633-461

TOPEX/POSEIDON Project

Laser Retroreflector Array Interface Description

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TOPEX/POSEIDON Mission

Laser Retroreflector Array

Interface Description Document

Prepared by
Jon A. Schwartz

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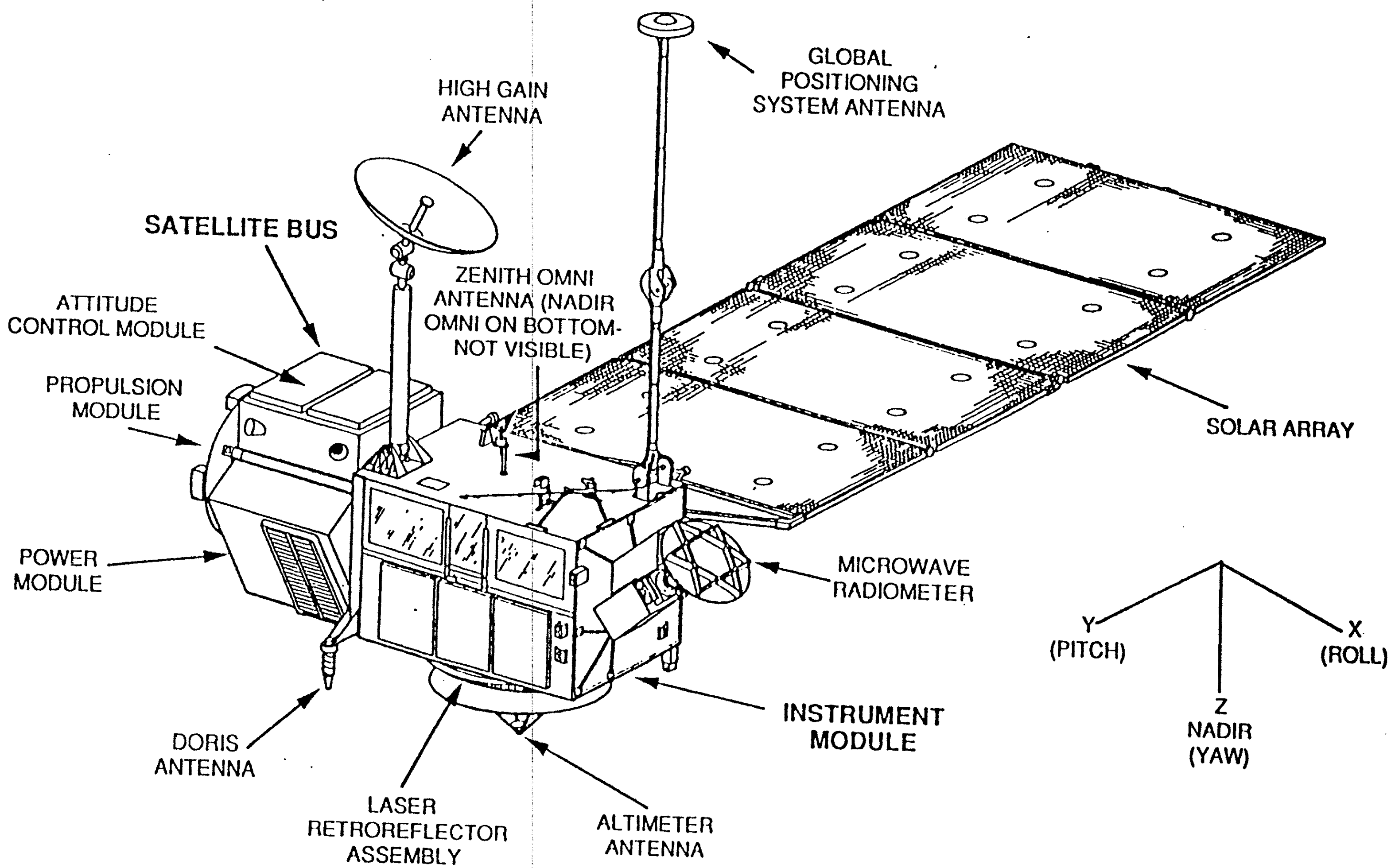
a) abbreviations

CM	-	center-of-mass
GPS	-	global positioning system (antenna)
HGA	-	high gain antenna
IDD	-	interface description document
LRA	-	laser retroreflector array
POD	-	precision orbit determination
SA	-	solar array

TOPEX Spacecraft



1) Introduction

1.1) Purpose

This Interface Description Document (IDD) for the TOPEX/POSEIDON Laser Retroreflector Array (LRA) defines the LRA/ground station operational interface characteristics from the instrument point of view. This IDD is meant to be the prime source of LRA interface information for the laser ranging network.

1.2) Mission operations summary

The LRA is the flight component which interfaces with the lasers located at the calibration or ground tracking stations. It consists of a conical array of cube corner retroreflectors mounted on a ring which is situated around the outer perimeter of the altimeter antenna. The LRA is made up of 192 cube corner retroreflectors evenly arranged into 2 rows and divided into 16 mounting trays. Each of the cube corners is mounted such that its entrance-face normal is off-pointed from the altimeter antenna axis by 40^{o} (+/- 1^{o}).

Prime use of the LRA is for altimeter height calibration measurement to +/- 5 cm (1 sigma cumulative error for the entire system) for altimeter verification, over the calibration sites. The orbit will pass over the calibration sites every ten days. At other times the LRA will be utilized for laser tracking for Precision Orbit Determination (POD). The LRA will be used at both the U.S. calibration site at Point Conception, California, and the European calibration site at Lampedusa, Italy to verify the height measurement of the altimeters. Mission design for TOPEX/POSEIDON will ensure combinations of ascending and/or descending passes pass directly over these stations at least once every 10 days so that height measurements from the altimeters may be calibrated.

