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The CloudSat Mission: A Virtual Platform

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JPL Clearance CL#





NASA's Earth Science Enterprise

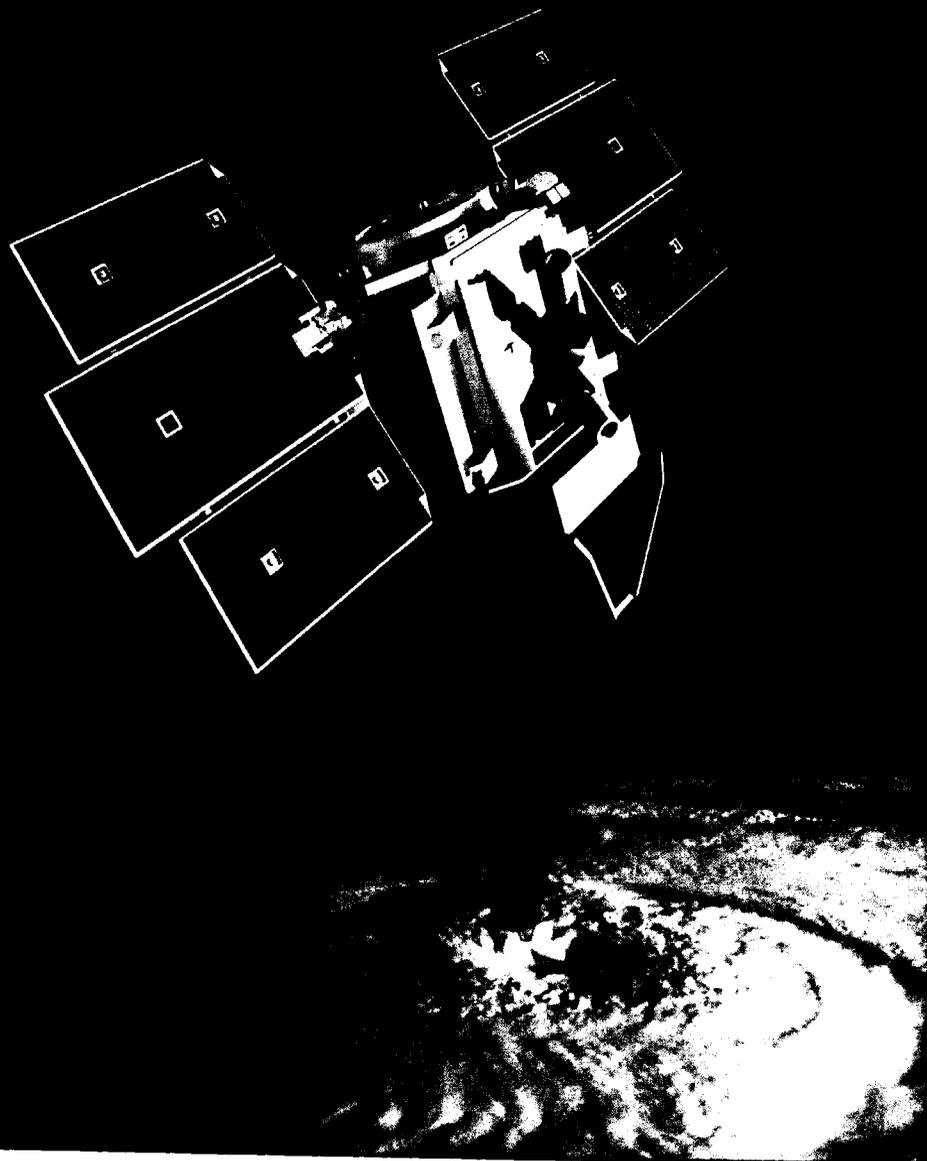
- Earth Observing System (EOS) Missions
 - Terra in the AM Constellation
 - Aqua leading the PM Constellation (A-Train)
 - Aura at the back end of the PM Constellation

- Earth System Science Pathfinder Missions
 - GRACE
 - CALIPSO (formerly known as PICASSO-CENA)
 - CloudSat
 - Working risk mitigation: OCO, Aquarius, Hydros

The PM Constellation is comprised of Aqua, as the leading satellite, followed by CloudSat, CALIPSO (labeled E-C in the figure), Parasol, and Aura.

