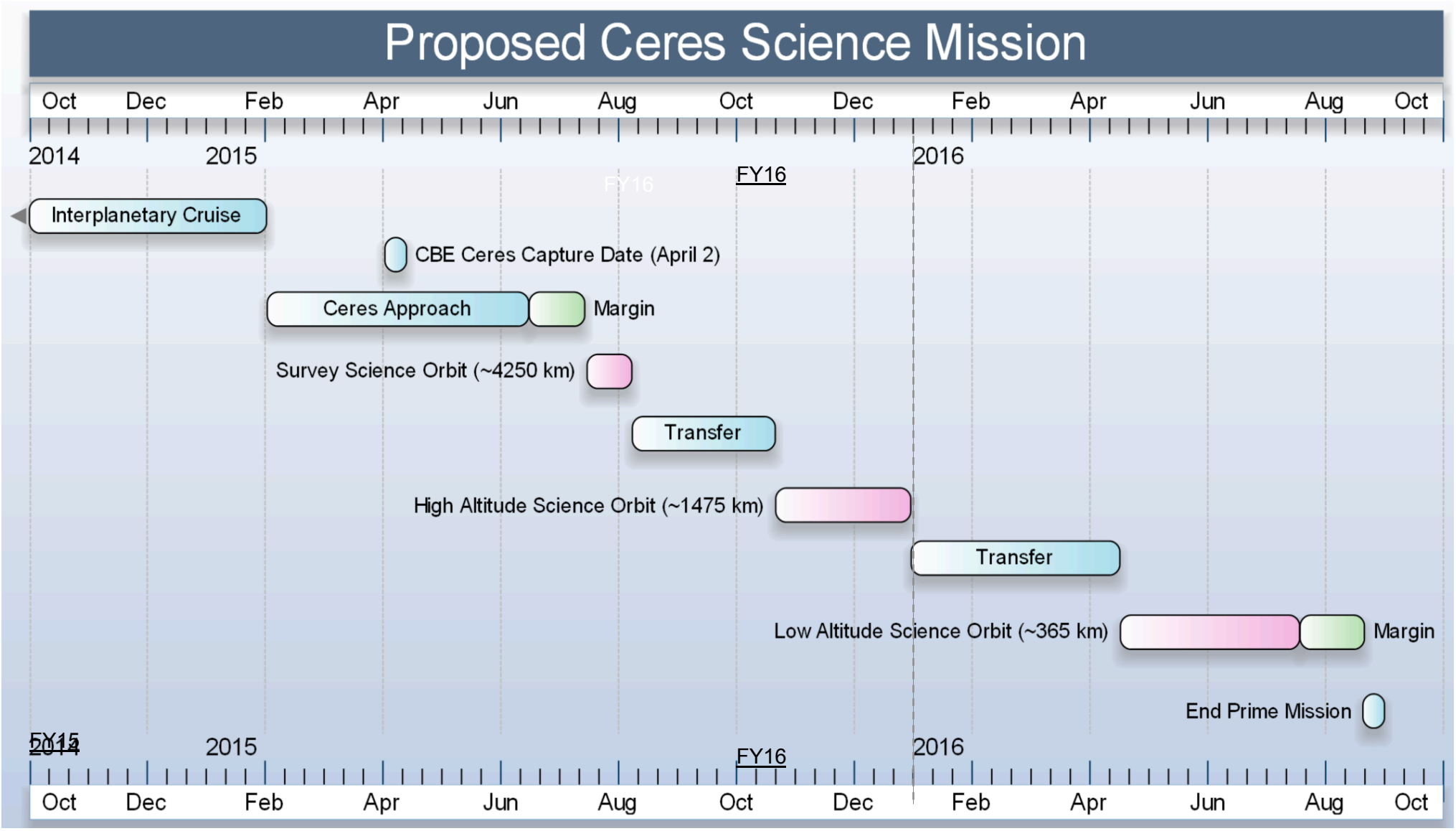
Ceres Science Plan Overview

Phase	Radius*	FC Res	Observations
Approach	163,000 km 80,000 km < 50,000 km	15 km 7.4 km n/a	OpNavs (9) FC & VIR RC1 FC & VIR (pole & spin rate) RC2 FC & VIR (pole & spin rate) FC Satellite search
RC3	14,028 km	1,262 m	Three full rotations (north, equator, south) FC & VIR FC High Phase observations (2 rotations)
Survey	4725 km	395 m	VIR 80% Global coverage nadir FC Global coverage clear + 7 filters nadir FC Limb observations (3)
HAMO	1950 km	136 m	FC Global clear nadir + 4 off-nadir global maps FC Global color coverage (minimum 3 filters) VIR Low resolution L1 requirement
LAMO	841 km	33 m	GRaND 75% nadir duty cycle Gravity HGA + LGA coverage VIR High resolution L1 requirement FC Global coverage for chronology

Items in blue are not yet in plan pending detailed hydrazine estimates

*Orbit radius will shift based on gravity model and technique used to develop the trajectory