The LRA is mechanically and thermally isolated from the altimeter antenna and does not interfere with this antenna in any way. The central axis of the LRA's conical ring is aligned parallel to the altimeter's electrical boresight [1].

2) Configuration

2.1) Physical characteristics

Table 2.1-1 gives the design specification for the TOPEX/POSEIDON LRA. Table 2.1-2 gives the design for the optical subsystem. Table 2.1-3 gives the specification for the antireflection coating applied to the entrance face of the cube corner retroreflectors. And Table 2.1-4 gives the specification for the coatings that make up the retroreflector's high-reflectance surfaces.

Table 2.1-1
TOPEX/POSEIDON LRA DESIGN SPECIFICATION

number of cube corner retroreflectors:	192
configuration:	2 rings, uniform spacing, outer ring 64 CCR's, inner ring 128 CCR's
orientation of cube corners:	40 degrees off ring-plane normal
dihedral angle offset:	+1.75 arcseconds
coatings - entrance face:	MgF_2 antireflection
- back surfaces:	Ag high-reflectance

Table 2.1-2
OPTICAL SUBSYSTEM DESIGN

type of glass:	Corning fused silica #7958 selected as a result of radiation test results
glass manufacturer:	Corning Incorporated
retroreflector manufacturer:	Zygo Corporation
optical coatings:	
antireflection	magnesium fluoride (MgF_2)
reflection	silver (Ag)
operational wavelengths:	300 - 800 nm
index of refraction:	1.455 at 532 nm
dihedral angle:	90^{o} 0' 1.75" (+/- 0.25")
retroreflector FOV:	0 - 54^{o} [54^{o} is the angle at which the retroreflector has 5% of the cross sectional area obtained at normal (0^{o}) incidence]
optical efficiency:	
MgF_2	98% [2 interfaces]
fused silica	97% for 27.25 mm
silver	97% [3 reflections]
radiation losses	negligible
total transmission	$(0.98)^2 \cdot (0.97)^2 \cdot (0.97)^3 = 0.825$
alignment:	
boresight axis total misalignment	+/- 5 arcminutes
knowledge of misalignment	+/- 1 arcminute

Table 2.1-3
ANTIREFLECTION COATING

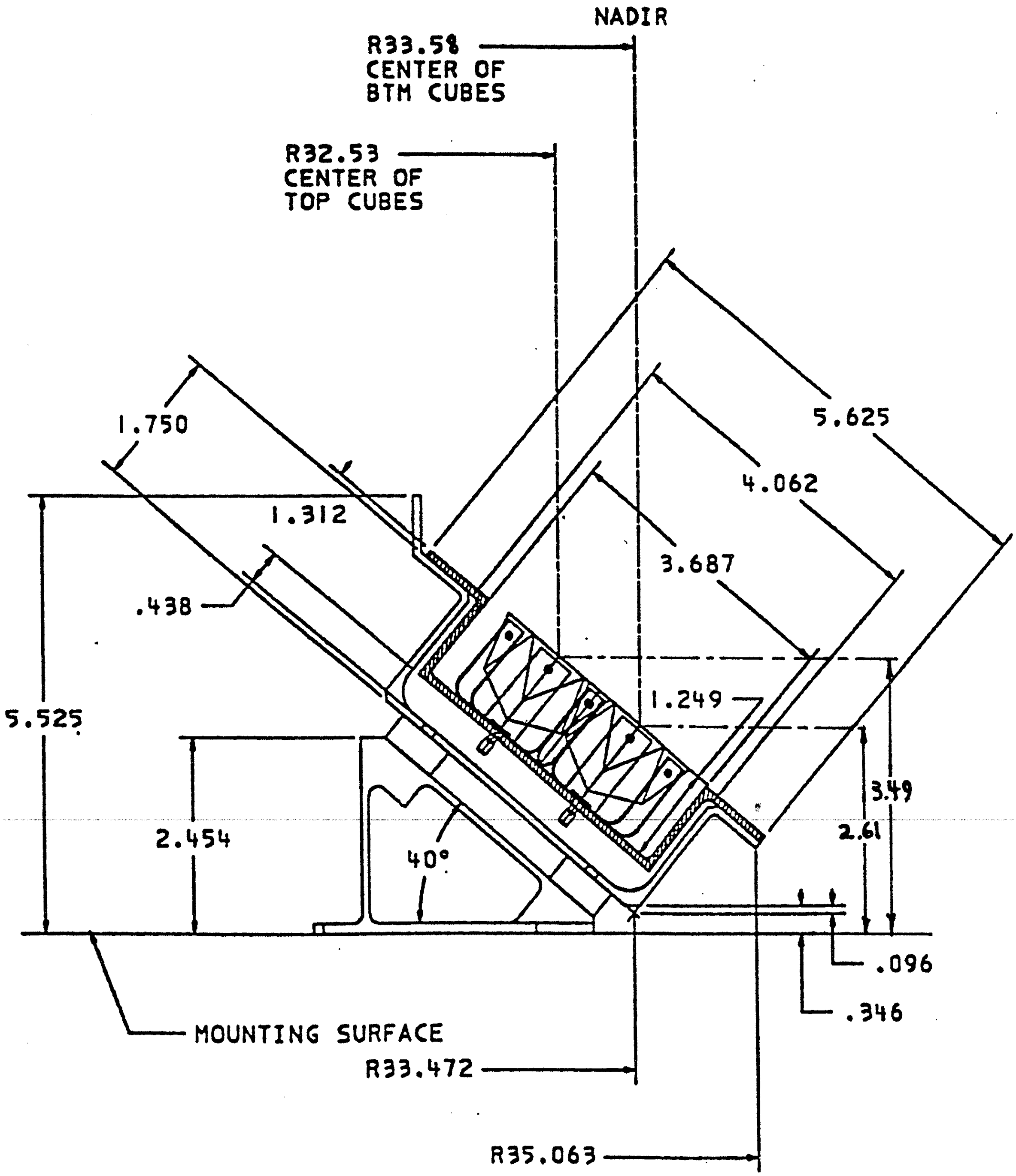
optical properties:	broadband optical transmission (300 - 800 nm) good index matching with substrate material superior durability no degradation over the temperature range of -60°C to +35°C
radiation insensitivity:	negligible loss in transmission due to radiation environment of the TOPEX/POSEIDON mission (55 Mrads of 1 MeV free electrons)
coating:	quarter-wave magnesium fluoride (133 nm - optimized for operation at 532 nm)

