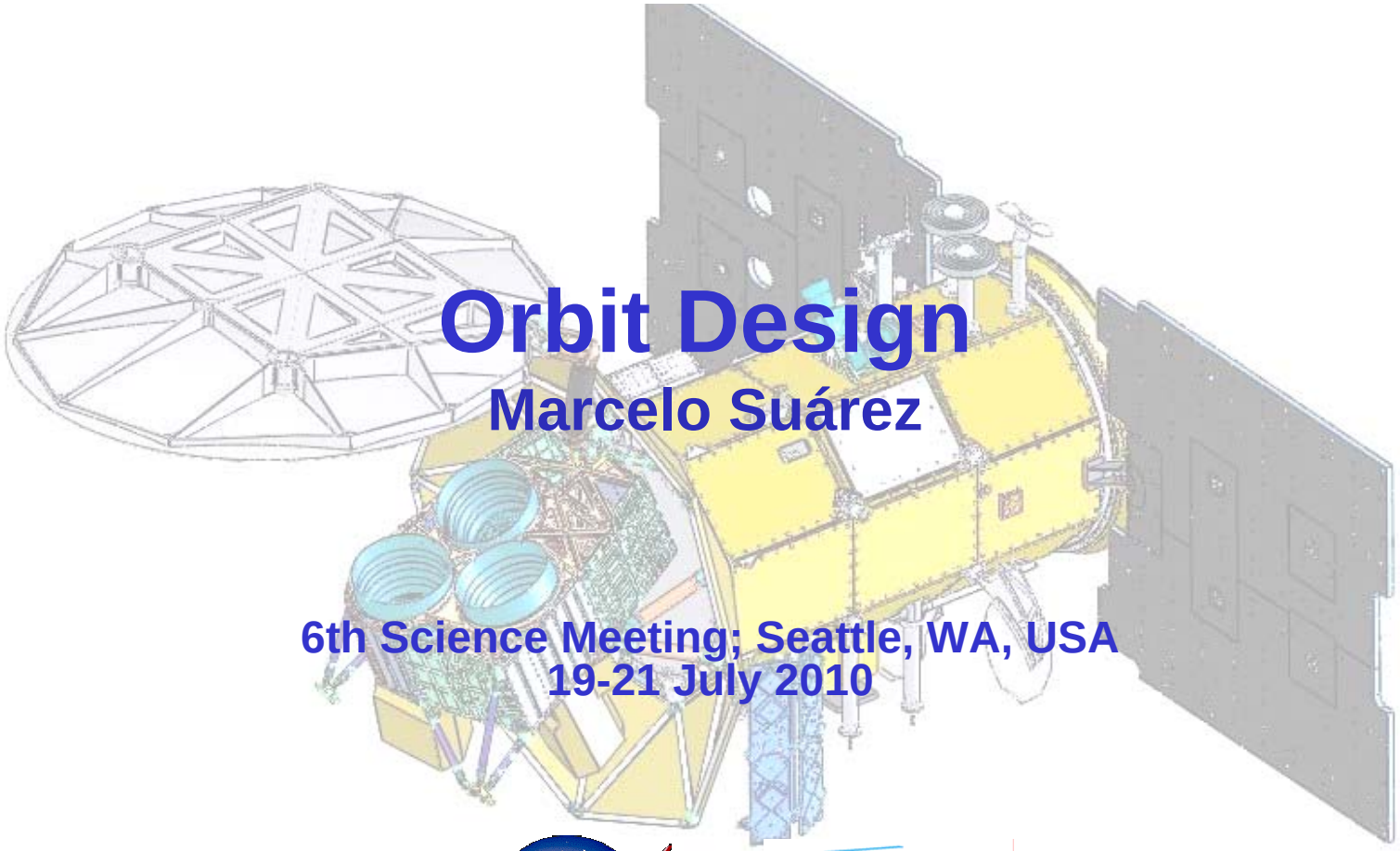
AQUARIUS/SAC-D



Orbit Design

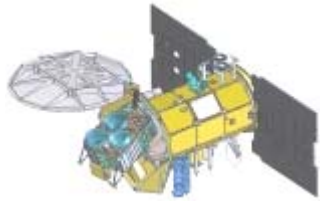
Marcelo Suárez

6th Science Meeting; Seattle, WA, USA
19-21 July 2010

NASA

CONAE
COMISION NACIONAL DE ACTIVIDADES ESPACIALES

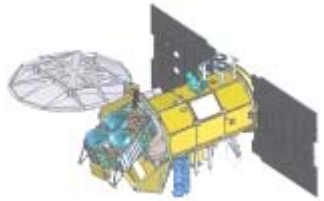
Orbit Design Requirements



The following ***Science Requirements*** provided drivers for ***Orbit Design***:

- Global Coverage: the entire extent (100%) of the ice-free ocean surface to at least ±80° latitude should be observed.
- Swath shall be at least 300 km with gaps between the footprints within a swath not exceeding 50 km on average.
- Temporal Coverage: In order to provide monthly accurate salinity measurements, grid point should be visited at least 8 times per month (counting both ascending and descending passes)
- Radiometer Geometry: Zenith angle of the Sun on the footprint should be greater than 90° (in shadow) to the extent possible.
- Instruments should operate in the 600 +100/-50 km altitude range.
- Orbit shall have a repeat pattern of less than or equal to 9 days maintained within ± 20 km

Orbit Design



The Aquarius/SAC-D ***Mission Orbit*** is defined by the following parameters and tolerances:

- Mean Semi-major axis: 7028.871 km +/- 1.5 km
- Mean Eccentricity: 0.0012 +/− 0.0001
- Mean Inclination: 98.0126 deg + / - 0.001 degrees
- Mean Local Mean Time of Ascending Node: 18:00 0 /+5 min
- Mean Argument of perigee: 90 deg +/- 5 deg

Remarks :

