Jet Propulsion Laboratory
California Institute of Technology

Design and Execution of Dawn HAMO to LAMO Transfer at Ceres

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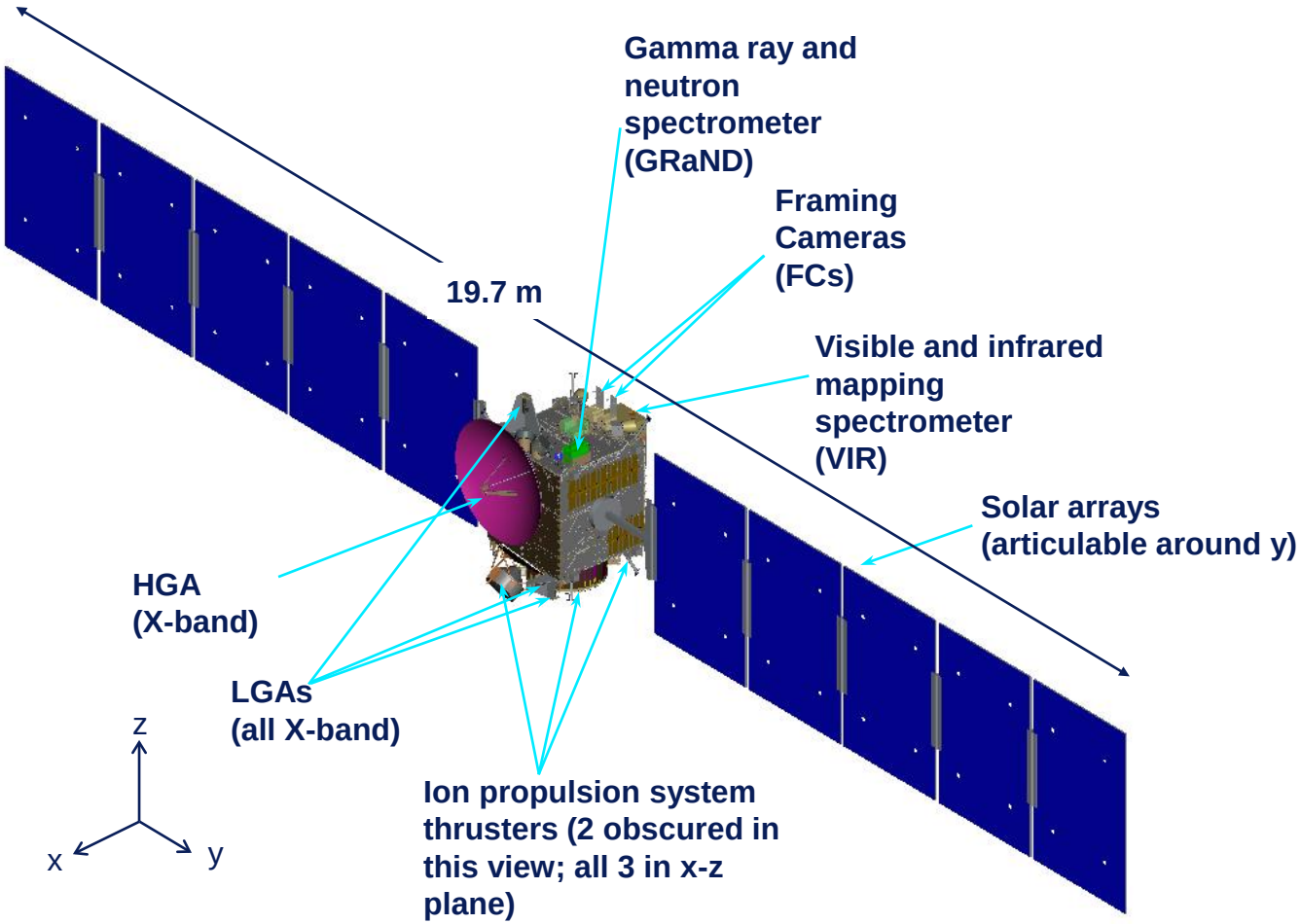
Dawn Flight System Configuration