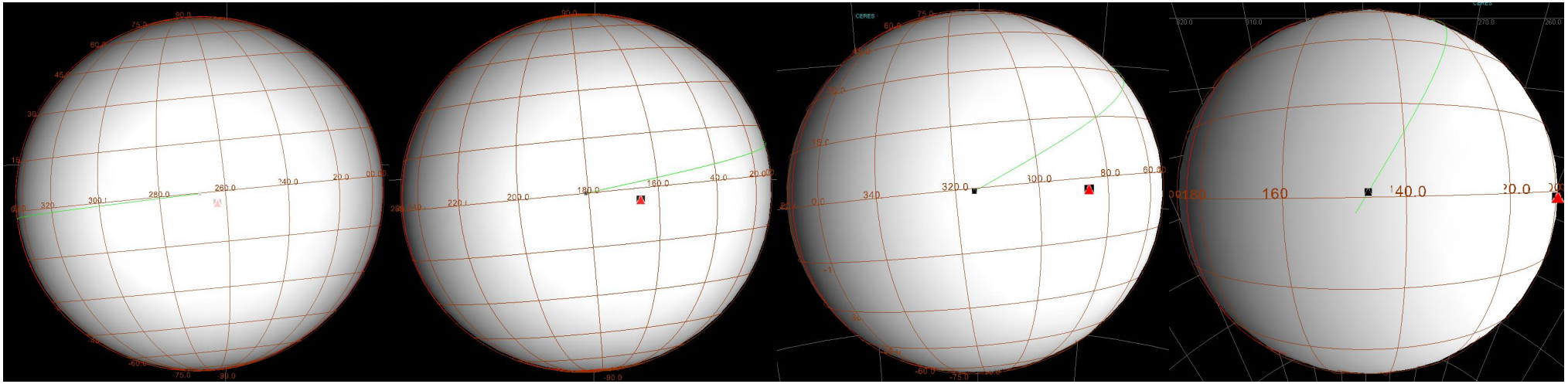
Proposed Ceres Mission Timeline



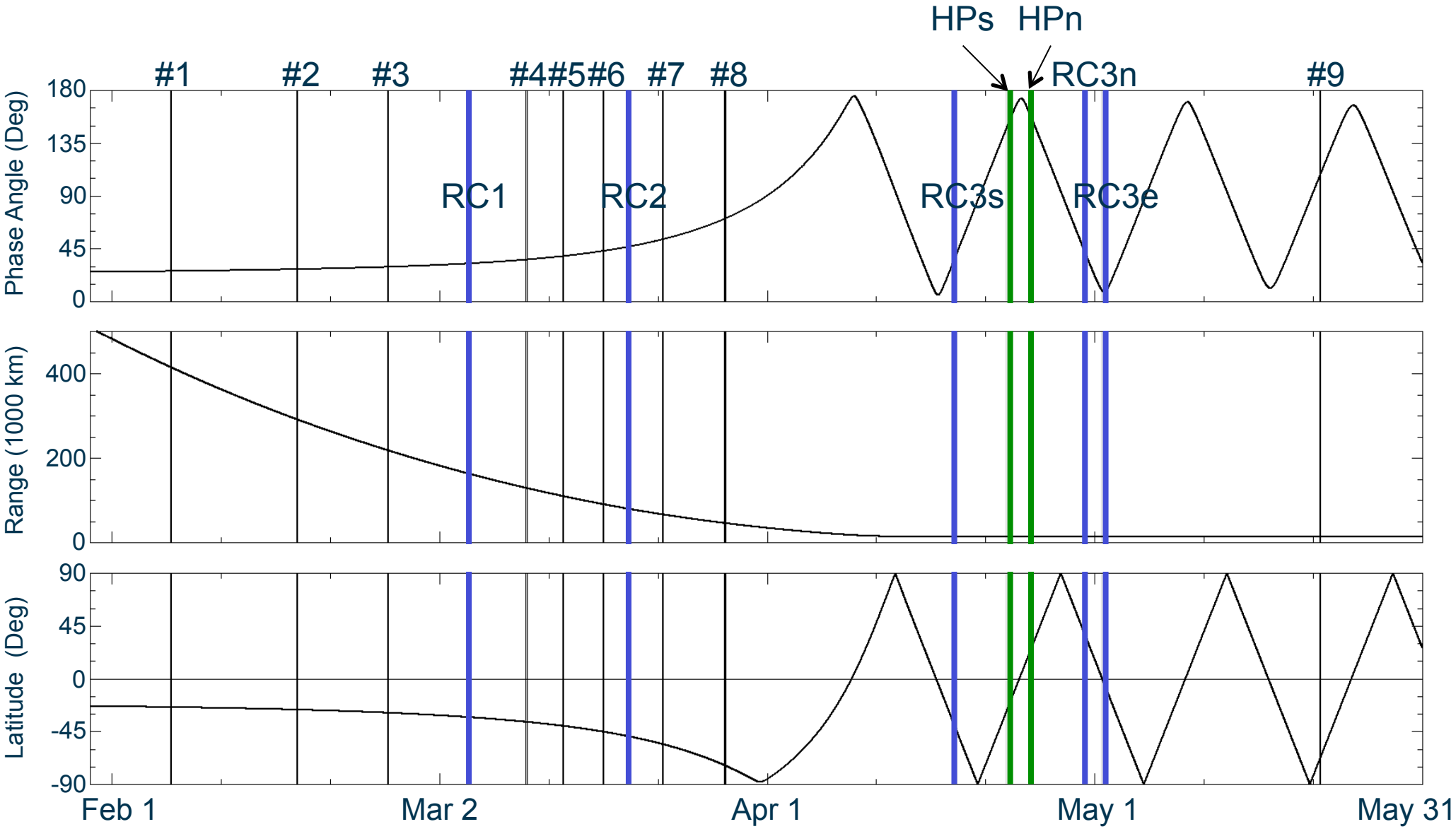
Ceres Lighting Conditions

- Lighting conditions will not drive the Ceres operations timeline as it did at Vesta

RC3	Survey	HAMO	LAMO
SS Lat = -3.9 deg	SS Lat = -3.7 deg	SS Lat = -3.2 deg	SS Lat = -1.8 deg