Equatorial altitude: 657 km +/- 1.5 km

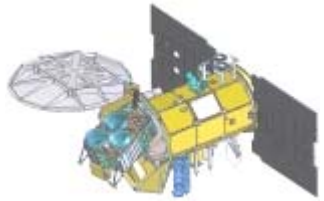
Ground-track Repeat: 7 days

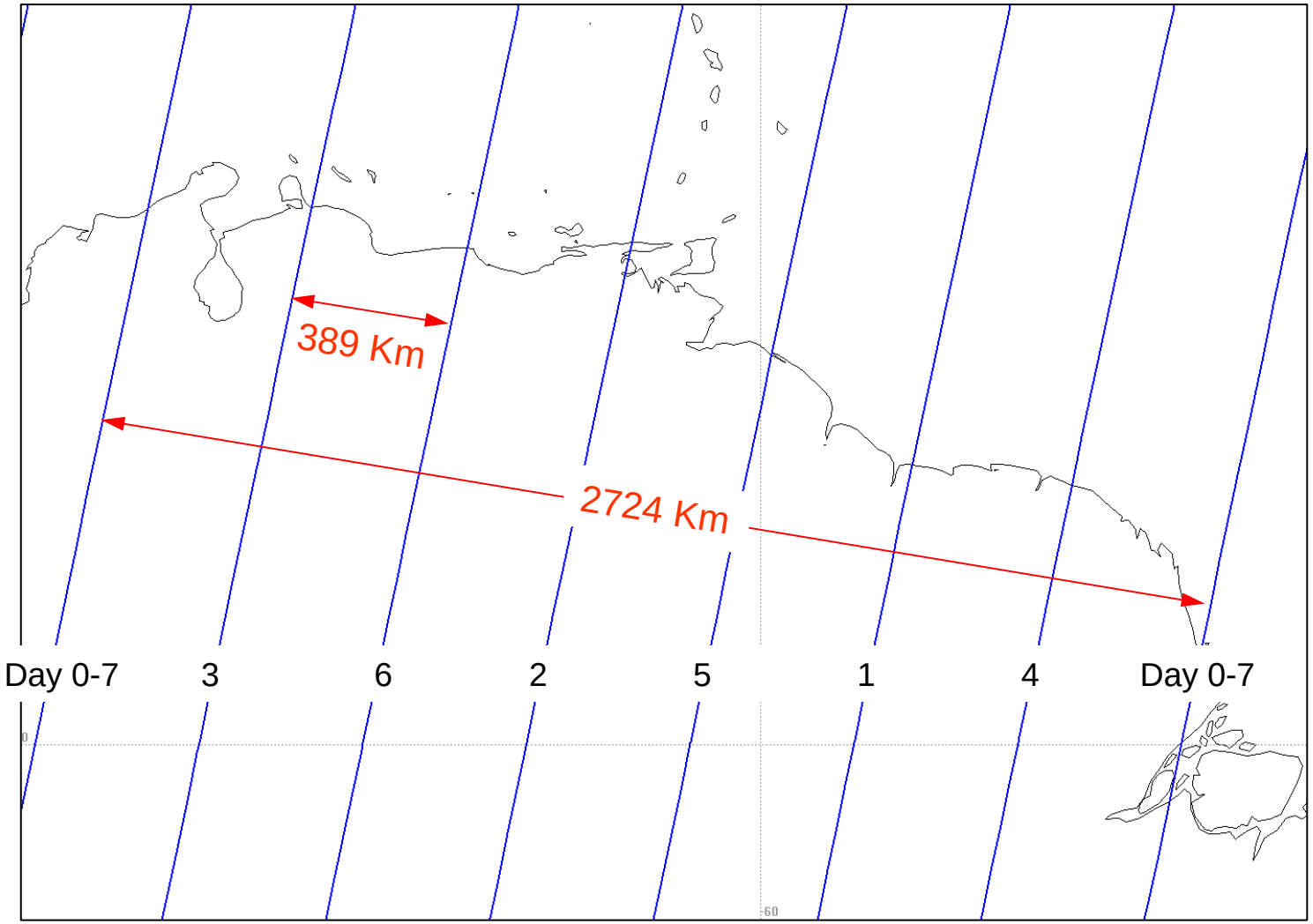
Ground-track Separation at Equator: 389 km