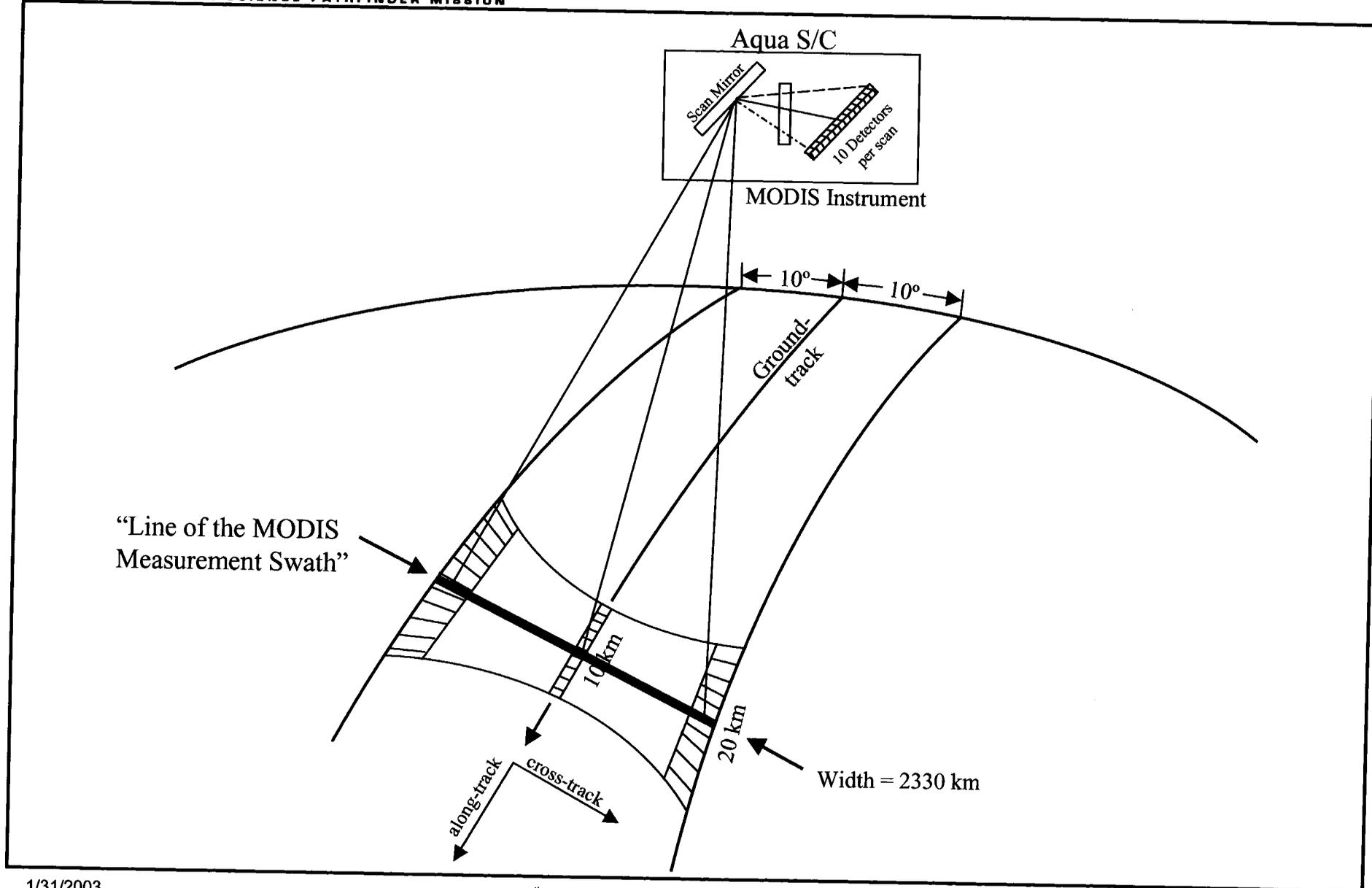


Spacecraft Baseline



- Spacecraft
 - Bus based on BATC's RS-2000 bus
 - NTE mass = 999 kg
 - NTE orb avrg power = 700 w
 - Pointing control acc = 0.067 deg
 - Hydrazine propellant = 76 kg
 - Max data-rate = 1 Mbps
 - SGLS compatible. S-Band telemetry
 - Nadir pointed radar
- Science Instrument
 - 94 GHz Cloud Profiling Radar
 - NTE mass = 250 kg
 - NTE peak power = 322 w
 - NTE data rate = 25 kbps
 - Vertical resolution < 550 m
 - EOL sensitivity < -26 dBz
 - Instantaneous Footprint < 2 km
 - Time-tagging acc. < 15 msec

