LASER TRACKING OF THE PROPOSED COSMIC SATELLITES

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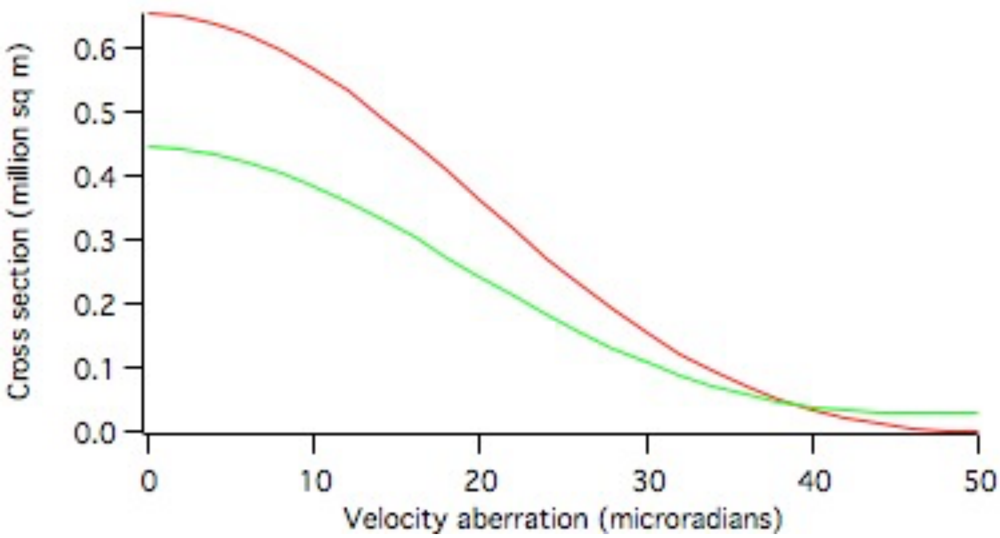
Abstract: The purpose of this paper is to determine the conditions under which the proposed COSMIC satellites can be tracked by the laser tracking network.

1. Method of computation

The cross section of the COSMIC cube corner has been computed using the method described in SAO Special Report 382 (http://ilrs.gsfc.nasa.gov/docs/1979/1979SAOSR_382.pdf). Signal strength computations are done using the range equation and a simple orbital simulation with no perturbations. Since J2 is not modeled the plane of the orbit is fixed.

2. Cross section of the COSMIC cube corner vs velocity aberration

The COSMIC retroflector array consists of a single coated cube corner .5 inches in diameter and .4 inches in length. It points along the local vertical. At normal incidence the cross section vs velocity aberration is



Red = no dihedral angle offset
Green = 1.50 arcsec dihedral angle offset

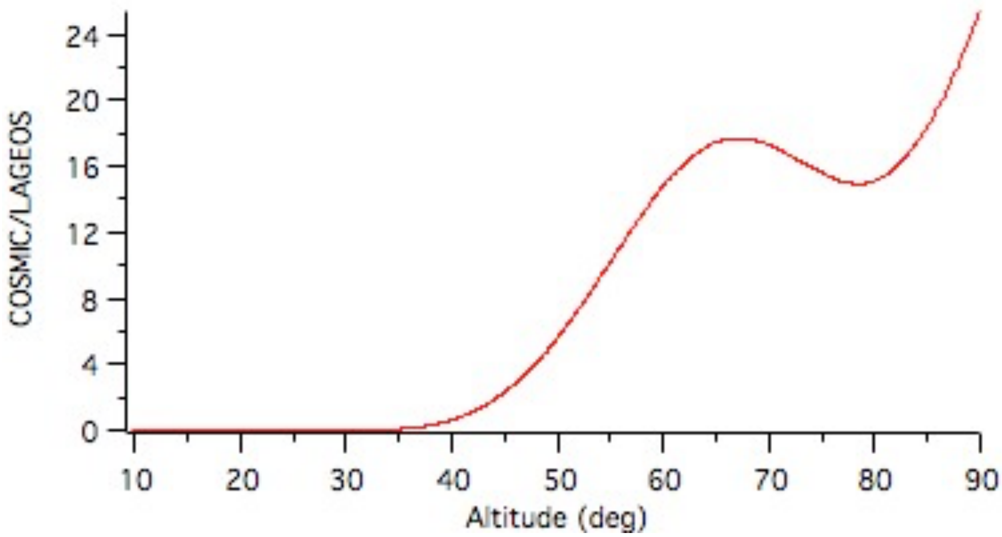
With no dihedral angle offset the cube corner gives virtually no signal at 50 microradians velocity aberration. Due to manufacturing errors there will be some unintentional offset. These simulations use a dihedral angle offset of 1.50 arcsec to approximate the properties of a real cube corner. The unintentional offset gives the cube corner the necessary beam spread to account for velocity aberration.