Table 2.1-4
REFLECTION COATING

chromium (adhesion)	1.5 - 2.0 nm
silver (reflection)	120 nm
inconel (protection)	75 nm
paint (thermal)	< 25.4 microns (< 1 mil) DSET TAWA 1300 (white)

LRA CROSS SECTION DETAIL

Figure 2.1-1 is a dimensional cross section of the LRA ring showing, among other things, the radius and height-above-deck of the centers of the cube corner entrance faces.

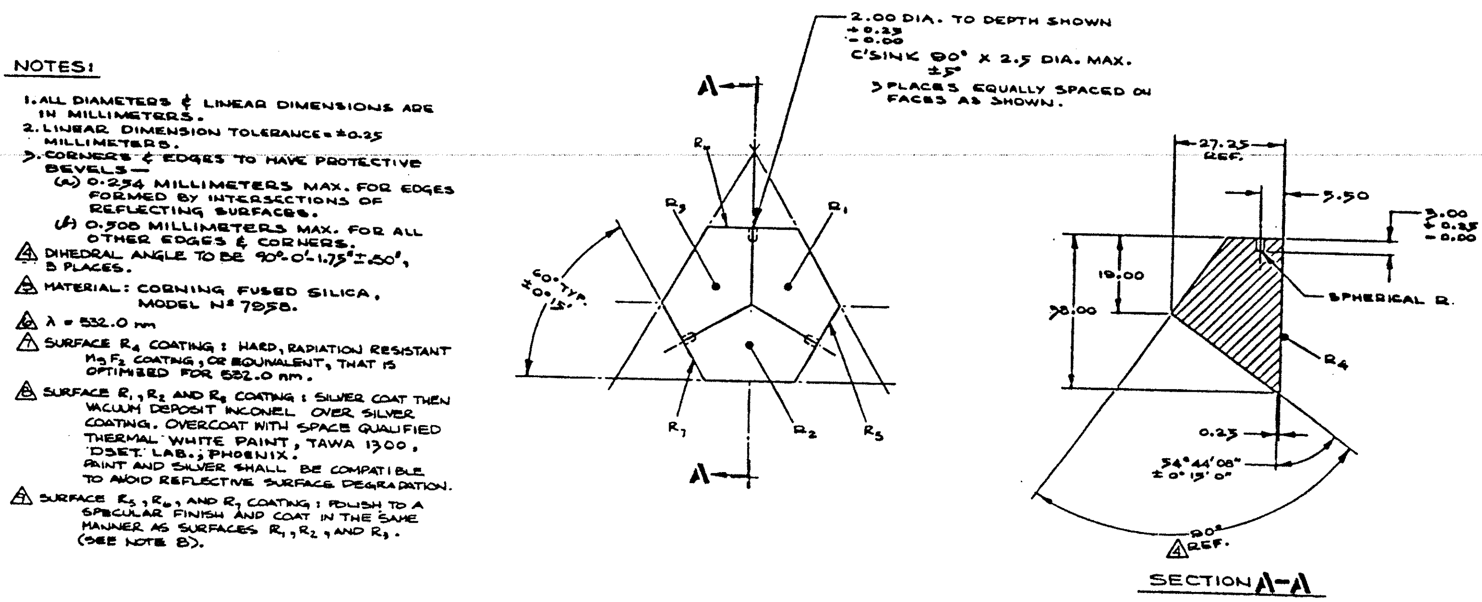