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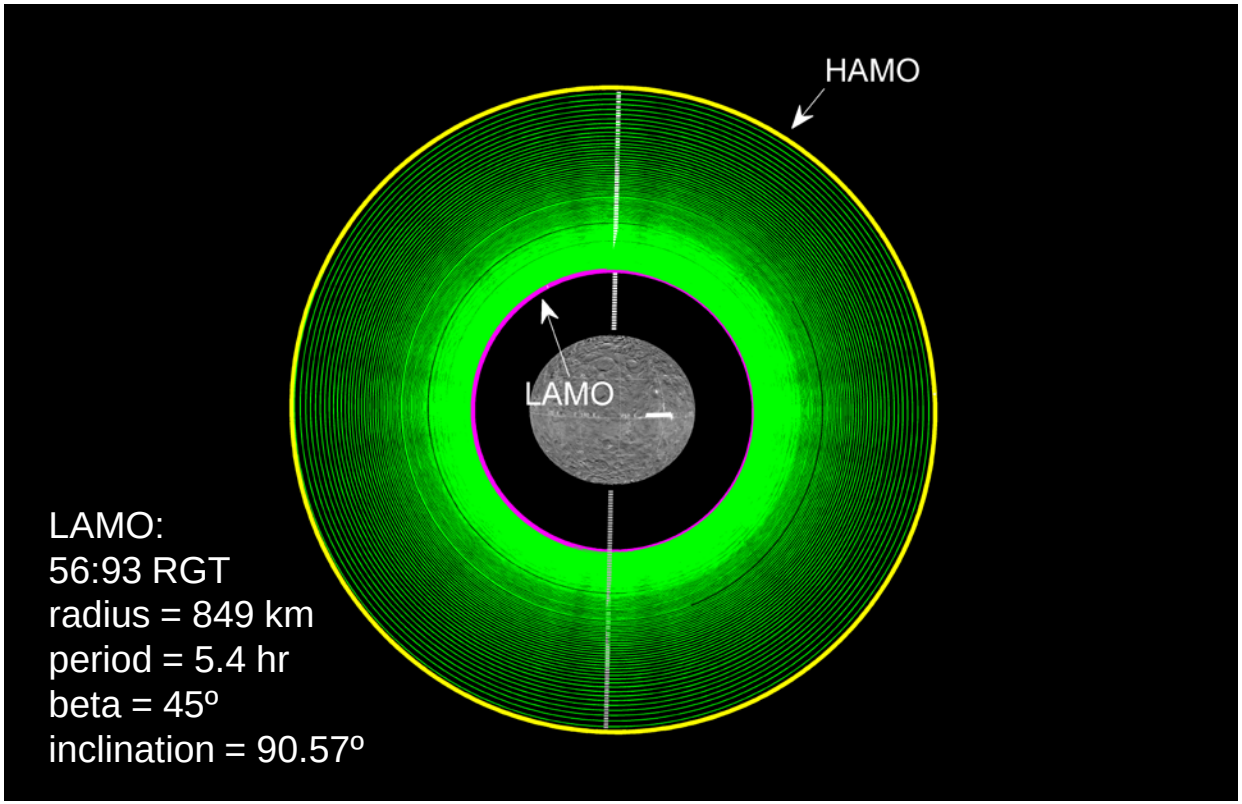
Ceres HAMO to LAMO

- Longest transfer between orbits around Ceres, 118 revs
- LAMO: FC map entire surface of Ceres, obtain GRaND and gravity coverage, high resolution VIR measurements