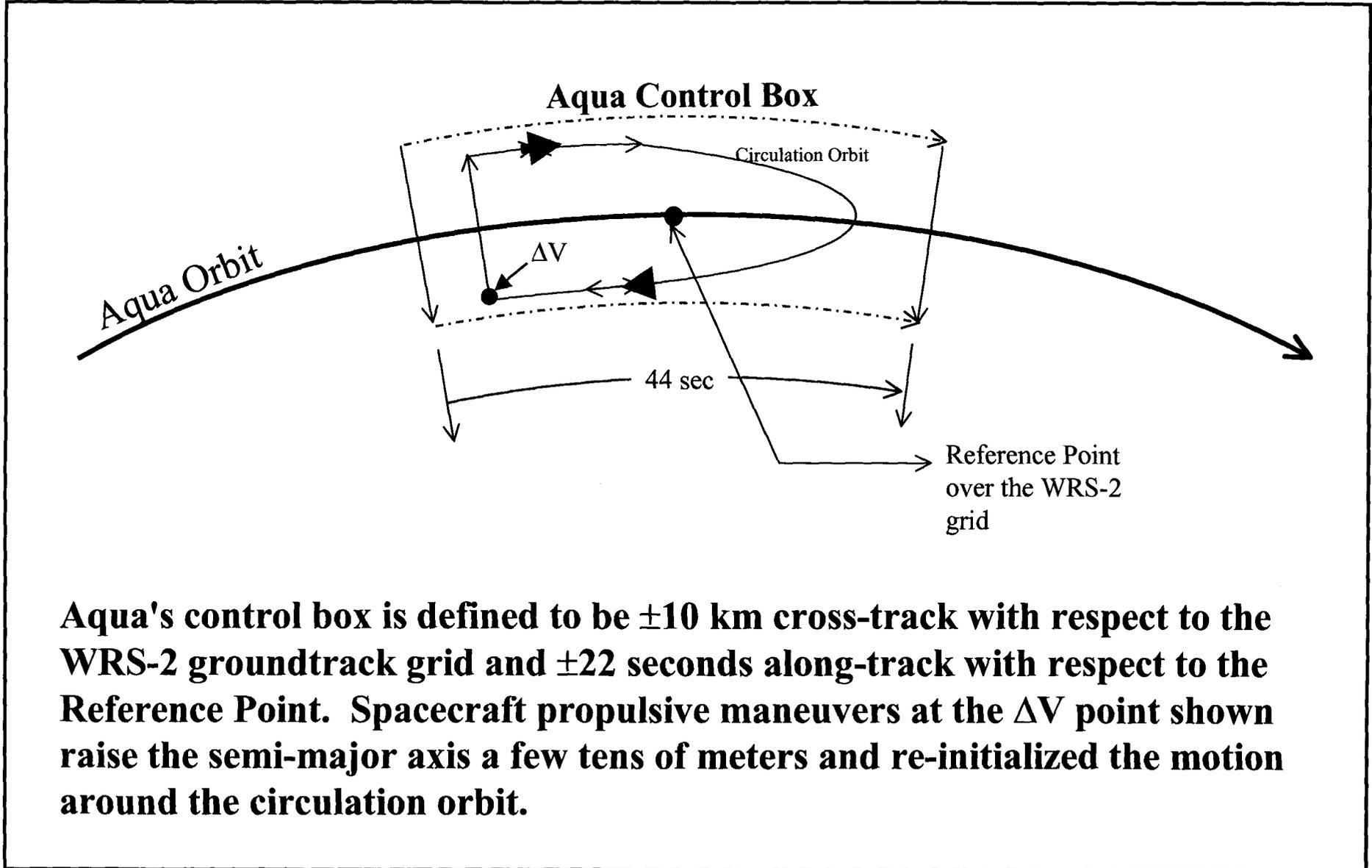
MODIS Scanning Geometry



Aqua's Key Orbital Parameters

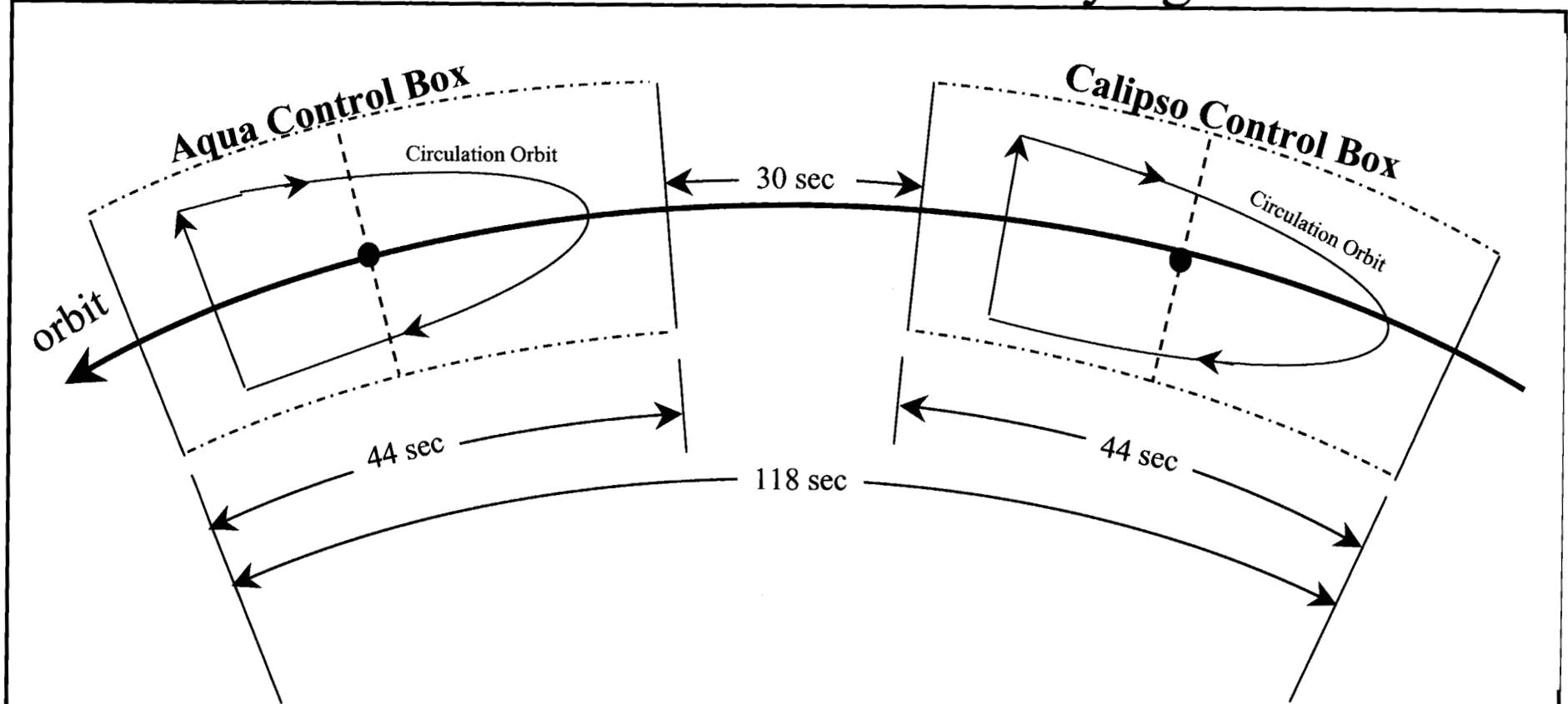
- Aqua uses a sun-synchronous orbit with inclination $\approx 98.2^\circ$
- The Mean Local Time of Aqua's ascending node is between 13:15 and 13:45 hours relative to the mean solar meridian
- Aqua uses a "frozen" orbit with eccentricity ≈ 0.0012 and argument of perigee $\approx 90^\circ$
- Aqua's mean semi-major axis fixes the orbital period so that the groundtrack repeats every 233 revs or equivalently 16 days
- Aqua's groundtrack is aligned with the WRS-2 grid and Aqua assumes a "reference" point to phase it with other satellites also using the WRS
- Owing to atmospheric drag, Aqua's groundtrack drifts in time wrt the WRS grid; bounds on this drift limit it to ± 20 km wrt the WRS
 - In practice, Aqua plans to control the cross-track deviation to ± 10 km
 - This equates to an along-track deviation of ± 22 seconds wrt the reference point