The array is not designed to give signal from all incidence angles. The cross section vs incidence angle on the cube corner at 0 and 50 microradians is shown at the end of this report. Since the cross section varies strongly with both velocity aberration and incidence angle one cannot use a constant cross section.

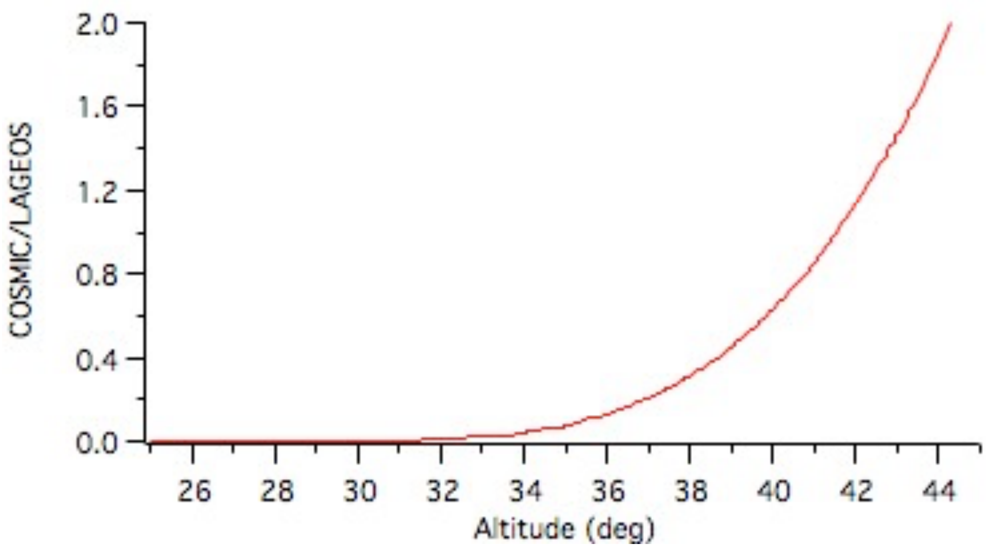
3. Signal strength relative to LAGEOS

Absolute signal strength calculations are not reliable due to many unmodeled effects. Therefor the ratio of the COSMIC signal to LAGEOS had been computed as shown in the figure below.

Signal strength relative to LAGEOS
Vs
Altitude



Signal strength relative to LAGEOS vs Altitude
Expanded plot from 25 – 45 deg altitude and 0 – 2 ratio