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Selecting LAMO

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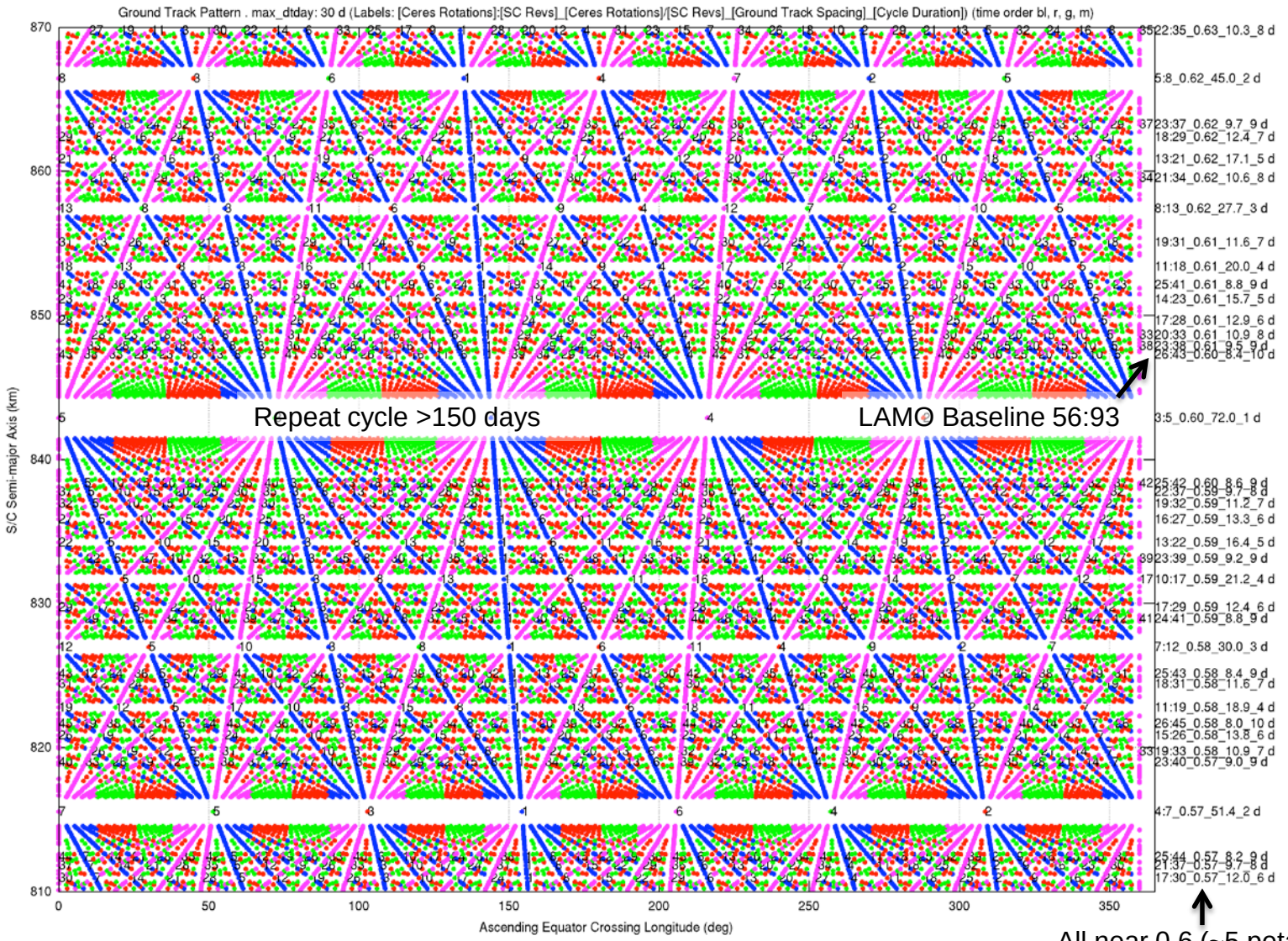
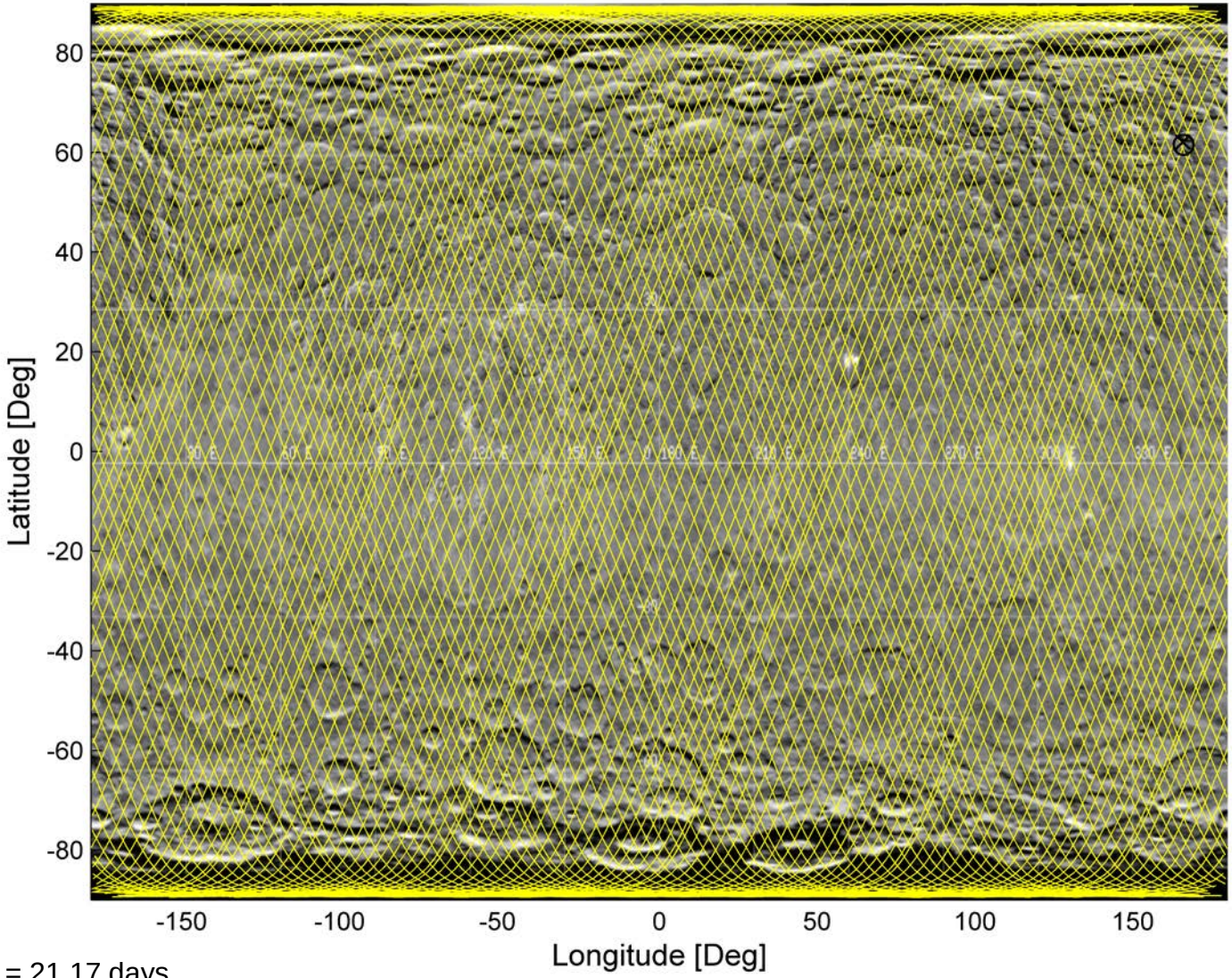