Ground-track kept within +/- 20 km of nominal along equator

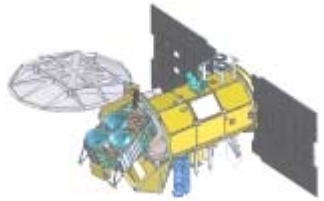
Sun-Synchronous Orbit

Leap-frog sampling pattern

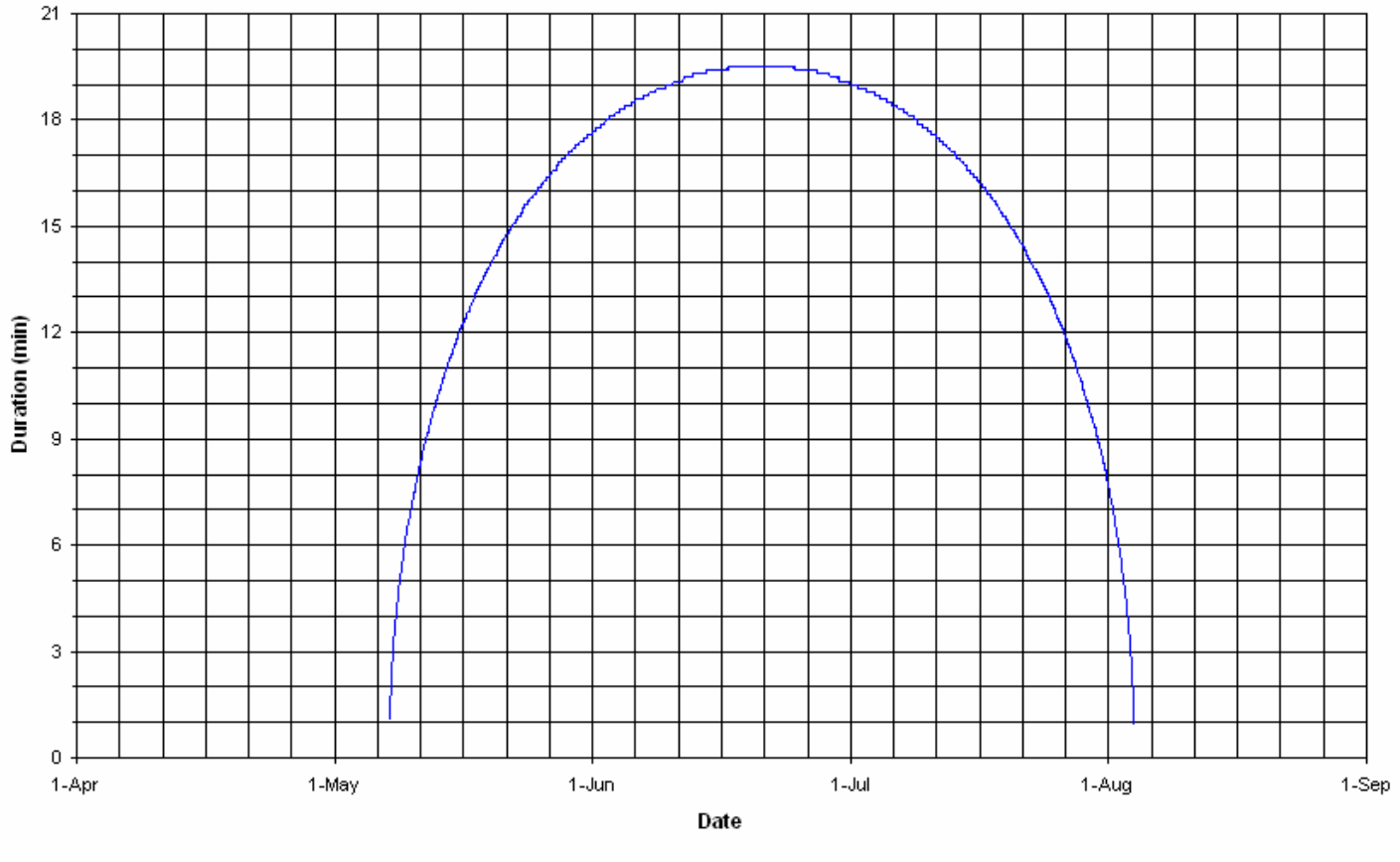




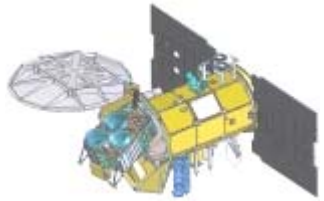
Eclipses



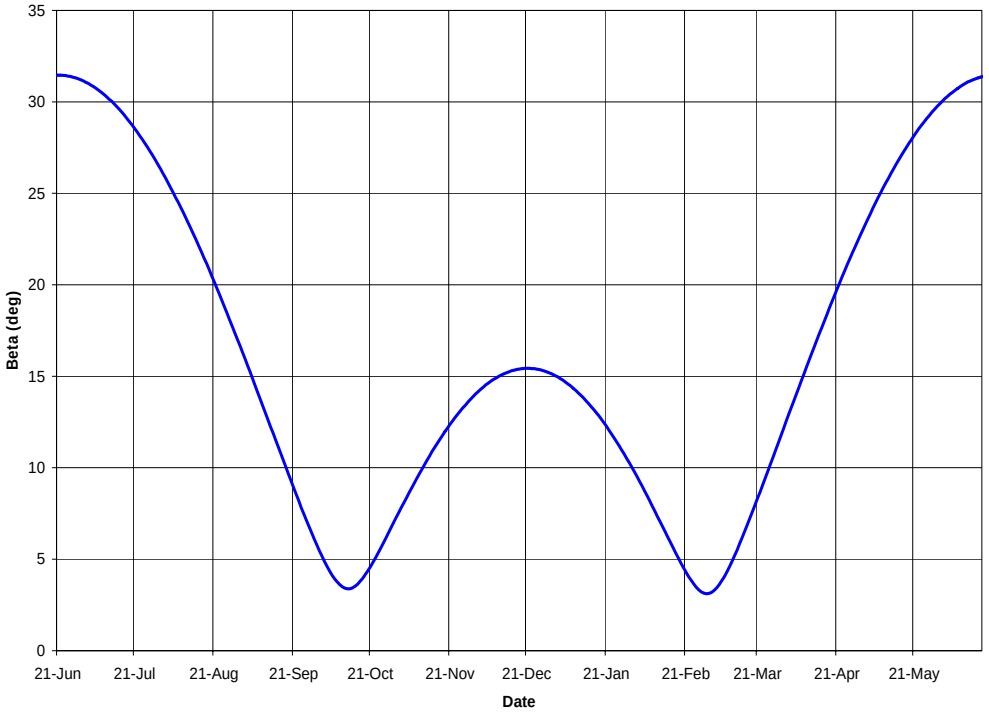
Because of the changing position of the Sun with respect to the orbital plane there are yearly *Eclipse seasons* which take place between May and August at southern latitudes.

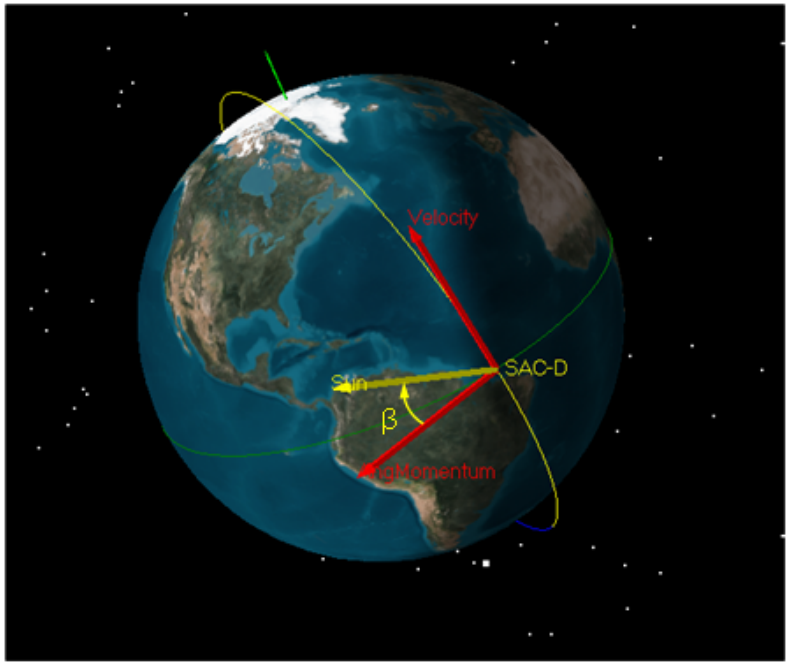


Beta Angle

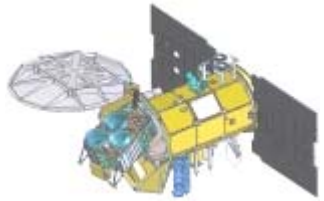


The *Beta angle*, defined as the acute angle between the Earth to sun vector and the instantaneous angular momentum vector of the orbit and its yearly evolution are shown in the figures bellow:

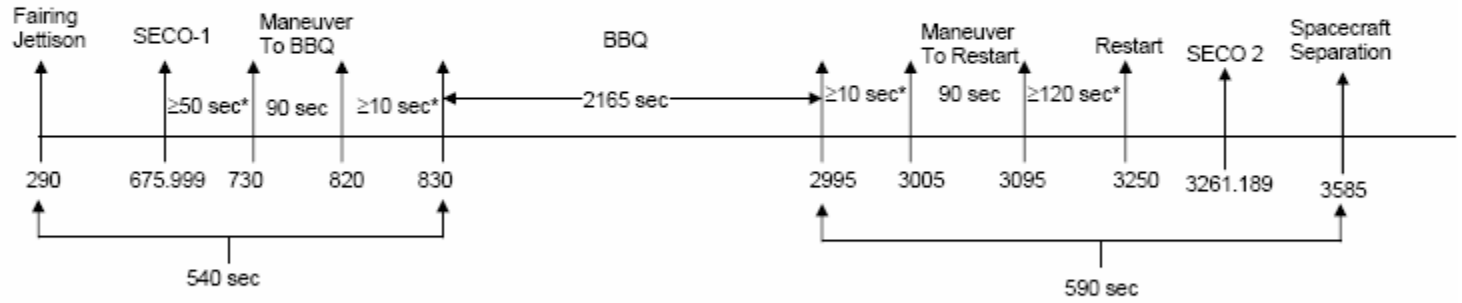




Launcher Ascent Profile



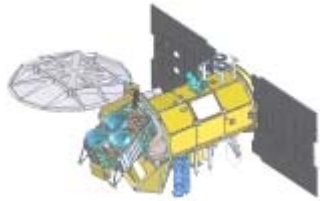
Timeline from Fairing Separation to Spacecraft Separation



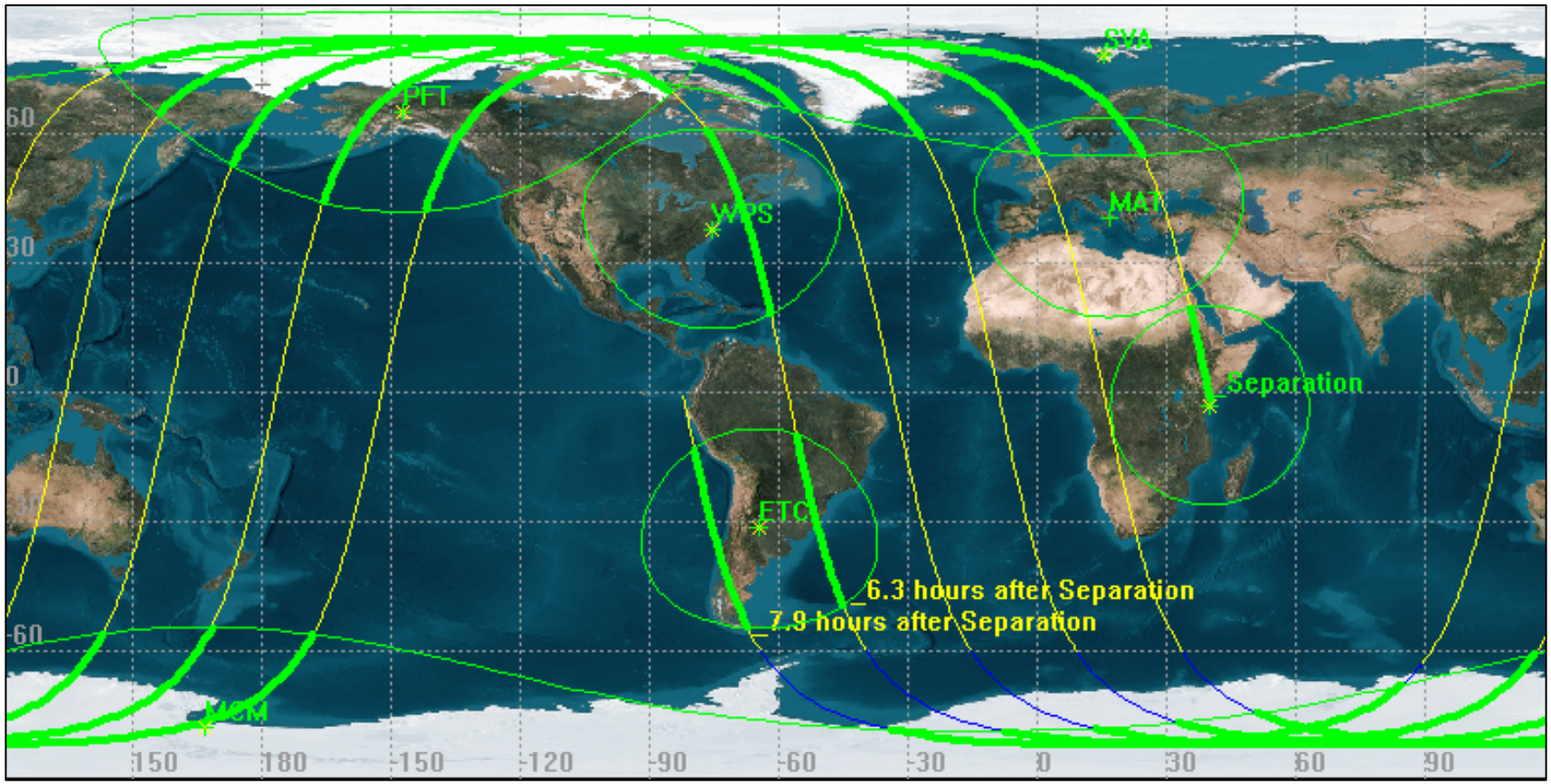
- **Requirement states < 600 sec. on each side of the BBQ**

* Guidance requirement

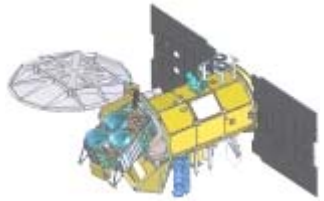
Early Orbits



S-Band and X-Band Contacts



Orbit Acquisition (1 of 4)

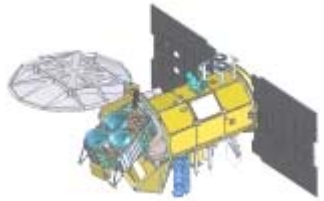


To place the Observatory into its operational orbit a sequence of Orbit Maneuvers is needed to correct Launcher Injection errors.