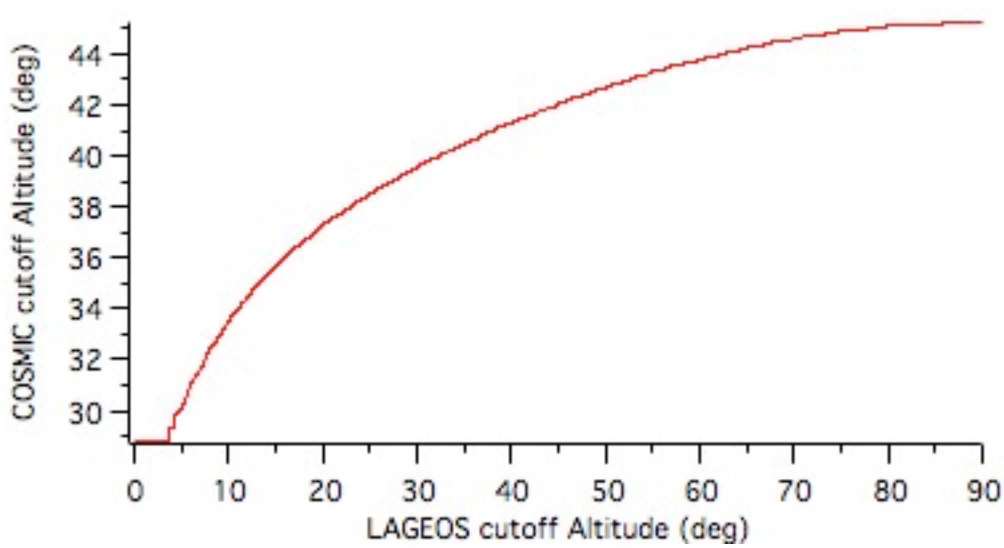


The ratio COSMIC/LAGEOS is unity at 41.5 deg Altitude.

4. Altitude cutoff angle for COSMIC

Because of the limited field of view of the COSMIC retroreflector there will be some limiting altitude below which the satellite cannot be tracked. This depends on the station parameters. If a station can track LAGEOS down to a certain altitude the station should be able to track COSMIC to the altitude where the signal is the same as LAGEOS at the LAGEOS cutoff angle. The signal from COSMIC and the signal from LAGEOS have been computed vs altitude for an overhead pass. The cutoff angle for COSMIC has been computed by comparison of these curves. In the figure below the vertical axis is the COSMIC altitude where the signal is the same as LAGEOS at the altitude on the horizontal axis.

COSMIC altitude needed to give the same signal as LAGEOS at the LAGEOS cutoff angle



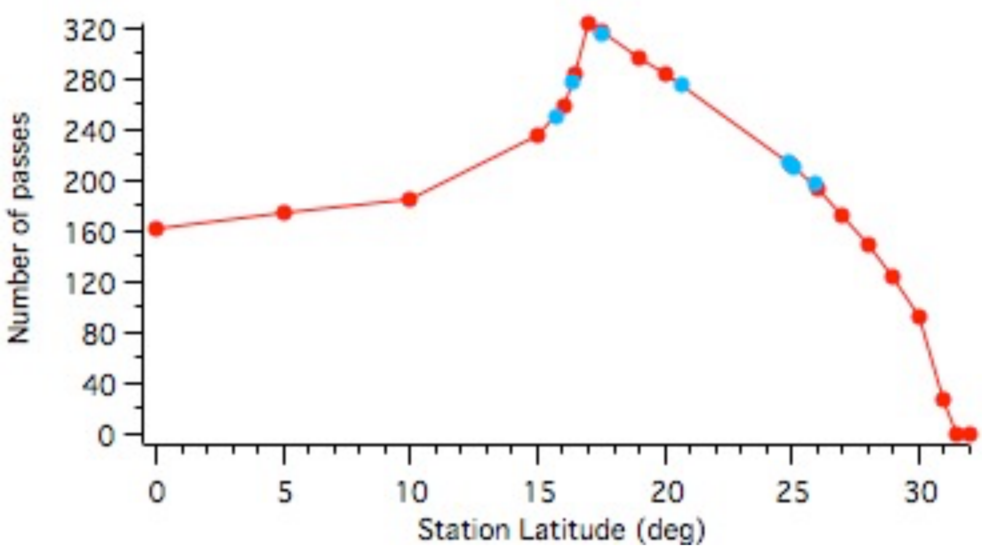
The table below gives the cutoff angle for COSMIC vs the cutoff angle for LAGEOS

LAGEOS	COSMIC
0.	28.8
5.	30.1
10.	33.5
15.	35.7
20.	37.2
25.	38.5
30.	39.5
35.	40.4
40.	41.3
50.	42.6
60.	43.8
70.	44.6
80.	45.1
90.	45.2

5. Number of passes vs Latitude

Since the inclination of COSMIC is only 24 degrees and the satellite is in a 550 km orbit, only low latitude stations will be able to track COSMIC. The figure below shows the number of passes that can be obtained in a 60 day period vs Latitude of the station. An altitude cutoff angle of 30 degrees has been used in these simulations. The resuls do not consider signal strength and depend only on observing geometry.