56:93 Repeat Ground Track



Cycle time = 21.17 days

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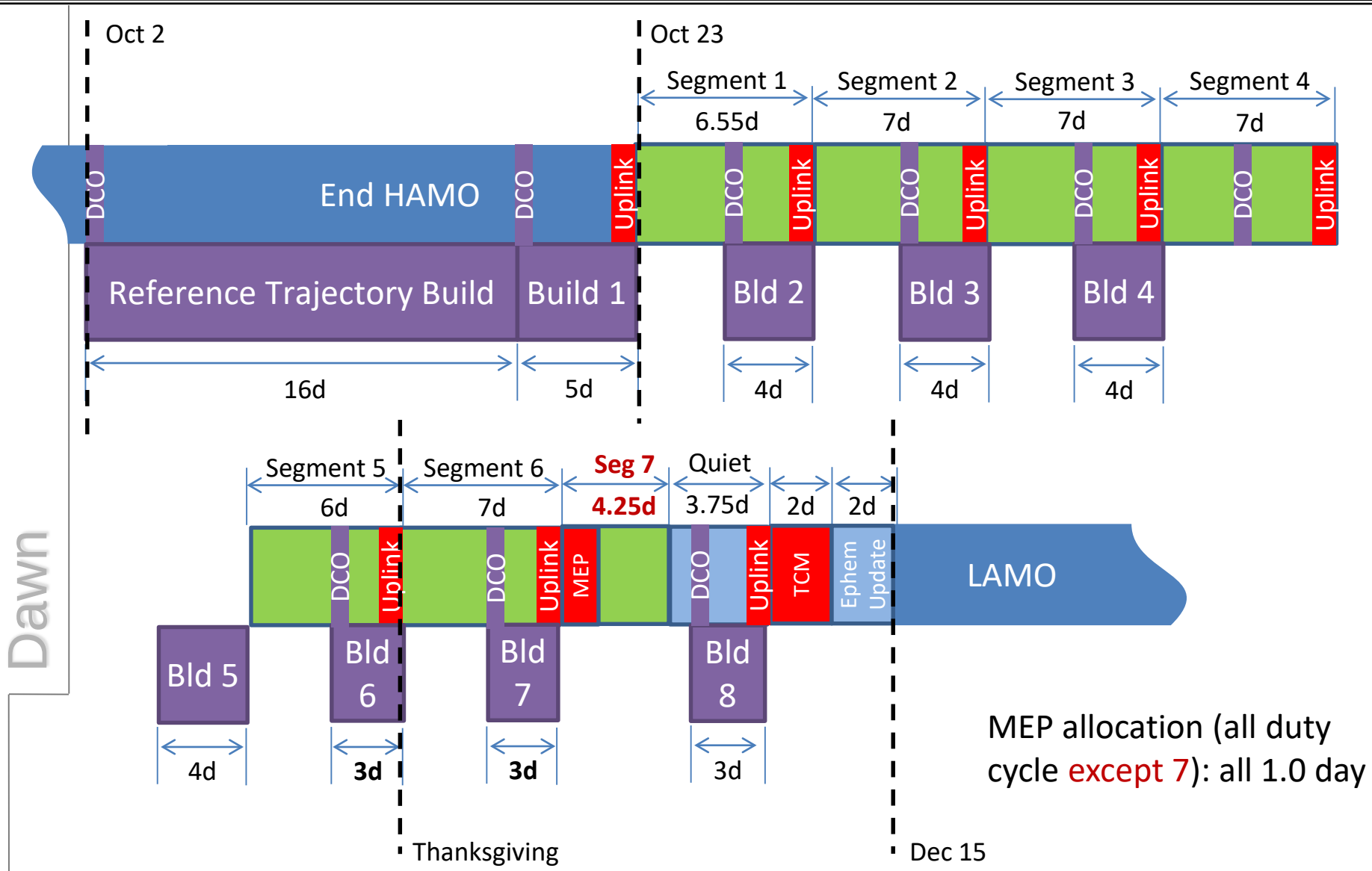
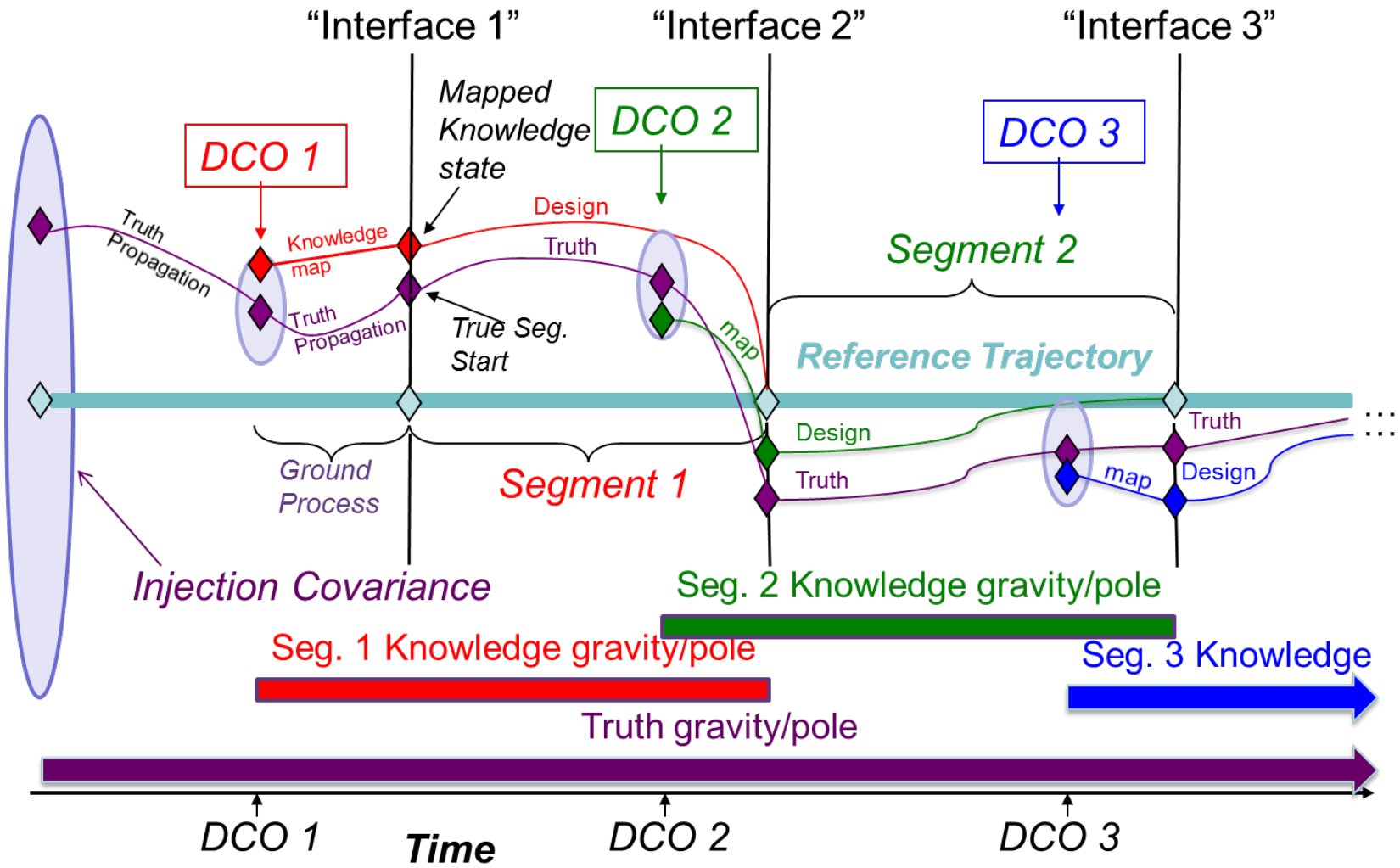
HAMO to LAMO Architecture