Aqua Control Box Relative to the WRS-2



Aqua's control box is defined to be ± 10 km cross-track with respect to the WRS-2 groundtrack grid and ± 22 seconds along-track with respect to the Reference Point. Spacecraft propulsive maneuvers at the ΔV point shown raise the semi-major axis a few tens of meters and re-initialized the motion around the circulation orbit.

Aqua and CALIPSO Formulation Flying Control Boxes



Aqua and CALIPSO shown flying in formation together, each moving along a circulation orbit constrained in their respective control boxes. With this formation, CALIPSO is never more than 118 seconds behind Aqua.

Aqua's and CALIPSO's Orbits



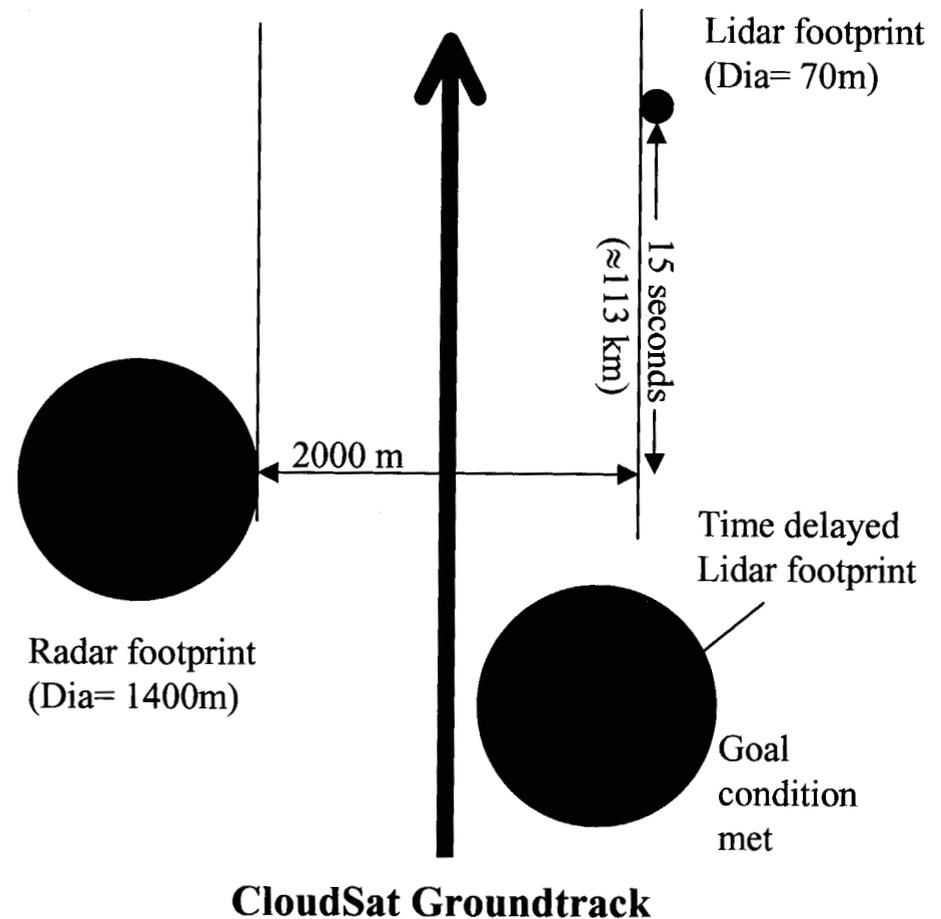
A "to-scale" view of the earth and orbits is seen from the sun for an epoch on 10 July 2005. The figure also depicts the approximate mean separation of 74 seconds along-track between Aqua and CALIPSO. Note the eastward displacement of CALIPSO's node in order to avoid the sun-glint zone.