Number of passes
Ve
Latitude of the station
(30 deg altitude cutoff angle)



Simulations have been done for 900 orbits (1443 hours, 60 days)
blue = actual stations
red = parametric study vs latitude

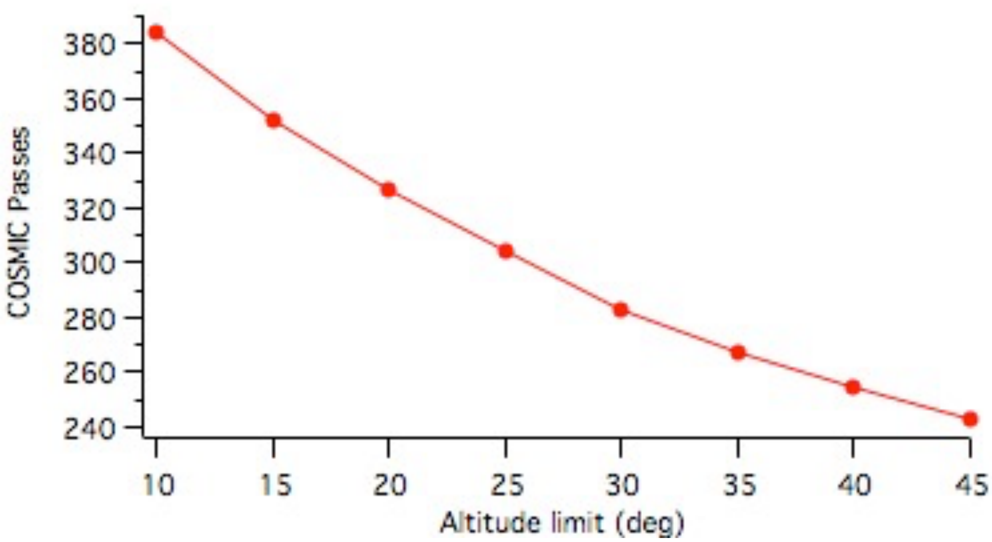
The curve shows a slope discontinuity at 17 deg. The reason for the discontinuity in slope has not been studied. The data for the actual stations (blue) is shown below.

Alt	Passes	Station
15.77	250.	Brasilia
16.46	277.	Arequipa
17.57	315.	Tahiti
20.70	276.	Haleakala
24.91	214.	Riyadh
25.03	210.	Kunming
25.88	198.	Hartebeesthoek

6. Number of passes vs cutoff altitude

The number of passes will also depend on the cutoff angle above the horizon. The plot below shows the number of passes for a station at 20 degrees Latitude vs the cutoff altitude angle.

Number of passes for a station at 20 degrees Latitude
vs
altitude cutoff angle



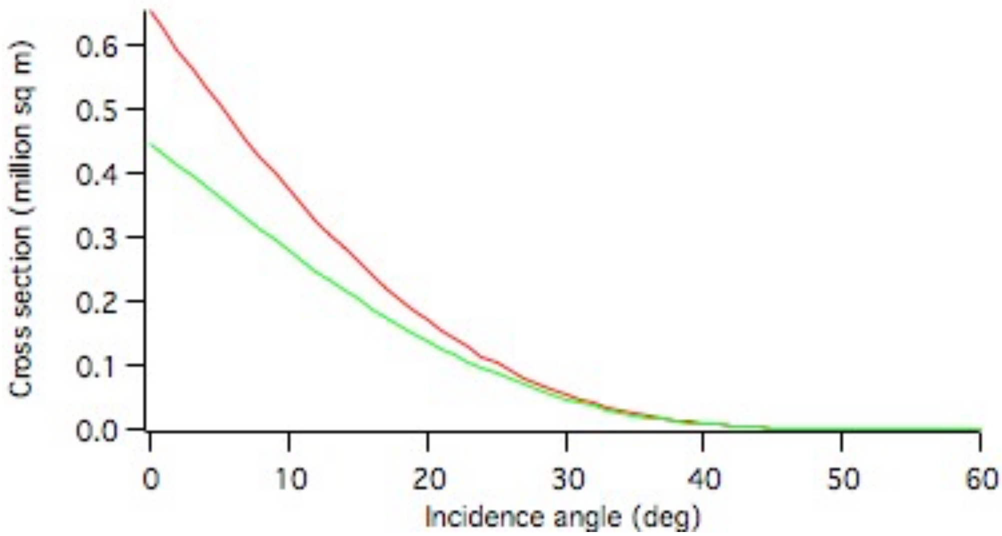
Simulations have been done for 900 orbits (1443 hours, 60 days). The data used in the plot is shown below.