MEP allocation (all duty cycle except 7): all 1.0 day

Veil Concept



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Veil Optimal Coast & Feasibility

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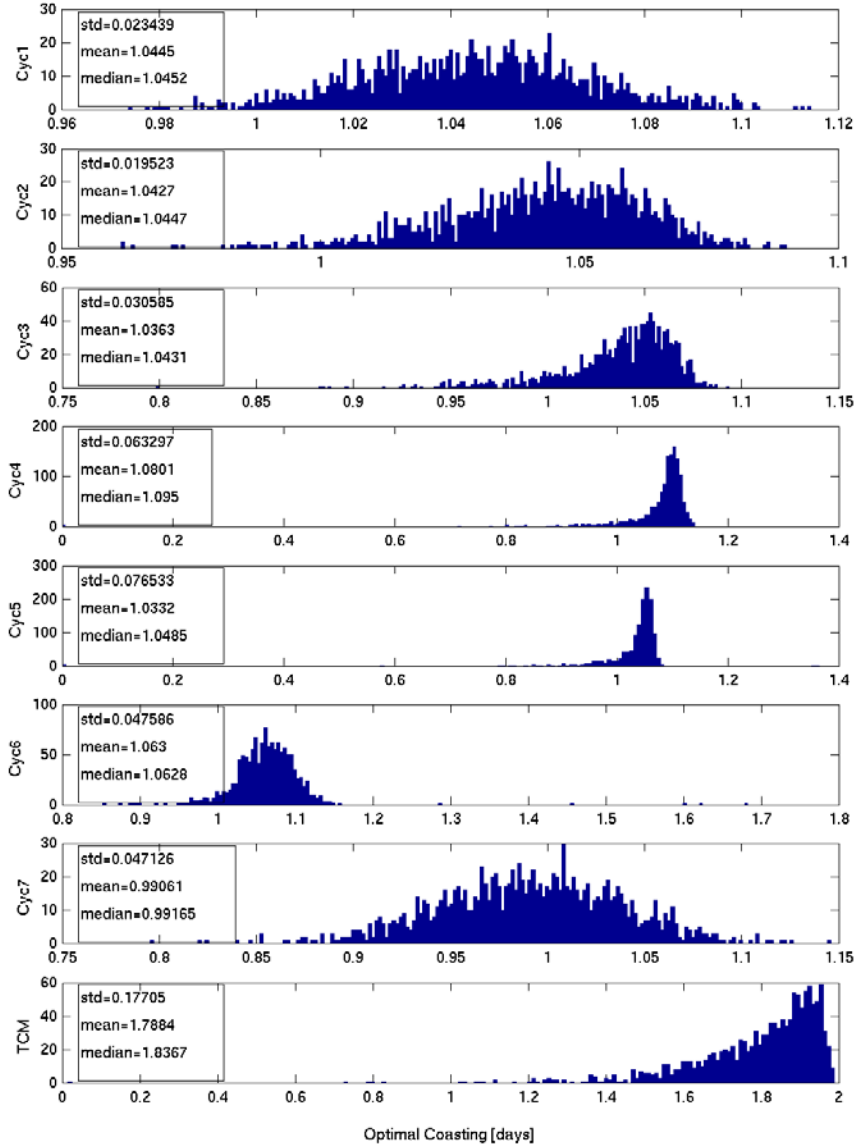