LRA CROSS SECTION DETAIL

Figure 2.1-1

CUBE CORNER RETROREFLECTOR

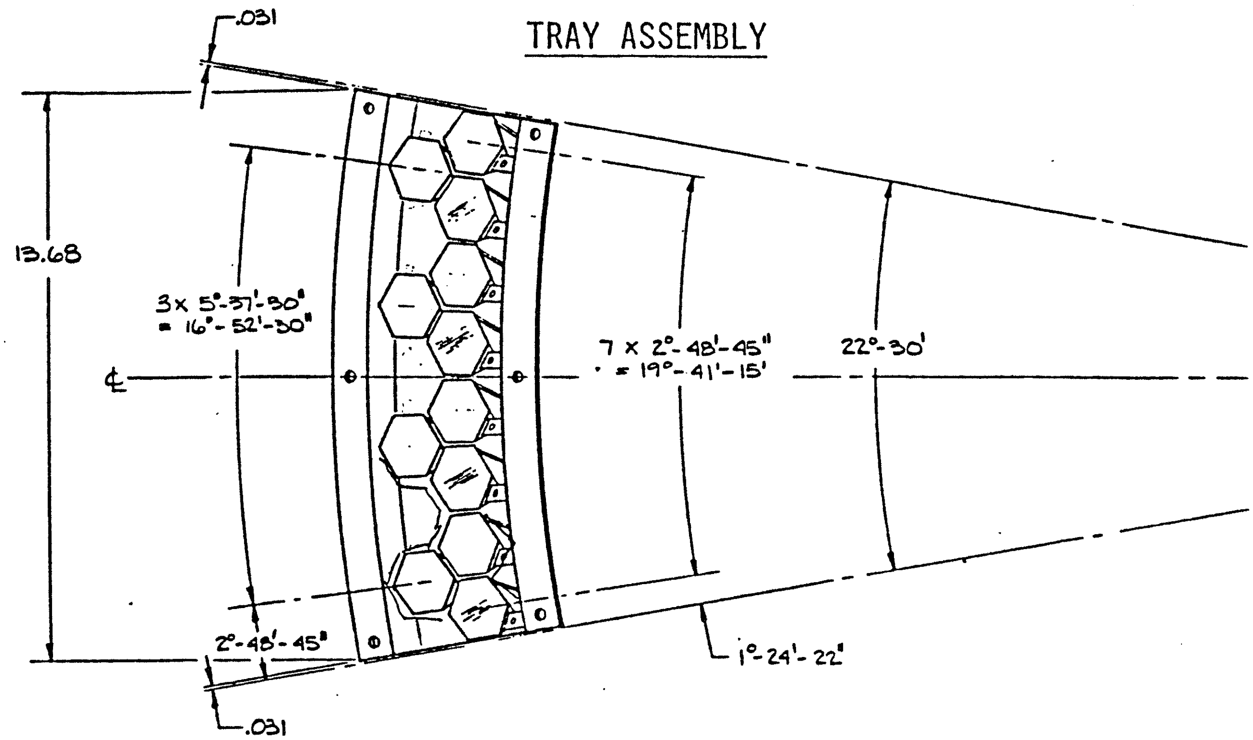
Figure 2.1-2 is a dimensional drawing of the cube corner retroreflectors used on the TOPEX/POSEIDON LRA.

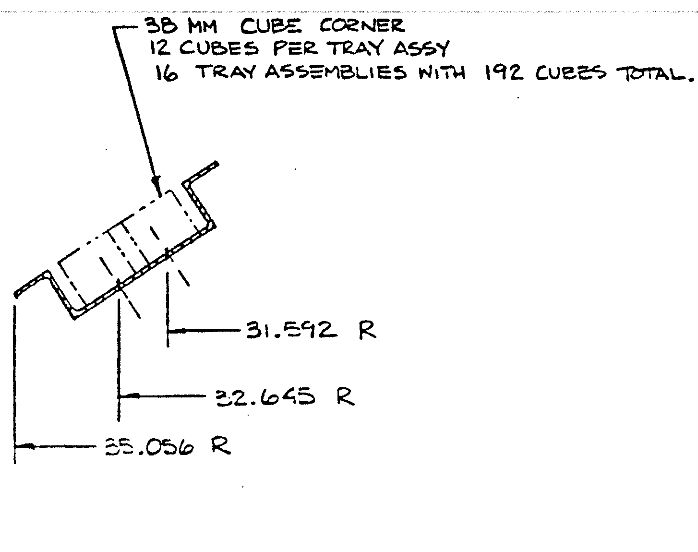


CUBE CORNER RETROREFLECTOR
Figure 2.1-2

LRA TRAY LAYOUT

Figure 2.1-3 shows the layout of one of the 16 trays that make up the LRA.