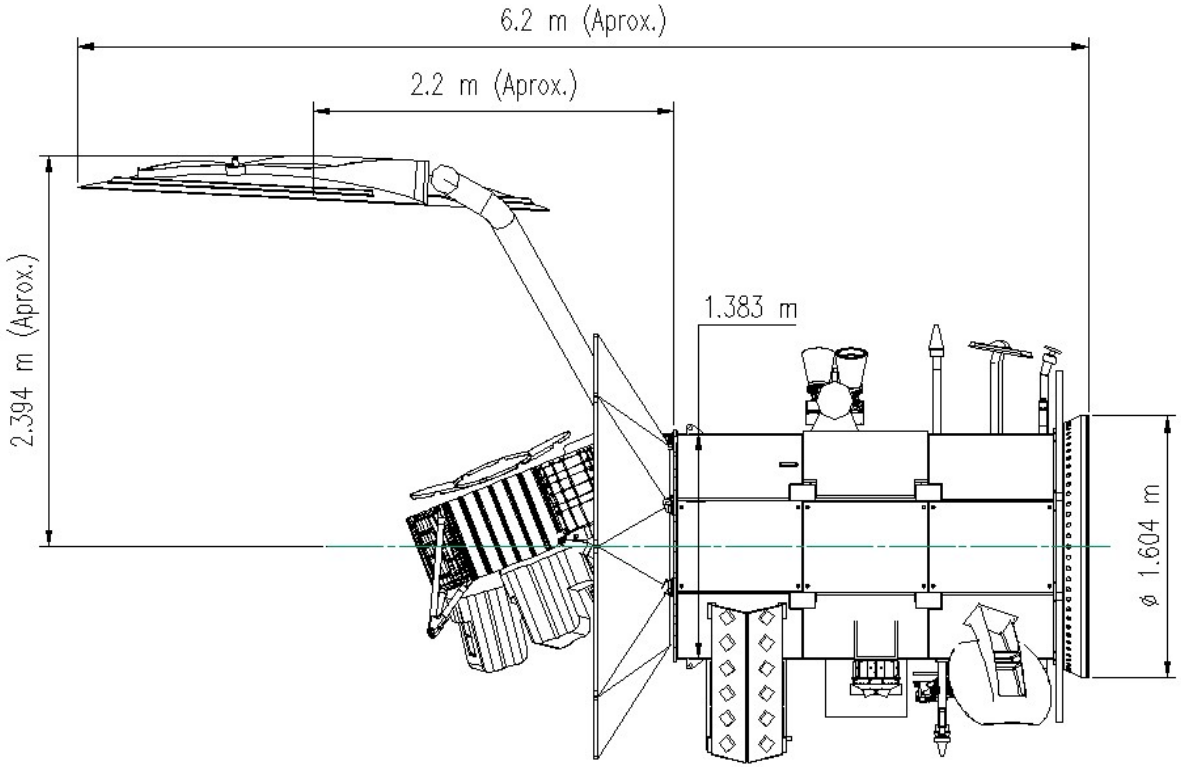
- The design of the Orbit Acquisition Strategy will be based on the current L/V injection errors and the propulsion system performance
- Time and duration of the burns shall take into account ground station visibility of the maneuvers.
- The acquisition sequence goals are:

  - Correct the orbit semi-major axis .
  - Correct the orbit inclination.
  - Correct the orbit eccentricity vector.

Orbit Maintenance (1 of 3)

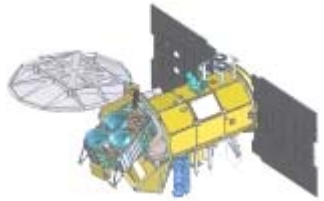


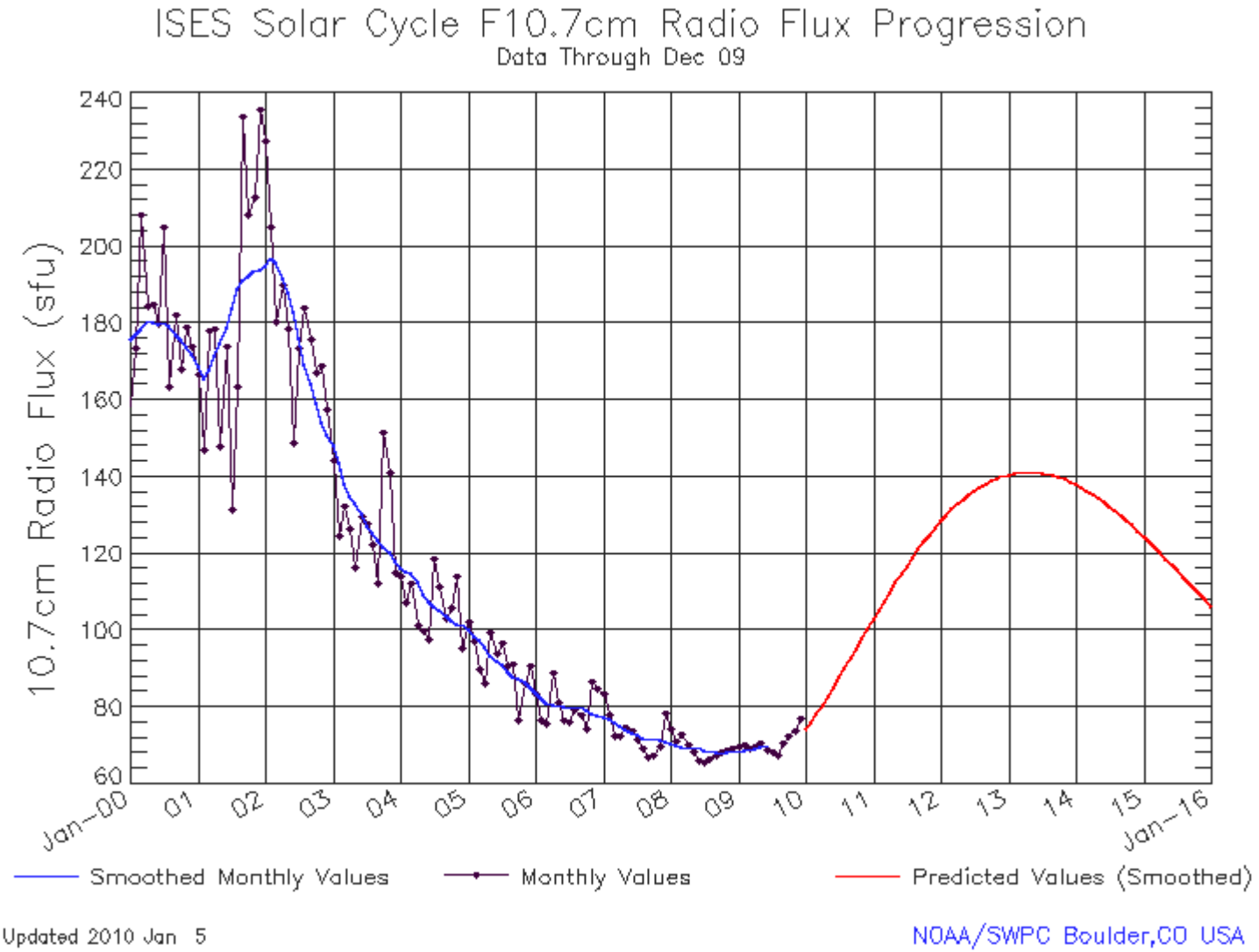
Atmospheric drag will decrease the orbit altitude at a rate that depend on the solar activity, the Observatory cross sectional area and Observatory mass.