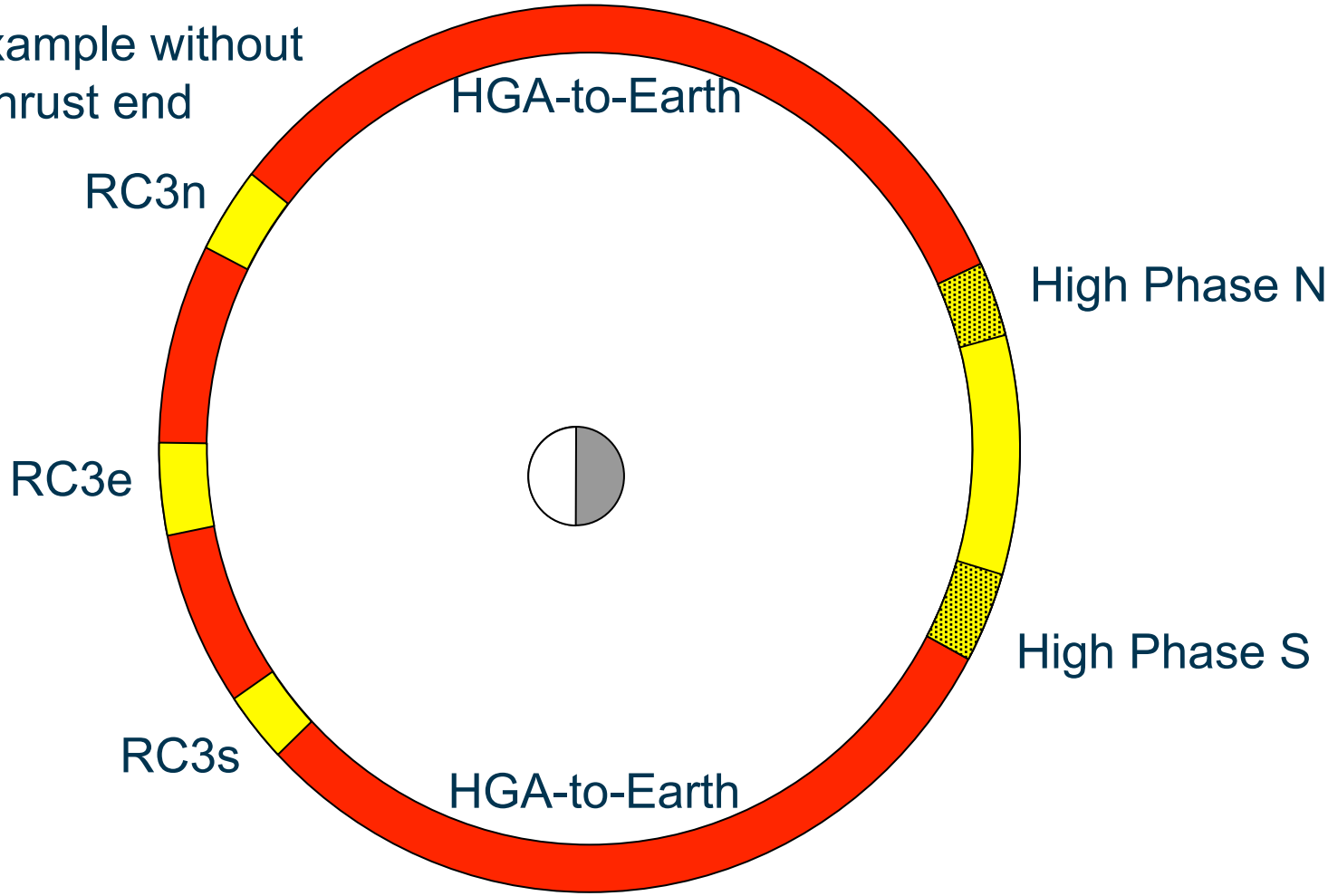


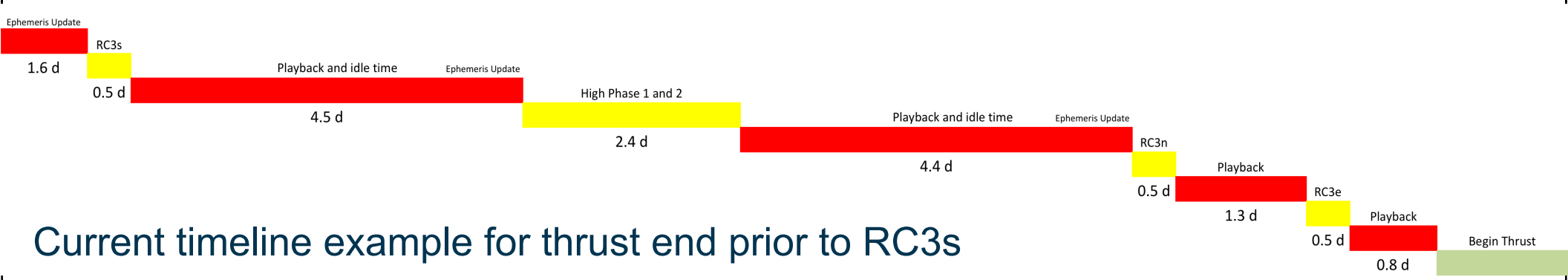
Approach Geometry



RC3 Attitude Profile

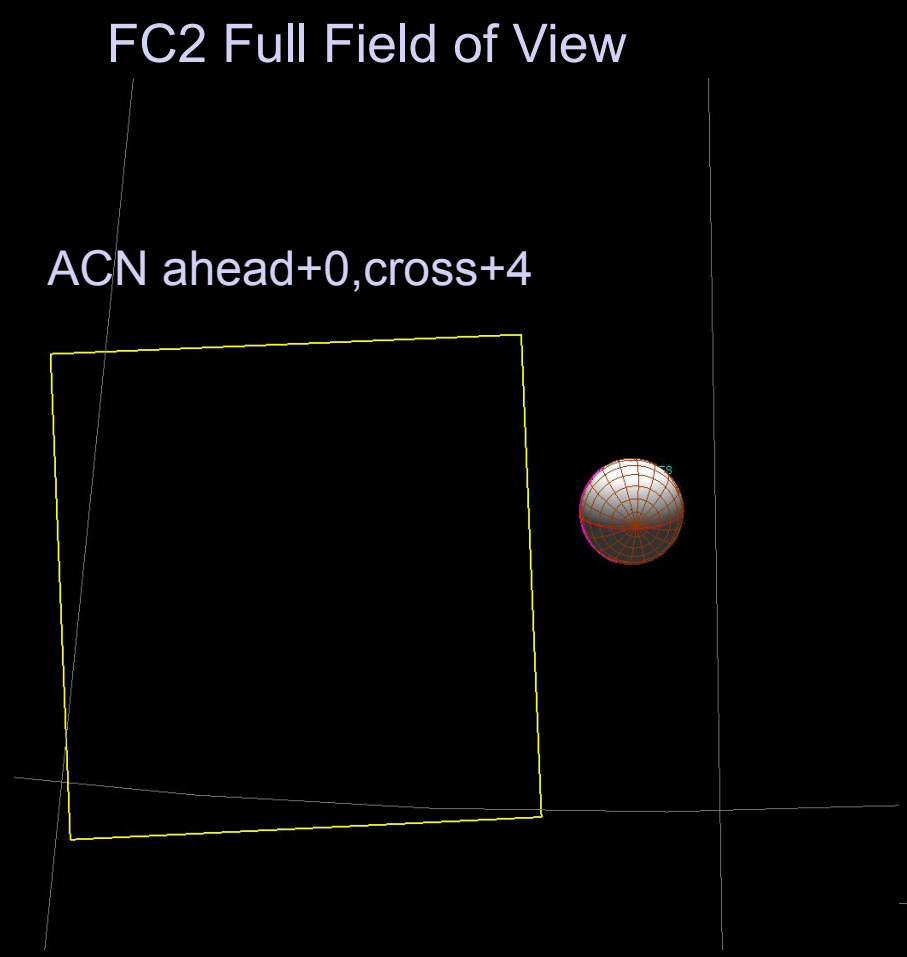
Generic example without details of thrust end

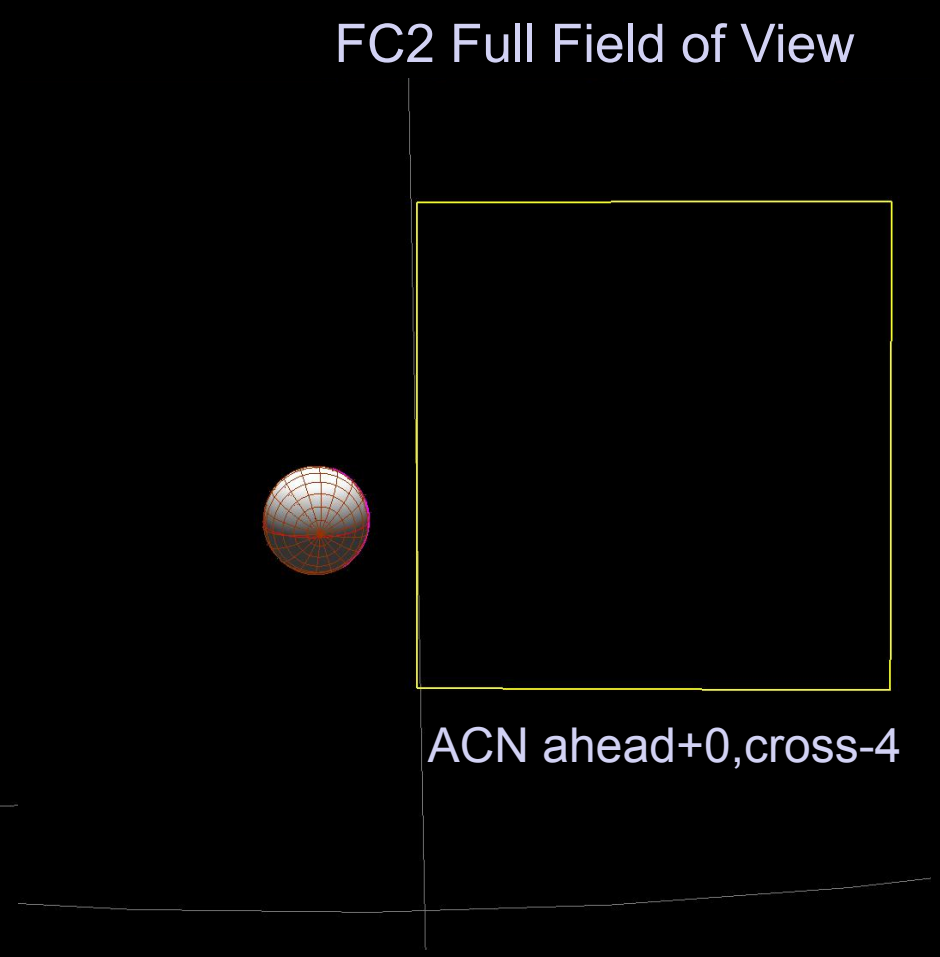




Current timeline example for thrust end prior to RC3s

OpNav 8 Satellite Search





Satellite Search 2: Mar 28 22:00 – Mar 29 01:00 and Mar 29 03:00 – 06:00 (around OpNav 8)

Duration: Two 3 hr observations

Range: 46×10^3 km

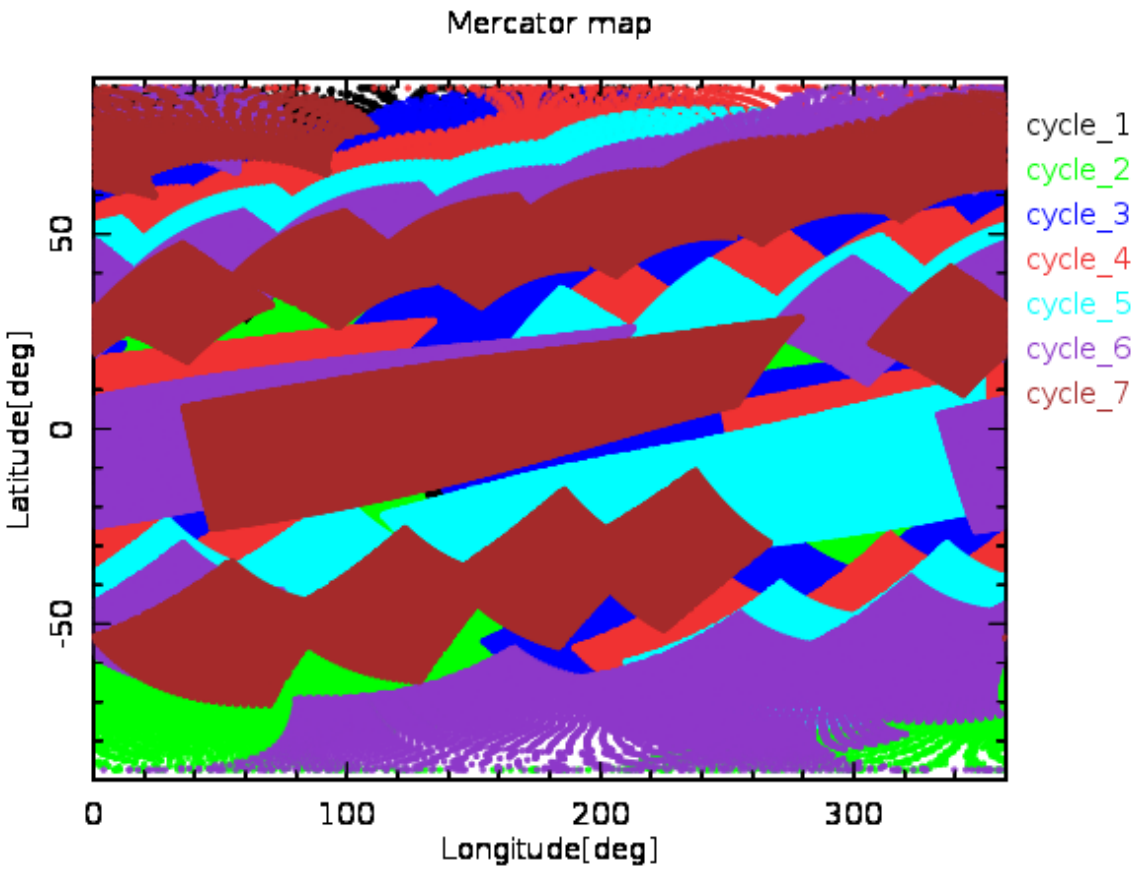
FC2: Each obs has 3 image stations with 4 sets of 16 images per station (384 images)