100.00%

100.00%

100.00%

99.84%

99.61%

100.00%

100.00%

99.92%

Mystic-Qstat (MQ) Tool

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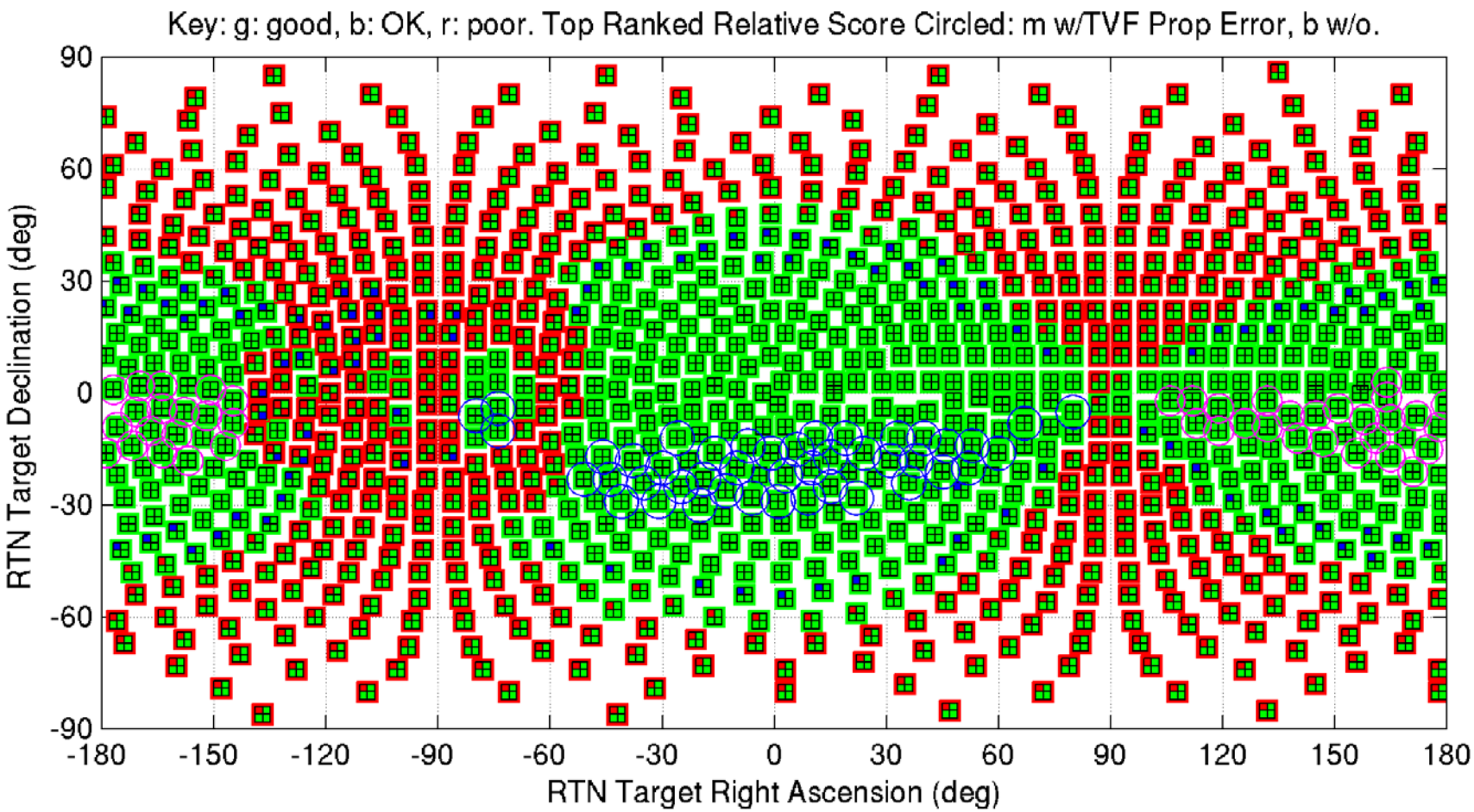