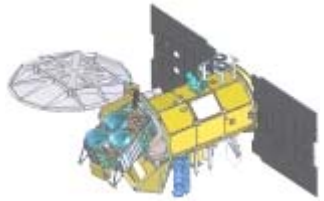
Drag Coefficient: 2.2
Drag Area: 8 m2
Satellite Mass: 1675 kg
(including propellant)

Orbit Maintenance (2 of 3)

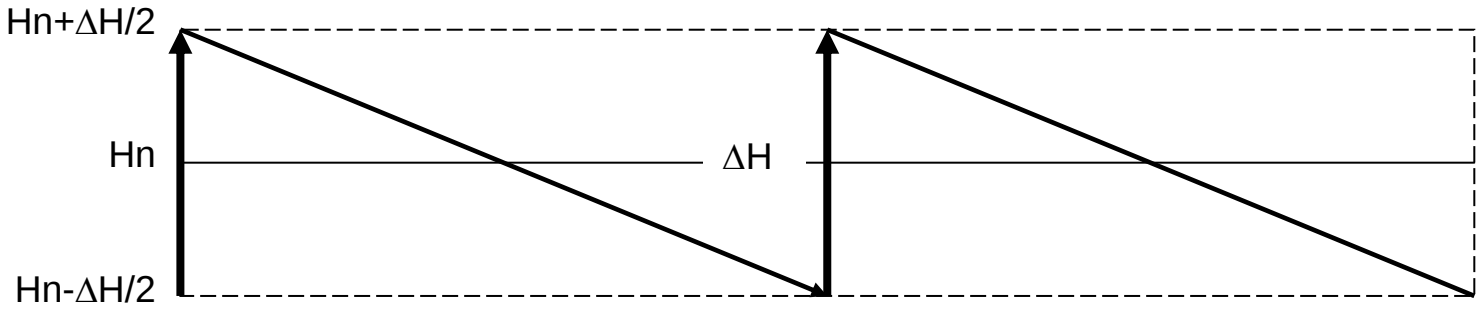




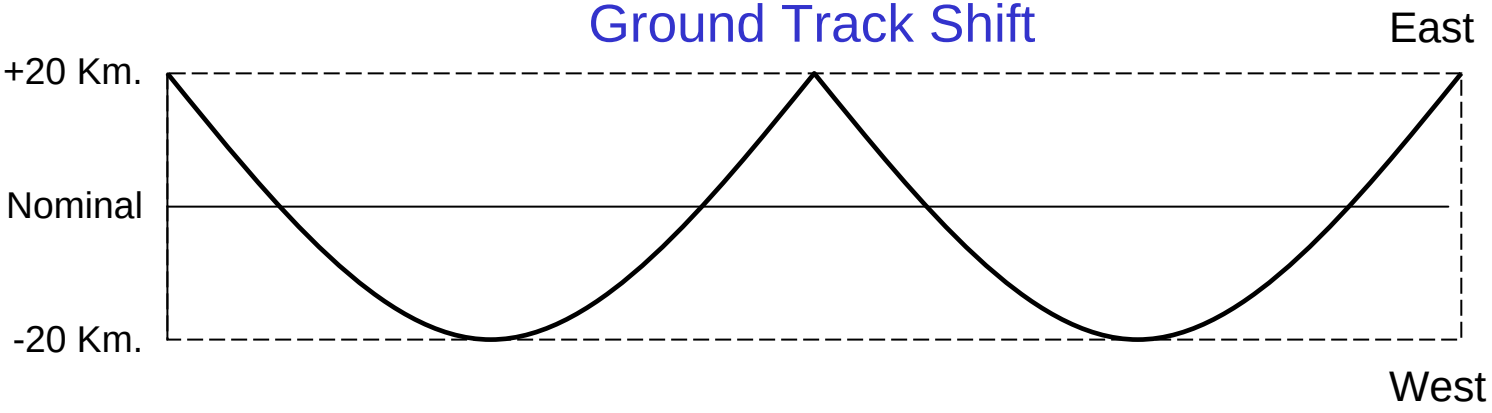
Orbit Maintenance (3 of 3)