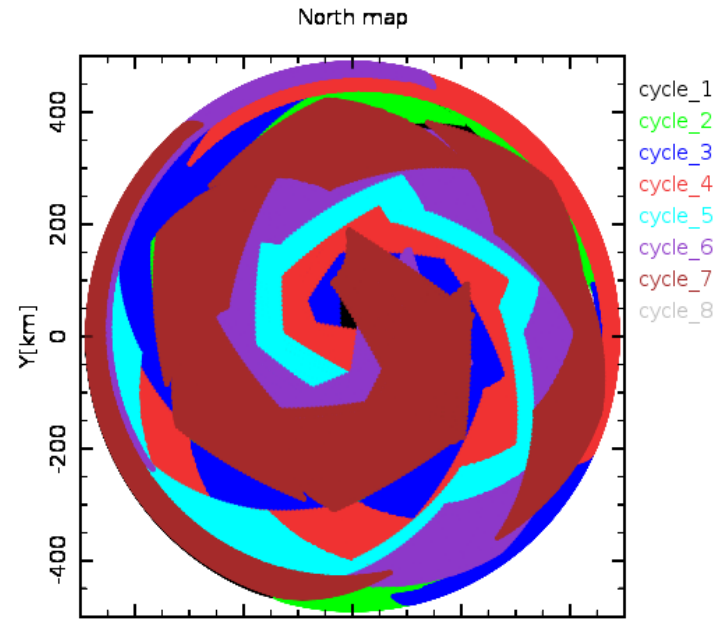
VIR: None

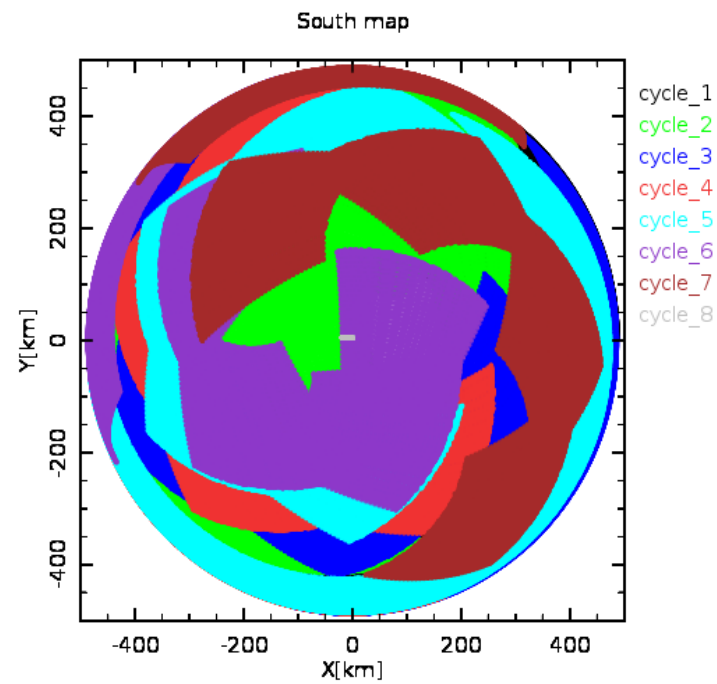
Pointing: FC2 pointed at two different explicit offsets from Ceres offsets

Survey: VIR Footprints – Seven Cycles

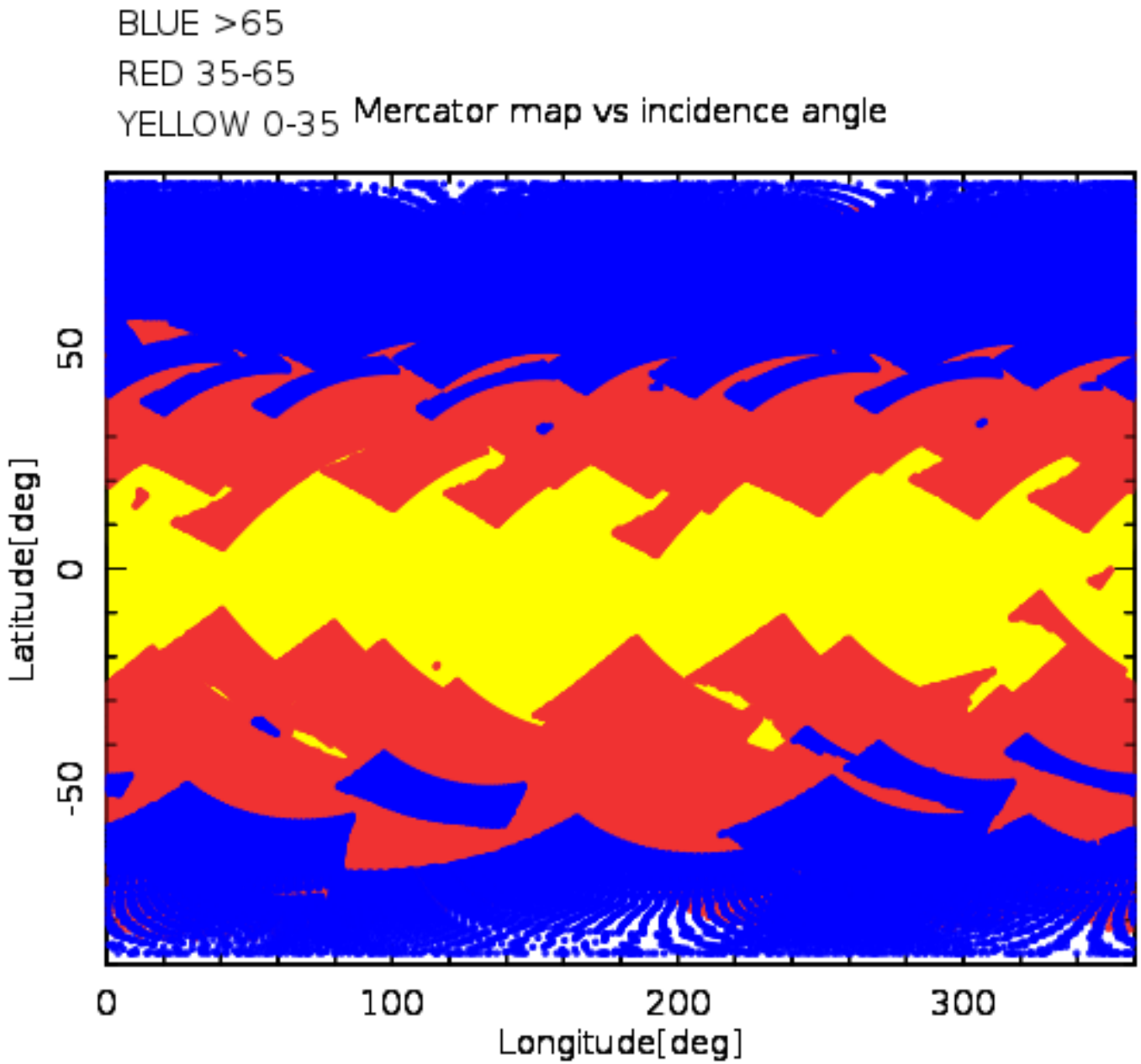
Global VIR coverage achieved with resolution of ~1200 km