Alt	Passes
10.	384.
15.	352.
20.	327.
25.	304.
30.	283.
35.	267.
40.	255.
45.	243.

7. Cross section of COSMIC cube corner vs incidence angle

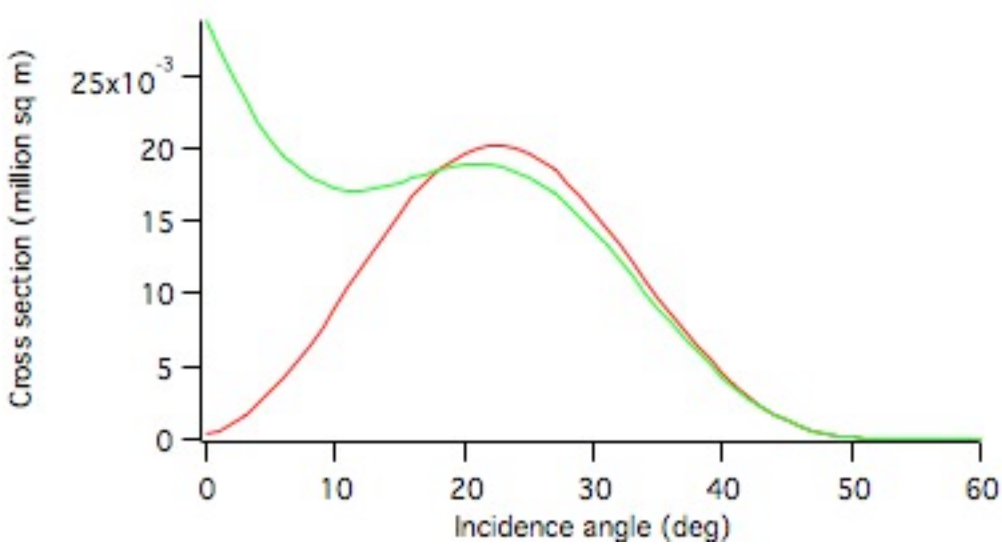
Cross section of the COSMIC retroreflector vs incidence angle

Central peak (zero velocity aberration)



Cross section at 0 microradians velocity aberration vs incidence angle
Red = no dihedral angle offset
Green = 1.50 arcsec dihedral angle offset

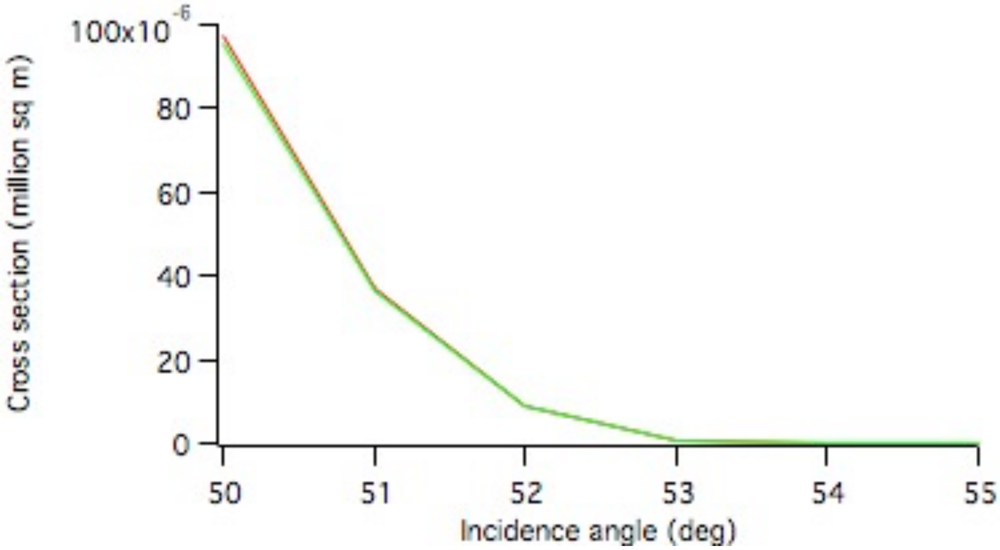
50 microradians velocity aberration



Cross section at 50 microradians velocity aberration vs incidence angle
Red = no dihedral angle offset
Green = 1.50 arcsec dihedral angle offset