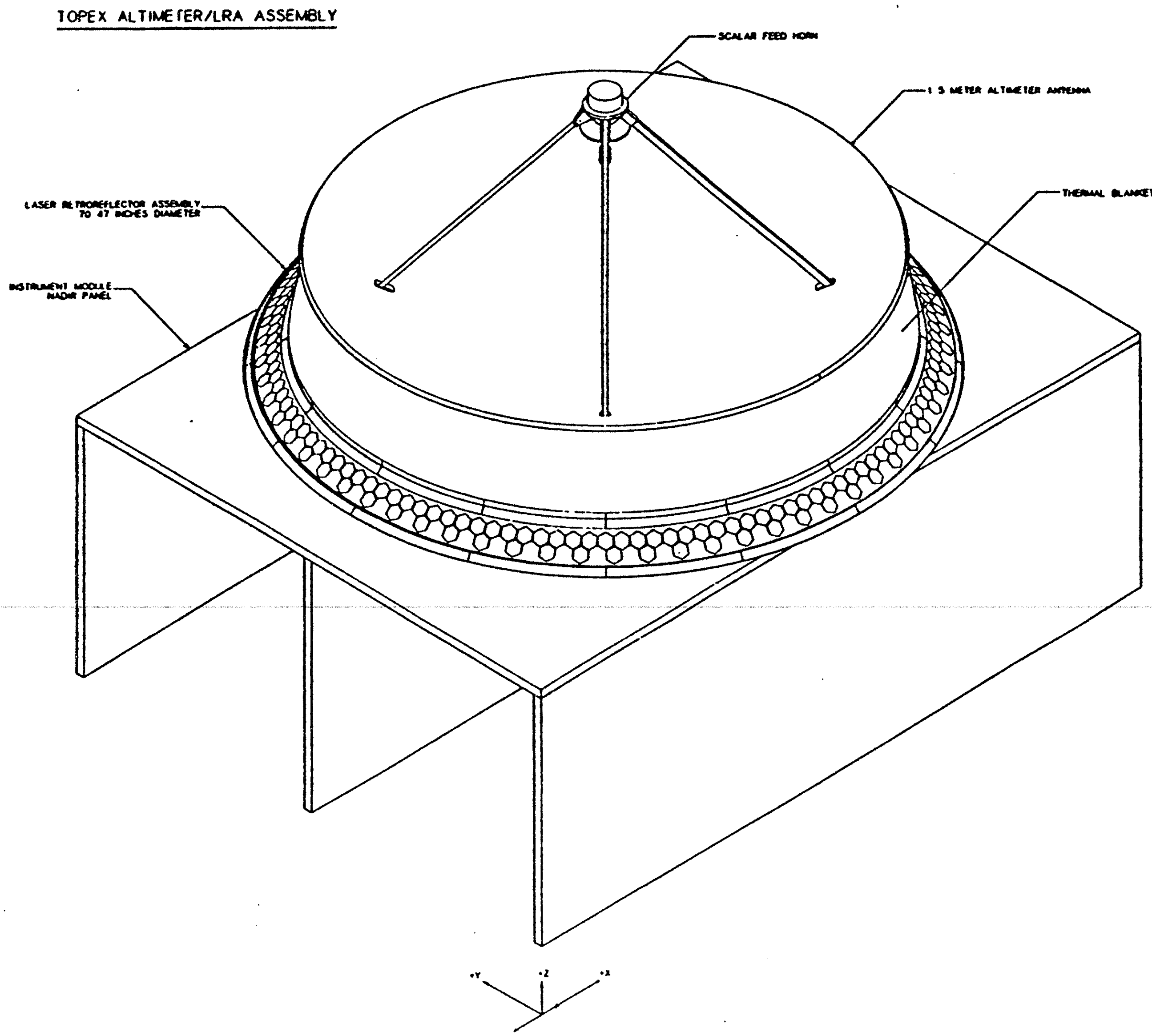




LRA tray assembly
Figure 2.1-3

ALTIMETER/LRA ASSEMBLY

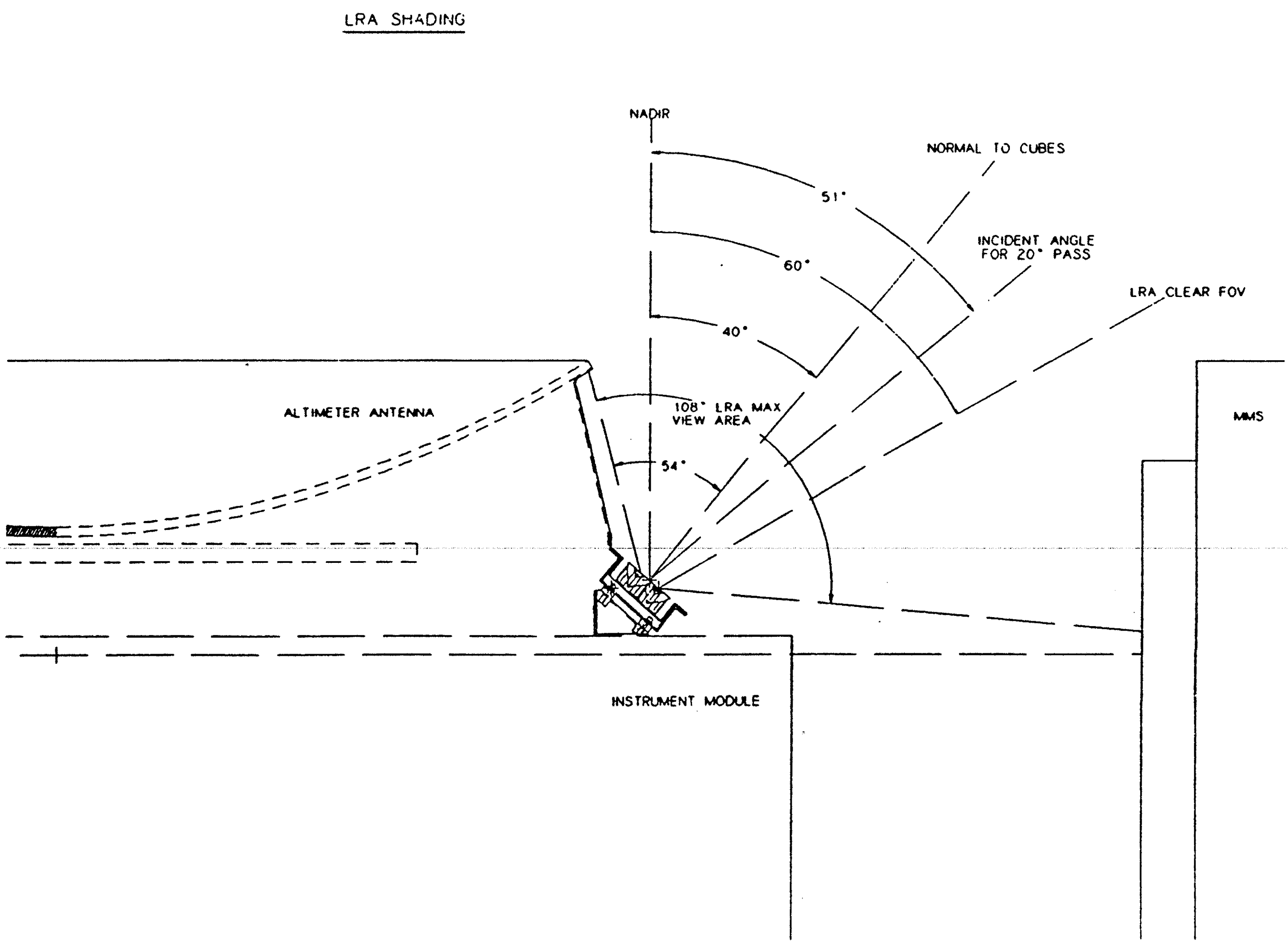
Figure 2.1-4 shows an isometric view of the TOPEX/POSEIDON altimeter/LRA assembly.