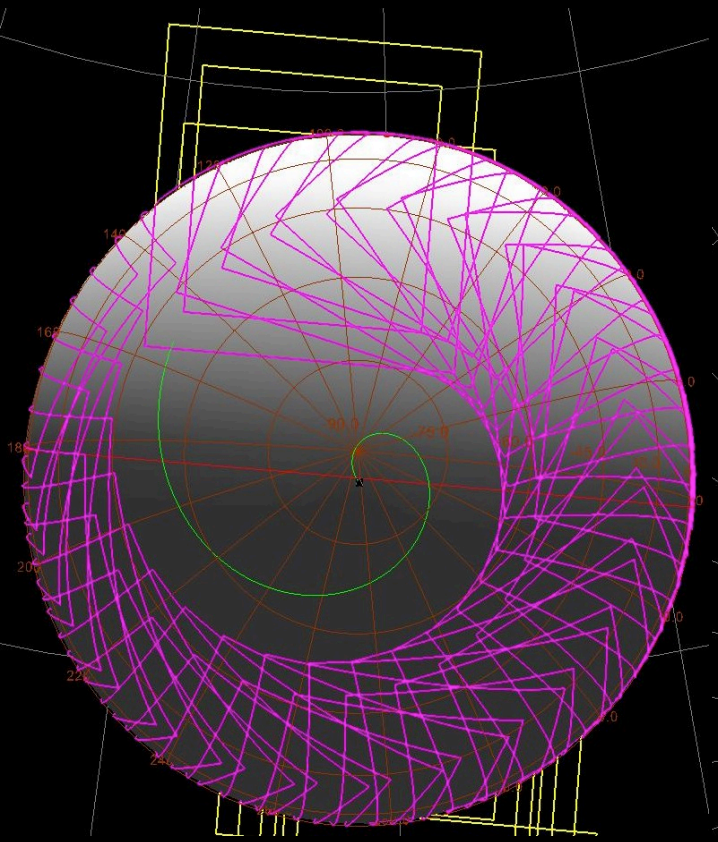




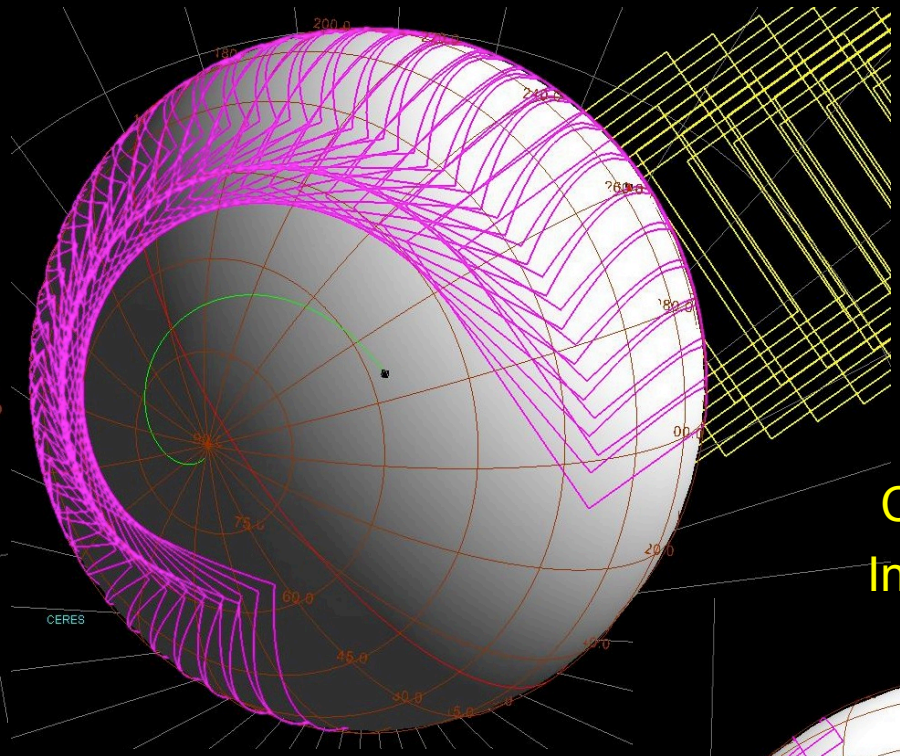
Survey VIR Incidence Angle



FC2 Limb Imaging Opportunity

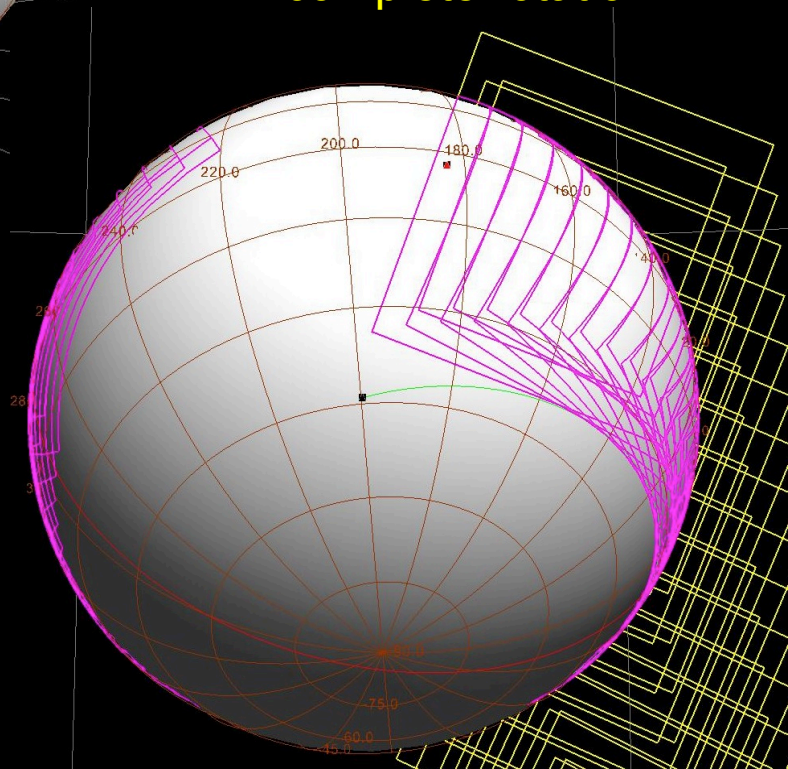


C1 from south pole



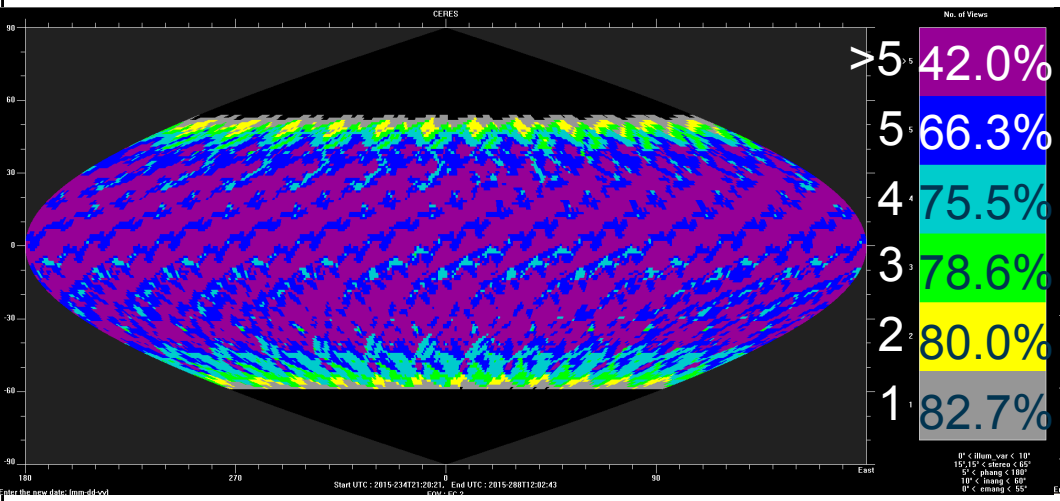
C2 from north pole
Incomplete rotation

C6 from the south
Incomplete rotation

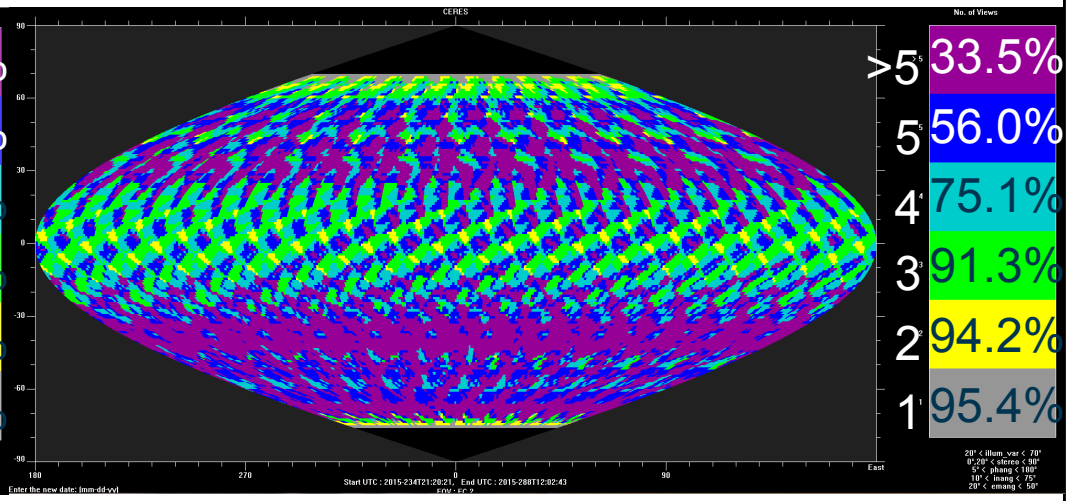


HAMO FC2 Stereo and SPC Coverage