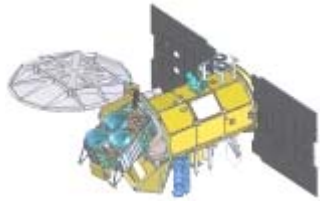


Mean Altitude Evolution



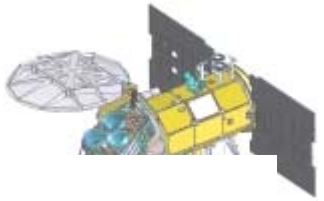
Ground Track Shift

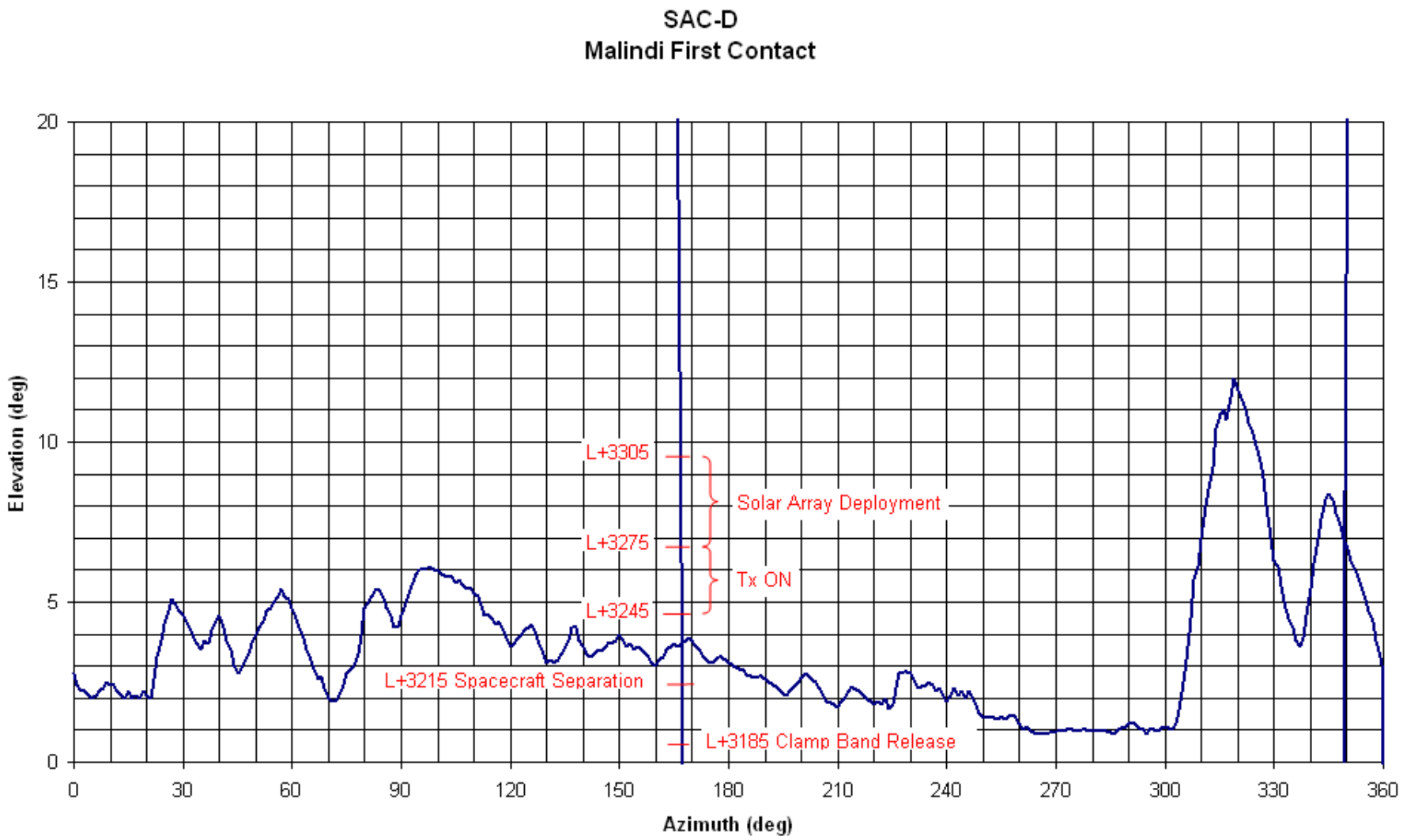




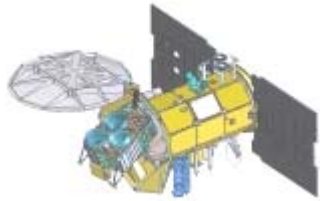
Backup Slides

Malindi First Contact

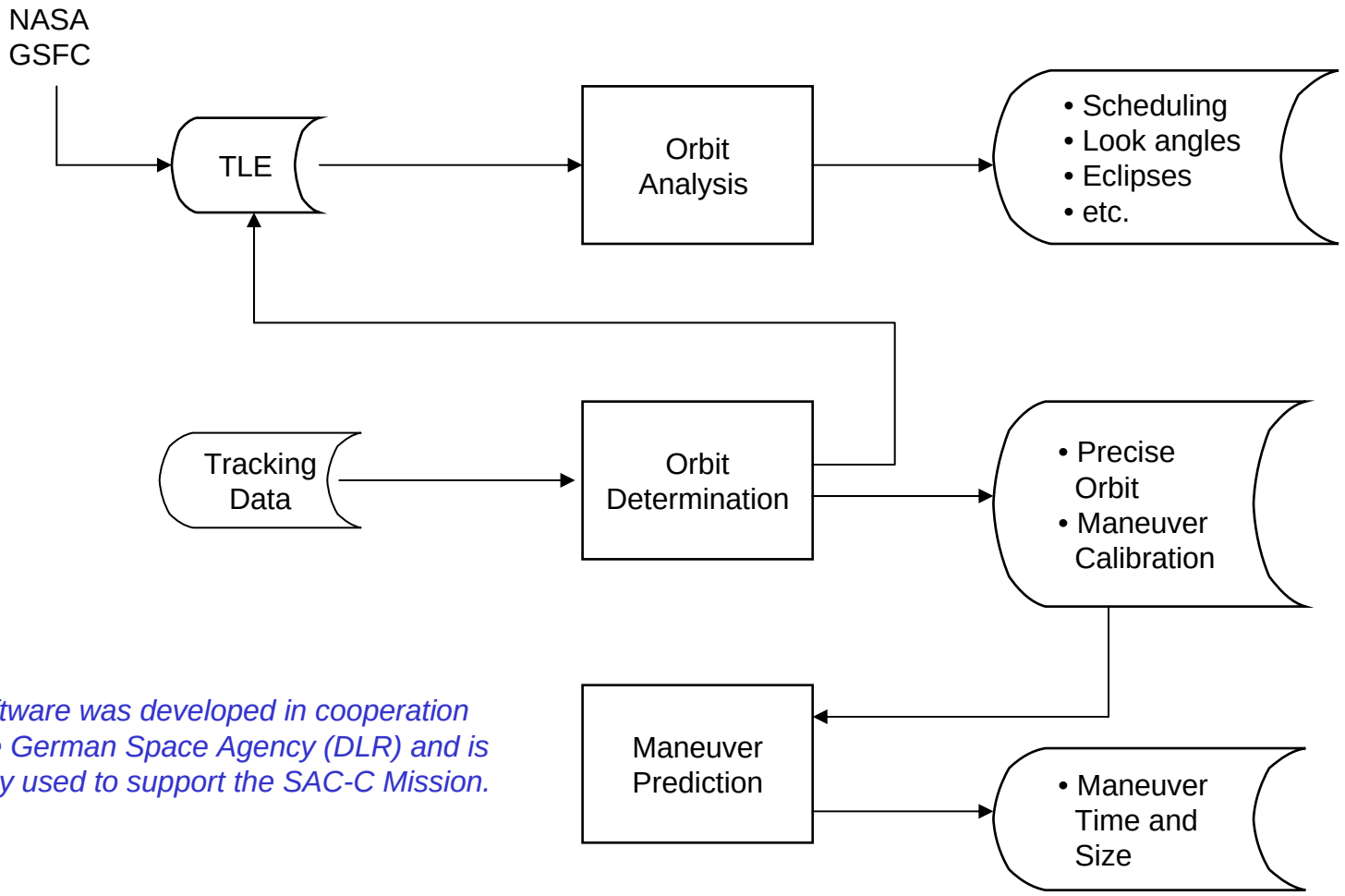




Orbit Determination (OD)