Altimeter/LRA Assembly
Figure 2.1-4

2.2) Field of view

Figure 2.2-1 illustrates the field-of-view of the LRA. The cross-section is taken along the spacecraft X-axis. The designed field-of-view corresponds to the maximum off-nadir angle of the spacecraft as viewed from a ground station on the horizon. Or, put another way, the Earth-horizon for TOPEX/POSEIDON at an altitude of 1335 km. is 55.78°.



LRA field-of-view
Figure 2.2-1

2.3) LRA relationship to spacecraft center-of-mass

In order to accomplish the precision orbit determination for the spacecraft, laser ranging measurements made to the LRA must be related to the center-of-mass (CM) of the spacecraft. Conceptually, this is done in two steps. First, a range correction will have to be made to relate a specific laser ranging measurement to the center of the LRA, a subject treated in Section 3.2). Second, a vector must be traced from the center of the LRA to the CM of the spacecraft. This vector will be a function of the spacecraft orientation and configuration. The spacecraft orientation will be derived from other instruments, but three configurations are given below.

Positions on and within the spacecraft are defined by a Cartesian coordinate system, the axes of which are shown in the frontpiece figure. Table 2.3-1 gives the position of the center of the base of the LRA in this coordinate frame.

Table 2.3-1
POSITION OF CENTER OF THE LRA BASE IN SPACECRAFT COORDINATE FRAME

Axis:	X	Y	Z
LRA base center	123.876 cm	0.000 cm	87.630 cm

Table 2.3-2 locates the CM in this same coordinate frame for three selected spacecraft configurations. Configuration 3 corresponds to the beginning of the mission, and Configuration 3A corresponds to the planned end of the 5-year mission. These numbers are current as of 30 March 1990.

Table 2.3-2
POSITION OF CM IN THE SPACECRAFT COORDINATE FRAME

Axis:	X	Y	Z
Configuration 3 (HGA, SA, GPS: DEPLOYED; Propellent Tanks: FULL)	12.8 cm	-40.0 cm	3.6 cm
Configuration 3A (HGA, SA, GPS: DEPLOYED; Prop. Tanks: 60% DEPLETED)	21.1 cm	-42.3 cm	3.7 cm
Configuration 4 (HGA, SA, GPS: DEPLOYED; Propellent Tanks: DEPLETED)	26.7 cm	-43.9 cm	3.8 cm

The difference between the entries in Tables 2.3-1 and 2.3-2 yields the vector from the center of the base of the LRA to the CM for each of the representative configurations. The components of this vector are given in Table 2.3-3.

Table 2.3-3
LRA BASE CENTER-TO-CM VECTOR COMPONENTS

Axis:	delta(X)	delta(Y)	delta(Z)
Configuration 3	-111.1 cm	-40.0 cm	-84.0 cm
Configuration 3A	-102.8 cm	-42.3 cm	-83.9 cm
Configuration 4	-97.2 cm	-43.9 cm	-83.8 cm

The numbers in Table 2.3-3 are representative of the the vector that would have to be traced from the LRA base center to the spacecraft CM and combined with the orientation of the spacecraft in order to relate laser ranging measurements to the position of the CM.

3) LRA target signature

3.1) LIDAR crossection

The TOPEX/POSEIDON LRA LIDAR crossection is being generated by the Crustal Dynamics Project at the Goddard Space Flight Center, based on tests of individual LRA trays. The results of these measurements are to be supplied.

3.2) Range correction

As will be noticed in Figure 2.1-4 the LRA is made up of cube corner retroreflectors distributed about an annular ring. A consequence of this is that laser ranging pulses are reflected some distance before reaching the center-of-symmetry of the LRA; a distance that is a function of the satellite's look angle. This necessitates the use of a table to give a range correction based on measured LRA properties and precise information about the satellite's attitude relative to the laser ranging station. This information and the table are to be supplied.

3.3) **Predicted laser ranging signal**

Figure 3.3-1 shows predictions of the LRA signal return as predicted by two computer models. The models are the SALSA program developed by the Optical Communications Group at the Jet Propulsion Laboratory [2], and the RETRO program developed by Peter Minott at the Goddard Space Flight Center [3]. The depicted signal strengths are predicated on the use of the MOBLAS-7 laser ranging station.

The utility of the graphed signal strengths is in how they evolve during a satellite pass. In actual operation the signal will be attenuated to the 4-70 photoelectron level to correspond with the linear region of photodetectors currently in use on Crustal Dynamics Project laser ranging stations.