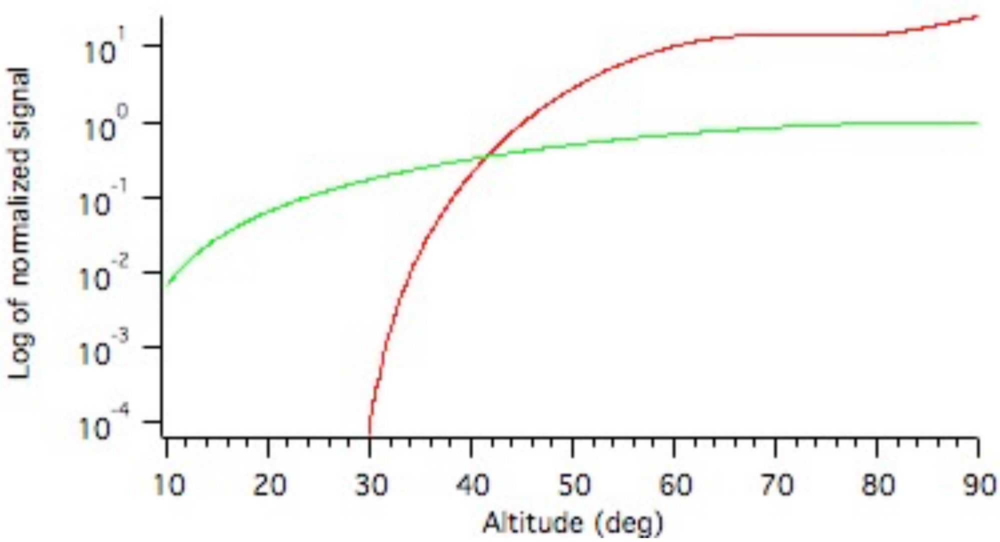
8. Cube corner cutoff angle, and altitude cutoff angle

The expanded plot below for the cross section at 50 microradians shows that the cutoff angle of the cube corner (to a resolution of one degree) is just past 53 degrees. This gives a cutoff angle of 29 degrees altitude above the horizon.



9. Dynamic range and ND filters

COSMIC has a very large dynamic range in the signal compared to other satellites. This may require changing ND filters to keep the signal within the dynamic range of the receiver during a pass. In order to facilitate the use of ND filters the signal strength has been plotted on a logarithmic scale. Each change of a factor of 10 in signal is the equivalent of a change of one ND filter. The plot below shows the signal strength of COSMIC (red) and LAGEOS (green) vs altitude normalized to the signal from LAGEOS at zenith.



The tables below show the normalized signal in logarithmic units vs altitude above the horizon.

LAGEOS

Normalized Signal	Altitude (deg)
1.0000	90.0
.1000	23.9
.0100	11.1

COSMIC

Normalized Signal	Altitude (deg)
25.4000	90.0
10.0000	59.9
1.0000	45.3
.1000	38.8
.0100	34.1
.0010	31.5
.0001	30.0

The signal from LAGEOS varies over 2 orders of magnitude from zenith to 10 degrees altitude. The signal from COSMIC varies by 5 orders of magnitude from zenith to 30 deg altitude. In particular, the signal changes very rapidly near the cutoff angle of 30 degrees.

10. Summary

- The COSMIC satellite should give a sufficient number of passes for low Latitude stations. Section 5 lists 7 stations that should be able to track COSMIC. The table gives the number of passes that can be expected for each station in a 60 day period.
- The data in section 4 can be used to decide what cutoff angle in altitude to use for COSMIC based on how low the station can track LAGEOS.
- Section 9 shows that there is a wide dynamic range of the signal for COSMIC. Each change of a factor of 10 is equivalent to one ND filter.