Cycle Delivery Errors

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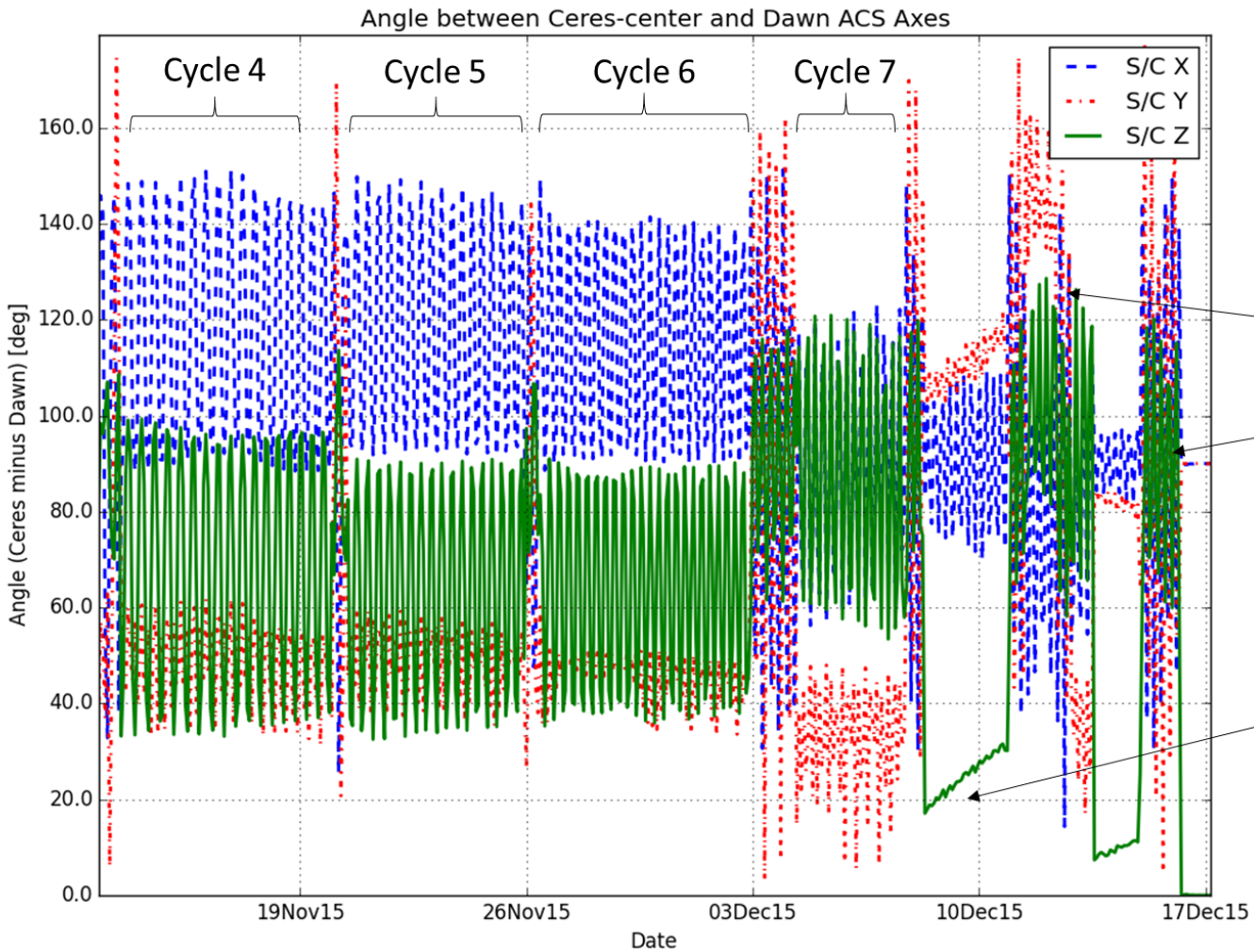
	Delivery Error [km]	Fraction of Sigma
Injection	92.82	0.70
Cycle 1	14.77	0.25
Cycle 2	0.70	0.01
Cycle 3	16.50	0.19
Cycle 4	5.83	0.06
Cycle 5	13.36	0.22
Cycle 6	3.69	0.06
Cycle 7	206.70	5.81
Quiet	514.80	6.17
TCM	107.80	6.30

Spacecraft Attitude



TCM leg 1

TCM leg 2

Phasing error during Quiet Period

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What happened?

- Six-sigma delivery to LAMO below 3:5 resonance
- Phasing error grew to 30º degrees in quiet period
- Cause
  - Tighter spiral, greater small forces (un-modeled)
  - RCS thrusters for FT2 are uncoupled
    - Resultant RCS thrust is in +z direction
    - 70% is along the direction of IPS thrust
  - Spacecraft relative position of Ceres changed in the final design causing grater gravity gradient torques
    - May have been caused by forced coast MEP
  - Estimating gravity field to order six not adequate
- TCM necessary
  - Design utilized SFF prediction from ACS and 8th-order gravity
  - OD and SFF prediction could not entirely correct error with TCM
- Error finally corrected to 0.05σ in first OMM

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LAMO Results

Lessons Learned

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- Better resolution of gravity field
- Need to resolve ‘chicken and egg’ problem with trajectory and ACS
  - ACS needs a trajectory to predict the small forces, small forces change trajectory
  - Potential solutions: iterate with ACS or simulate attitude control with trajectory as it’s designed
- Better understanding of uncertainty
  - Veil runs should reflect more accurately uncertainty of unknown parameters
- Rule of thumb: if a design process is working well, don’t change it unless there’s good reason to change it