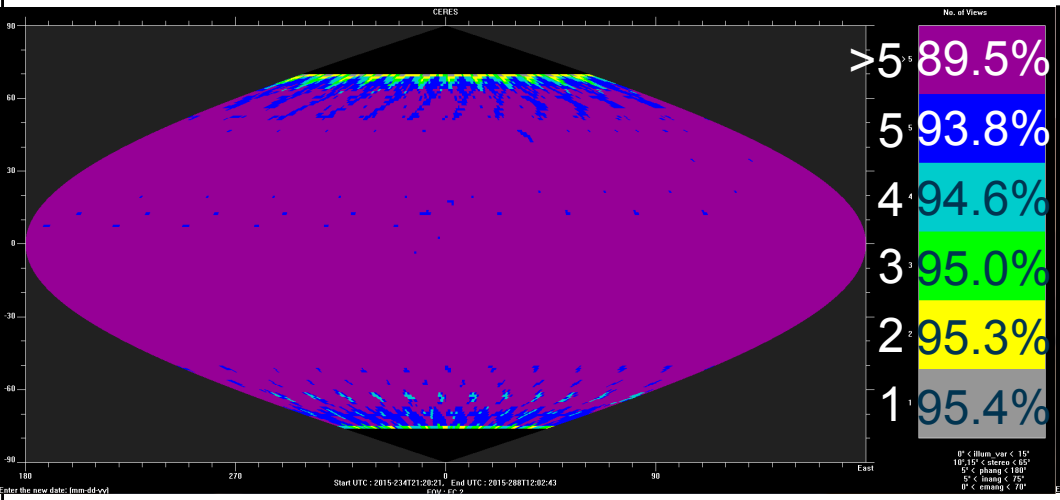
Optimal Stereo Coverage



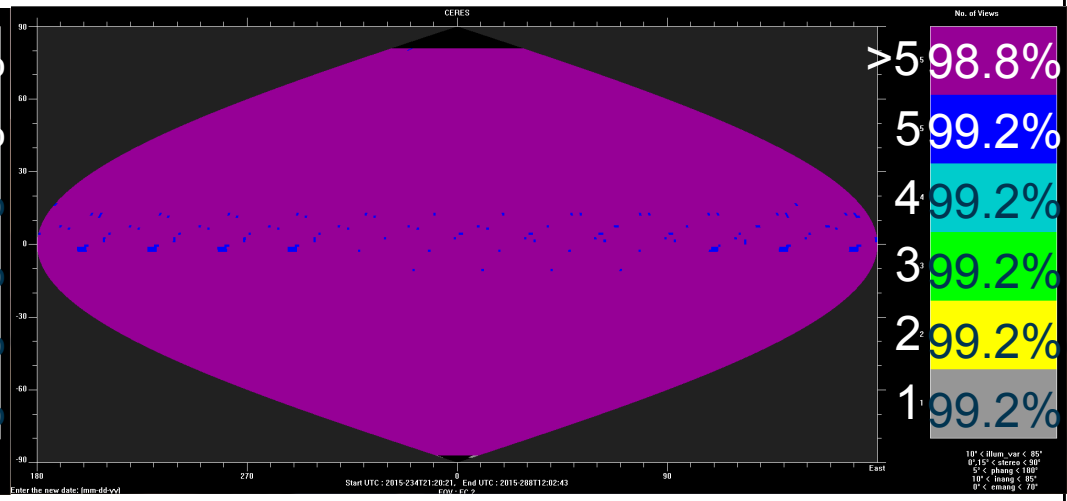
Optimal SPC coverage



Usable Stereo Coverage

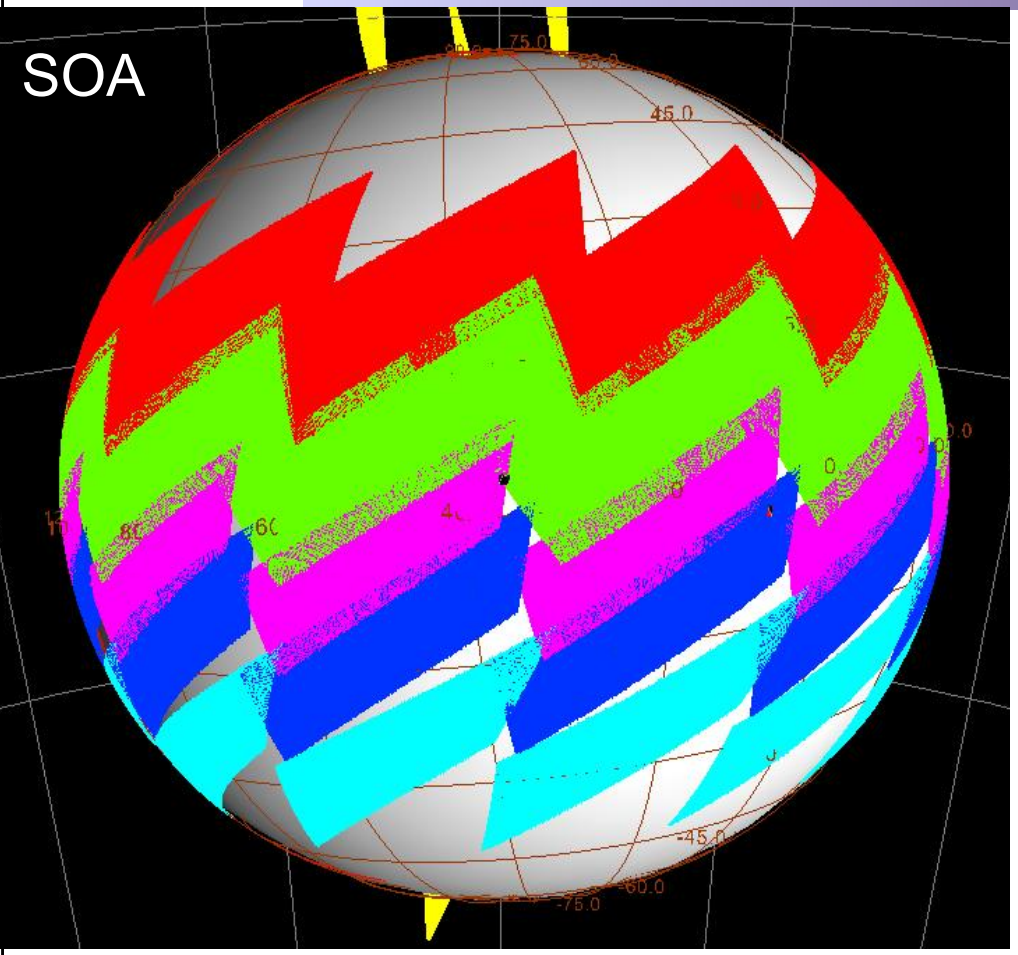


Usable SPC coverage



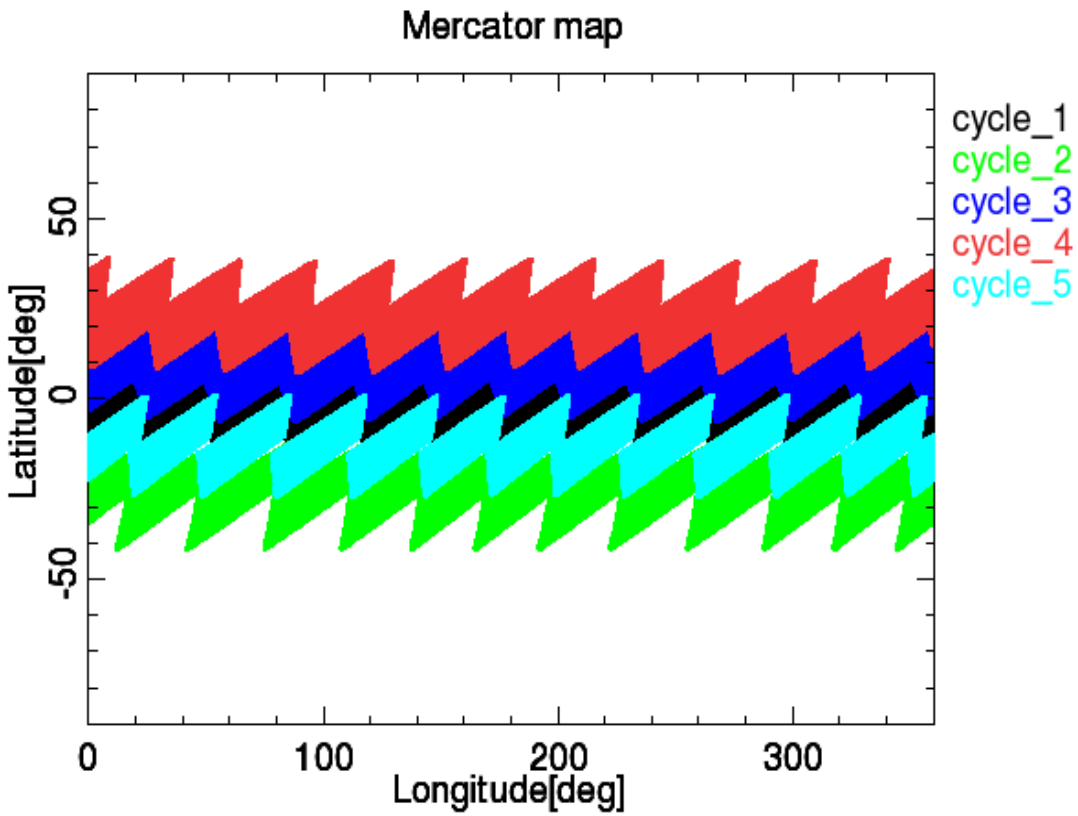
Coverage estimates include all 5 cycles

HAMO VIR Coverage – All Cycles



C1: Purple
C2: Cyan
C3: Green
C4: Orange
C5: Blue

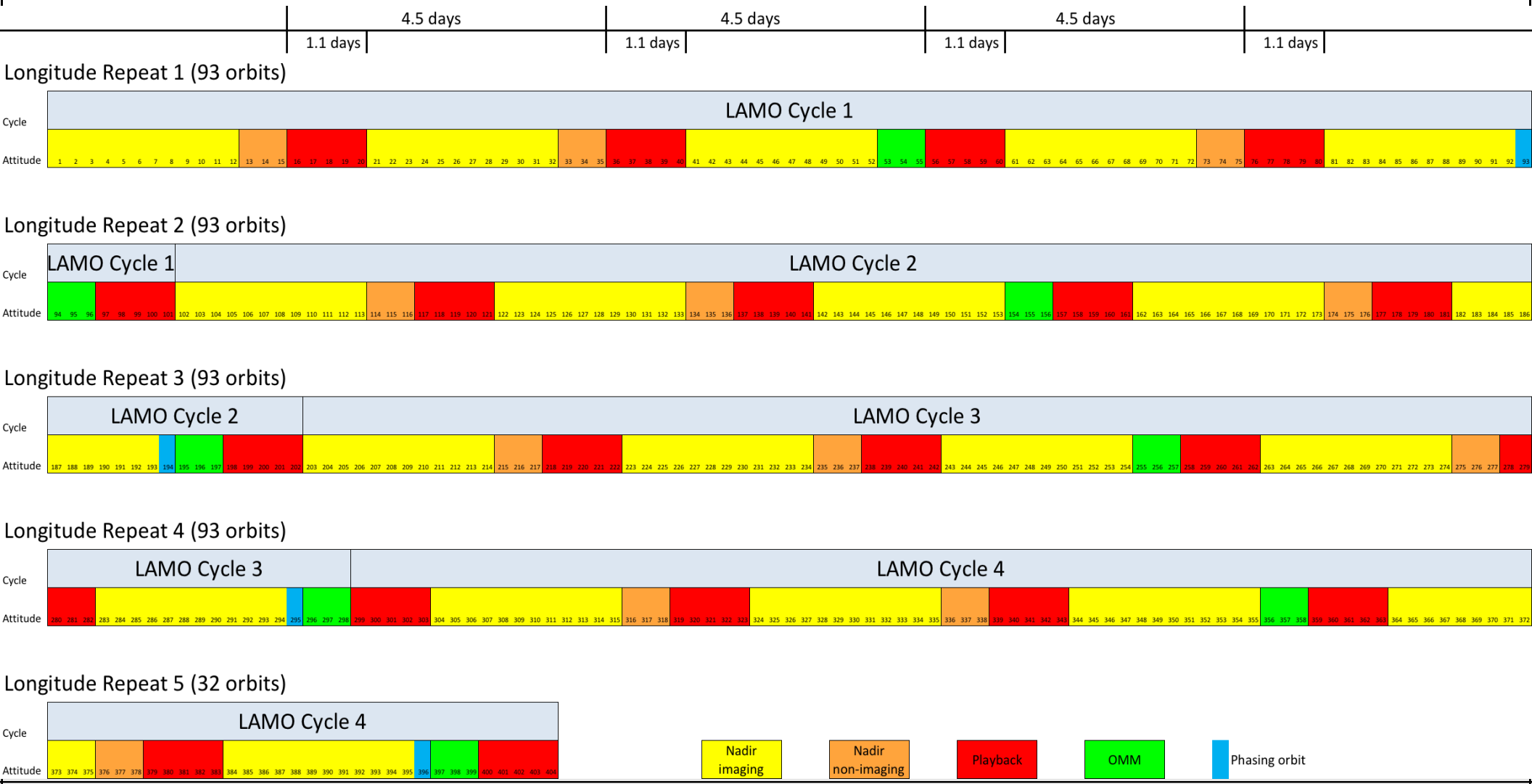