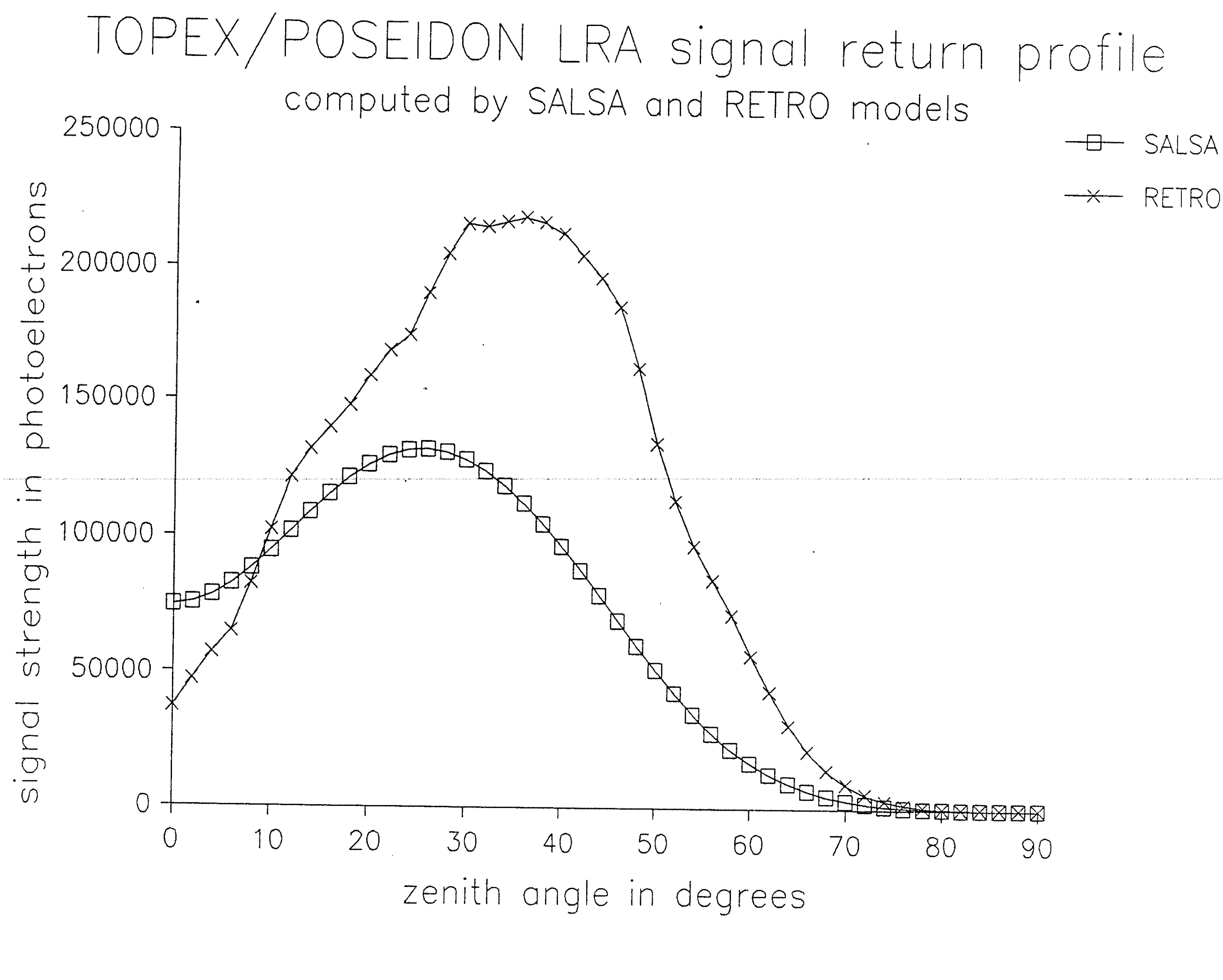


Figure 3.3-1

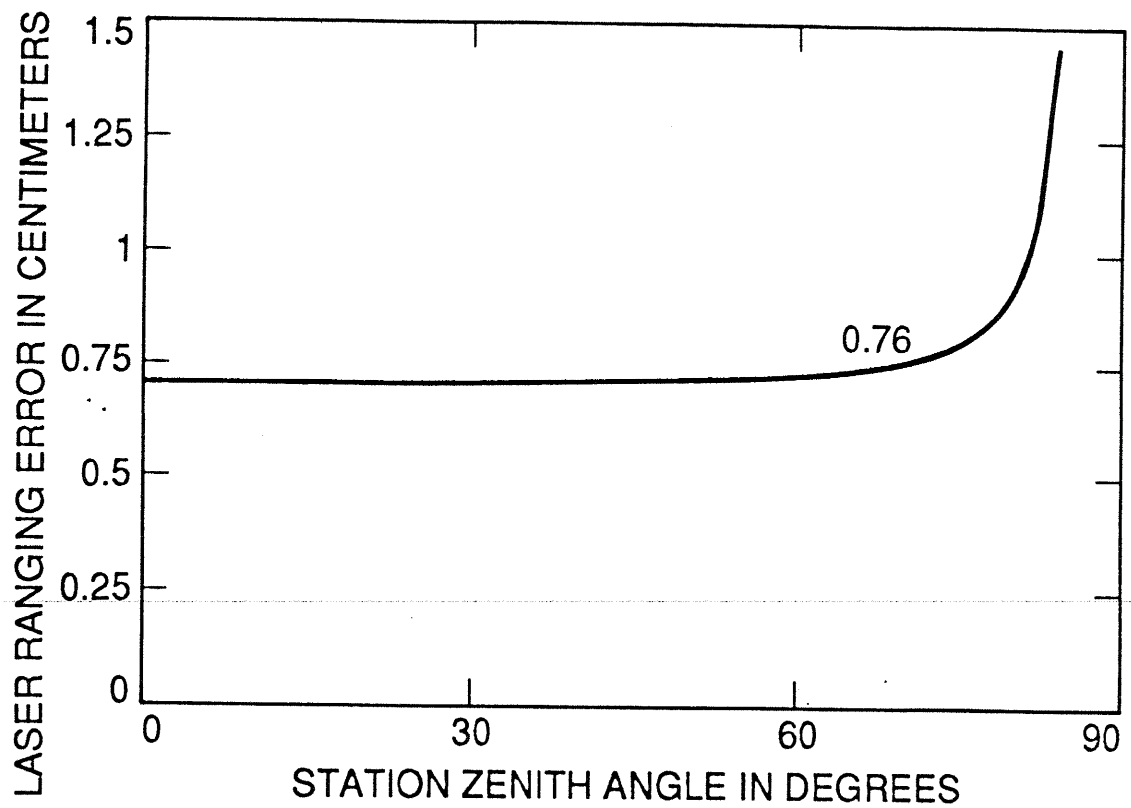
4) **Error budget**

An error budget has been derived for TOPEX/POSEIDON mission laser ranging [4]. Table 4-1 lists and quantifies the elements that make up this error budget. Most of the elements are system-dependent constants, others, denoted by asterisks (*), vary with the satellite look-angle. These angularly-dependent elements cause the error budget to increase dramatically for ground station zenith angles greater than about 70°. The error budget versus the zenith angle of the spacecraft, as seen from the ground station, is graphed in Figure 4-1.