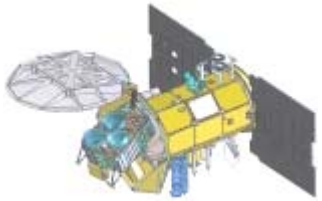
CONAE Mission Analysis, Orbit Determination and Maneuver Calculation Software



NOTE:

The software was developed in cooperation with the German Space Agency (DLR) and is currently used to support the SAC-C Mission.

Flight Dynamics (FD) Requirements



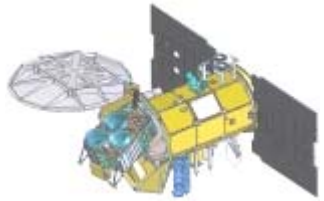
- Within 30 minutes after liftoff CONAE FD shall receive the exact lift off time.

- Within 15 minutes after Spacecraft Separation CONAE FD shall receive the current injection vector provided by the launcher.

- Within 3 hours after separation CONAE FD shall receive the first update of the orbit (TLE & State Vector)

- Within 5 hours after separation CONAE FD shall receive the second update of the orbit (TLE & State Vector)

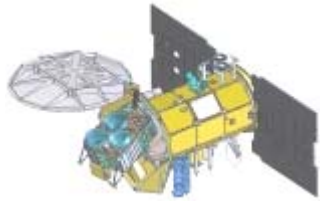
Program CODS



Program CODS is mainly intended to provide accurate orbital parameters by processing the GPS navigation solution and comprise the following features:

- Precise modeling of all relevant forces acting on near Earth orbiting satellites;
- Use of the GPS navigation solution as only source of tracking data for orbit determination;
- Simultaneous adjustment of osculating orbital elements and satellite drag coefficient;
- Estimation algorithm using a sequential least-squares method based on Givens rotations.
- OD Solution Accuracy: ~20 meters

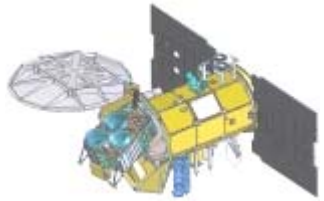
Program GPS2TLE



OD program GPS2TLE uses the GPS navigation solution to derive mean orbital elements (compatible with NORAD TLE).

- Use of the SGP4 analytical orbit model;
- Use of the GPS navigation solution as only source of tracking data for orbit determination;
- Simultaneous adjustment of mean orbital elements and satellite ballistic coefficient;
- Estimation algorithm using a sequential least-squares method based on Givens rotations;
- Generation of orbital information in the form of TLE.
- OD Solution Accuracy: ~1 Km

Orbit Acquisition (2 of 4)

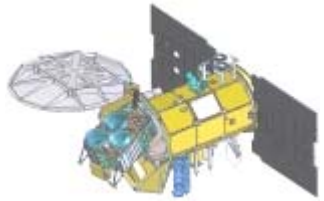


The orbital maneuvers needed to perform corrections to the semi-major axis and to the eccentricity (orbit altitude corrections) are along-track maneuvers.

- If the initial orbit altitude is lower than nominal, the correction maneuvers are performed keeping the nominal Observatory attitude
- If the initial orbit altitude is higher than nominal, the Observatory attitude has to pitch 180°, keeping the $+X_{SC}$ axis toward the anti-velocity vector during the maneuver.

The orbital maneuvers needed to perform corrections to the inclination are cross-track maneuvers The Observatory attitude during these maneuver is to yaw 90° and point the $+X_{SC}$ normal to the orbit plane and the $+Y_{SC}$ in the velocity or anti-velocity vector.

Orbit Acquisition (3 of 4)

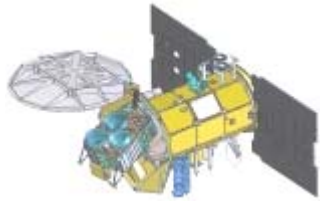


LV Injection Accuracies

The LV injection accuracies are:

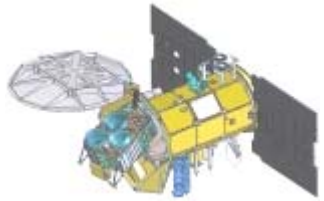
- Perigee altitude: ±10 km (3σ)
- Apogee altitude: ±10 km (3σ)
- Inclination error: ±0.03 deg (3σ)
- Launch Window: 5 minutes

Orbit Acquisition (4 of 4)



Maneuver Type	Correction	Attitude	Days after Launch	Duration (min)
Along-track (2 burns)	Altitude	0° or 180° pitch	10	7 (×2)
Along-track (2 burns)	Altitude	0° or 180° pitch	11	7 (×2)
Cross-track (1 burn)	Inclination	±90° yaw	12	9
Along-track (2 burns)	Altitude	0° or 180° pitch	14	7 (×2)
Cross-track (1 burn)	Inclination	±90° yaw	15	9
Along-track (2 burns)	Altitude	0° or 180° pitch	17	7 (×2)
Cross-track (1 burn)	Inclination	±90° yaw	18	8
Along-track (2 burns)	Altitude	0° or 180° pitch	20	7 (×2)
Cross-track (1 burn)	Inclination	±90° yaw	22	7
Along-track (2 burns)	Altitude	0° or 180° pitch	24	7 (×2)

DELTA-V and Propellant Budget



Phase	Delta-V (m/s)	Hydrazine Isp = 224 s (Kg)
Acquisition	15.07	10.4
Maintenance (5 years)	17.28	11.8
De-Orbit	41.50	28.0

Total	73.85	50.2