Science Requirements Related to Formation Flying with CALIPSO

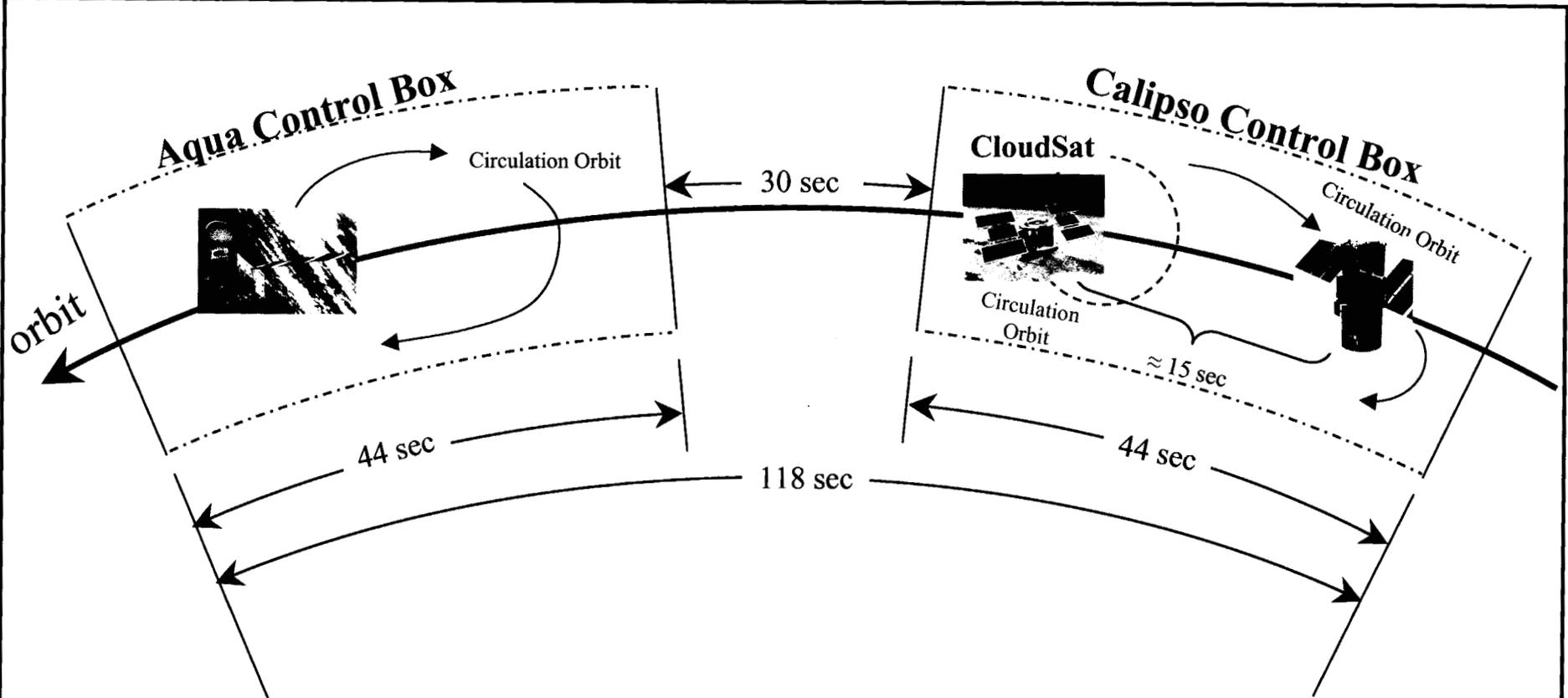
- Goal on the simultaneity of radar and lidar measurements:
 - Measurements of the same cloud fields taken ≤ 15 seconds
- Requirement/goal on spatial overlap of radar and lidar measurements:
 - Footprints must pass ≤ 2000 meters edge to edge*
 - Goal for footprints to overlap at least 50% of the time*