VIR Team simulation



- Coverage reported is <20% (not including smear)
- Results for the preliminary design with 8 sec repetition time

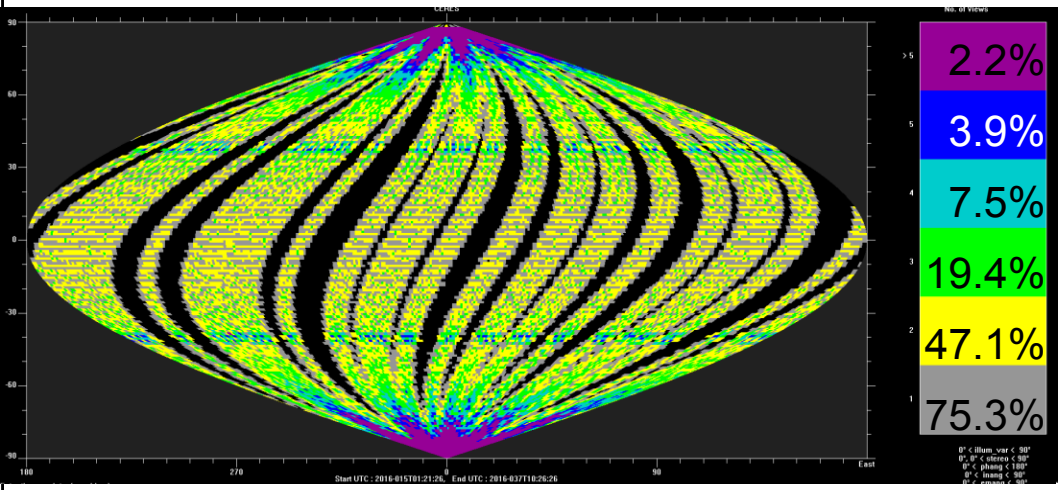
LAMO Orbit Repeat Cycles

- Each cycle is 101 orbits divided into five 20-orbit segments plus one phasing orbit
  - Segment: 12 orbits imaging, 3 orbits for OMM or nadir, 5 orbits for playback,
  - Playback passes every 4.5 days for 1.1 day in duration