*Requirement and goal compliance predicated on radar/lidar point and pointing error assumptions

Position of footprints relative to groundtrack

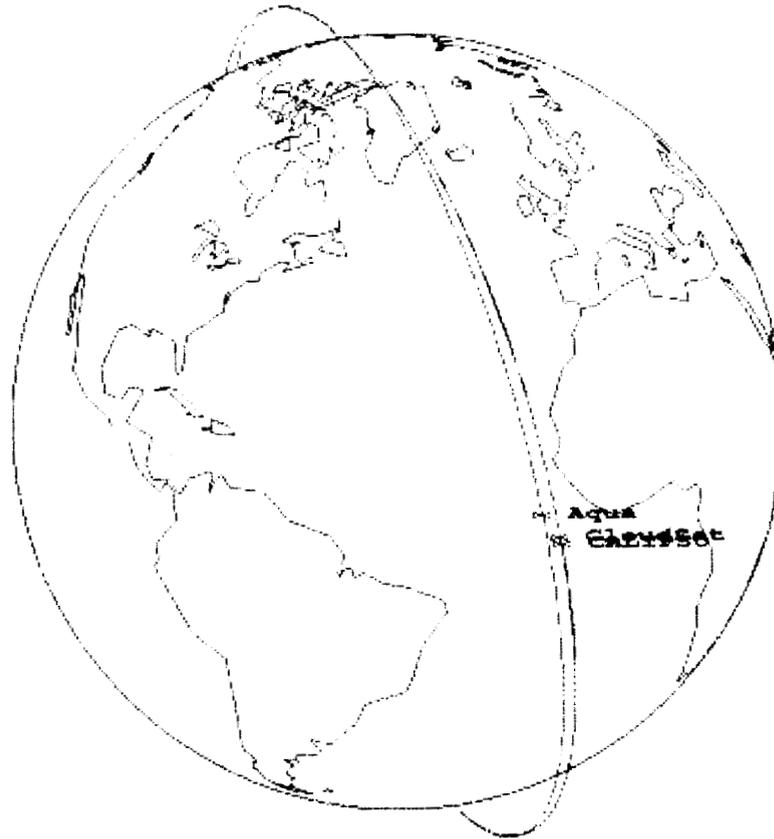


Configuration of the “Virtual Platform”



Shown is Aqua, CloudSat, and CALIPSO in their formation configuration. Aqua leads. CALIPSO follows but maintains its motion independent of Aqua within its control box. CloudSat follows a small circulation orbit, ± 2.2 seconds along-track, positioned ≈ 15 seconds in front of CALIPSO.

Aqua, CloudSat, and CALIPSO in Orbit



Shown is a "to-scale" view of the earth and orbits as seen from the sun for an epoch on 10 July 2005. Also shown are the approximate positions of Aqua, CloudSat, and CALIPSO in formation relative to each other for the mean along-track separation of 74 seconds between Aqua and CALIPSO.

- Aqua with its MODIS instrument was designed to make systematic measurements to quantify the earth's current climatological state and the rate of change
- CALIPSO with its lidar was designed to quantify the role played by aerosols and clouds on the earth's climate
- CloudSat with its radar was designed to provide from space the first global survey of cloud profiles and cloud physical properties needed to evaluate the way clouds are parameterized in global models
- CALIPSO recognized that it could enhance its science achievements by flying in formation with Aqua to utilize MODIS data
- CloudSat recognized that by flying in tight formation with CALIPSO it could utilize the both MODIS and lidar data to enhance its radar data products
- With formation flying, these three spacecraft have become, in effect, a "virtual platform"