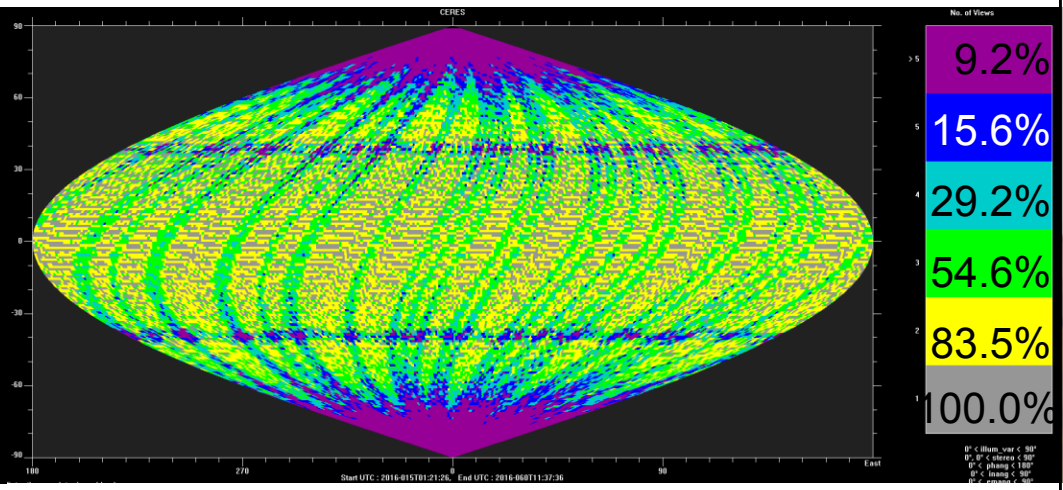


FC LAMO Observations

Cycle 1

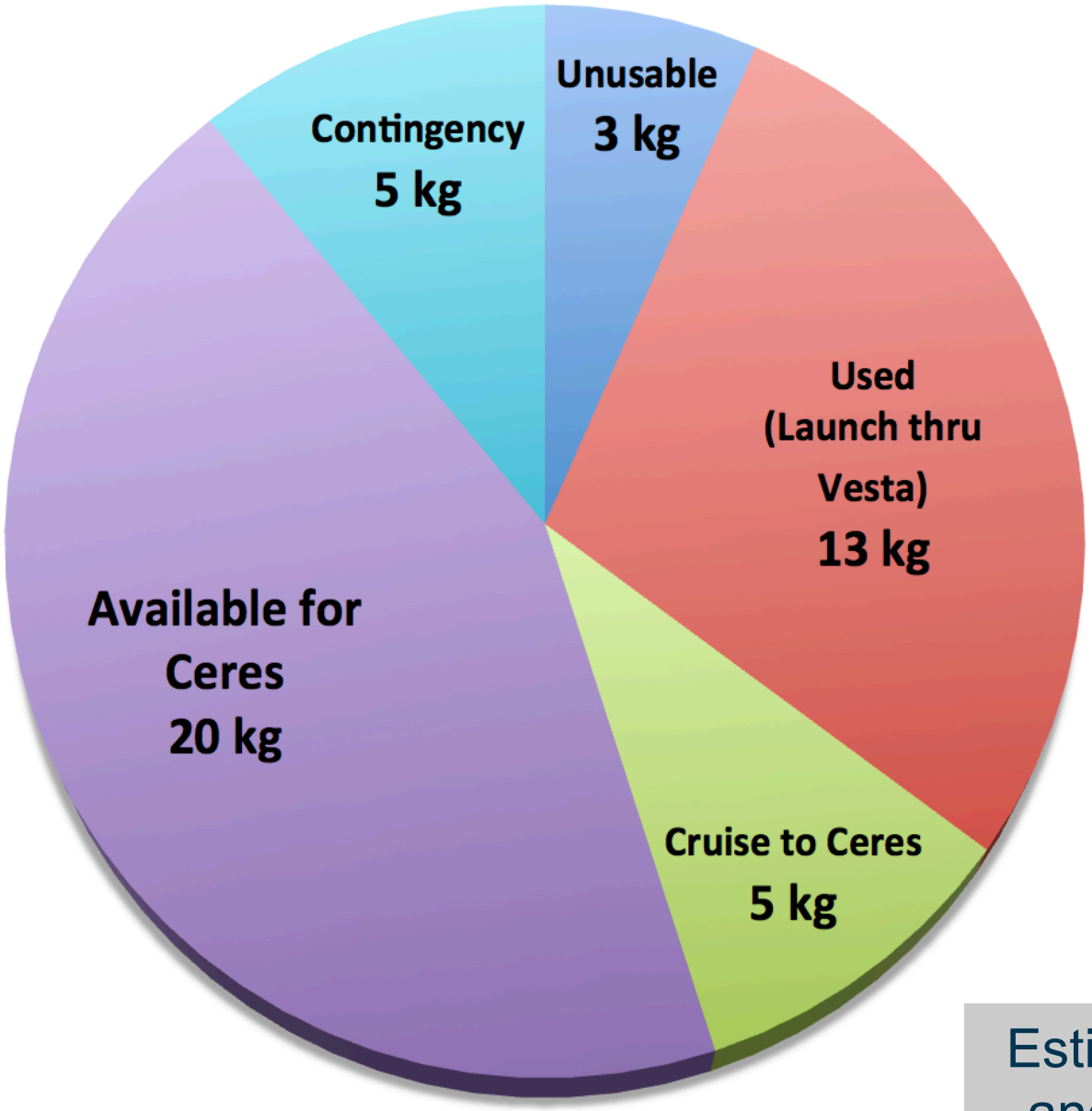


Cycles 1 and 2 combined



- Longitude repeats in 93 orbits and the cycle would include 101 orbits (93/101)
  - Each cycle would be composed of 5 segments each containing 20 orbits
  - 12 imaging orbits, 3 non-imaging orbits, and 5 playback orbits (12-3-5)
  - ~25 hr playback passes occur every 4.5 days
- Nadir imaging: 3:00 m:ss cadence in north and south, 2:20 m:ss at equator
  - Images compressed at 3.6:1 will fit into FC internal memory and playback
  - 61 images per orbit initially
  - 3,660 images/cycle for a total of 14,640 images for 4-cycle LAMO
- Images acquired during turns from nadir to Earth could improve the topography model over part of the surface at no additional hydrazine cost

Ceres Hydrazine Budget

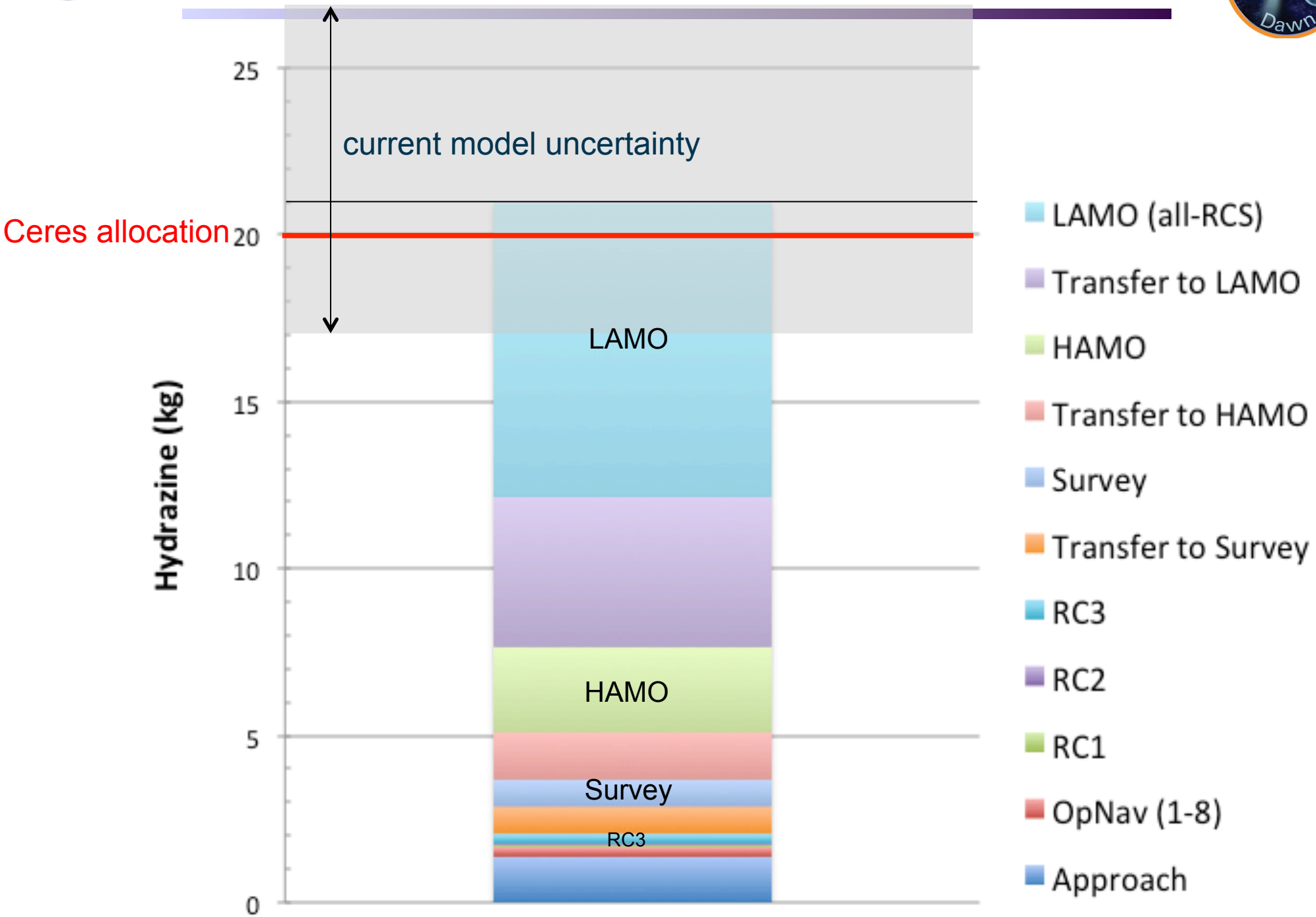


Post-Vesta ~30 kg of hydrazine available to complete the mission

- Project holds 5 kg as contingency to cover potential safe mode entries
- Anticipate ~5 kg to get to Ceres
- Leaving ~20 kg available to accomplish the Ceres mission

Estimates continue to be refined and uncertainty will be reduced

Current Hydrazine Estimate



Summary

- Initial plan for the Ceres science mission that achieves the science objectives and Level-1 Requirements has been completed
  - Mission plan is similar to Vesta
  - Lighting conditions will be nearly constant during encounter
- The hydrazine budget is limiting resource
  - Work is continuing to identify areas for additional hydrazine savings and to refine estimates of uncertainty
- Budget beyond FY15 is still uncertain