Table 4-1
SUMMARY OF TOPEX/POSEIDON LASER RANGING ERRORS

Error constituent		Range error
1) Laser wavefront spatial effects		0.0 cm
2) Temporal effects (stability test)		0.15 cm
3) Signal strength effects		0.45 cm
4) Calibration target distance		0.1 cm
5) Neutral density filter bias		0.0 cm
Meteorological measurement errors		
6a) Ranging	pressure	0.28 cm*
6b)	temperature	0.02 cm*
6c)	relative humidity	0.07 cm*
6d) Calibration	pressure	0.003 cm
6e) Check	temperature	0.023 cm
6f)	relative humidity	0.00056 cm
7) Azimuth and elevation dependence (MOBLAS-7)		0.27 cm
8) Pulse fire time		0.06 cm*
Modeling errors		
9) Atmospheric propagation		0.12 cm*
10) LRA center of symmetry		0.02 cm*
11) Ground survey of laser position		0.1 cm
12) Data aggregation		0.4 cm
Root sum square total		0.76 cm*

*at zenith angle of 70°



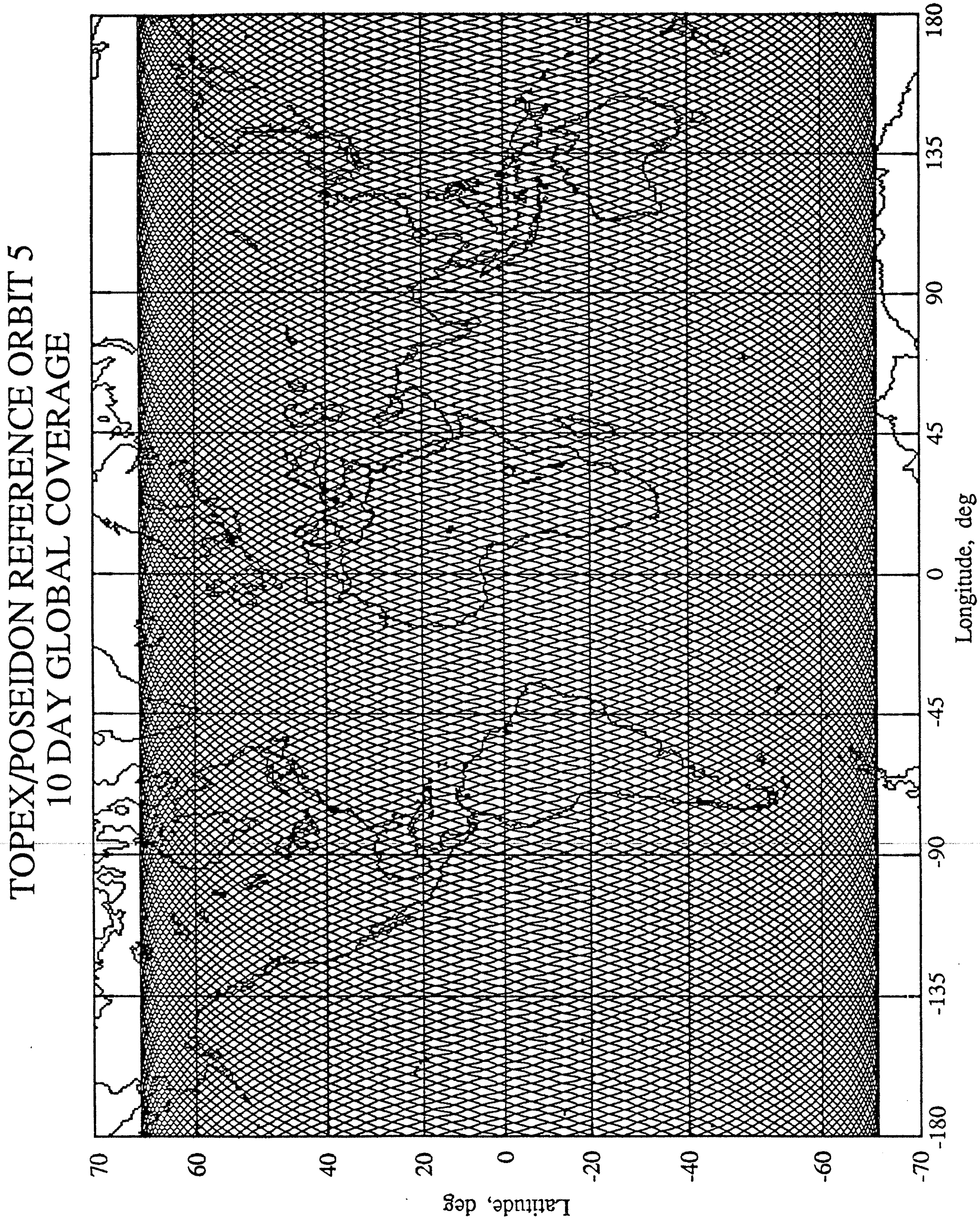
Projected TOPEX/POSEIDON budget for an overhead pass
Figure 4-1

5) Orbital parameters

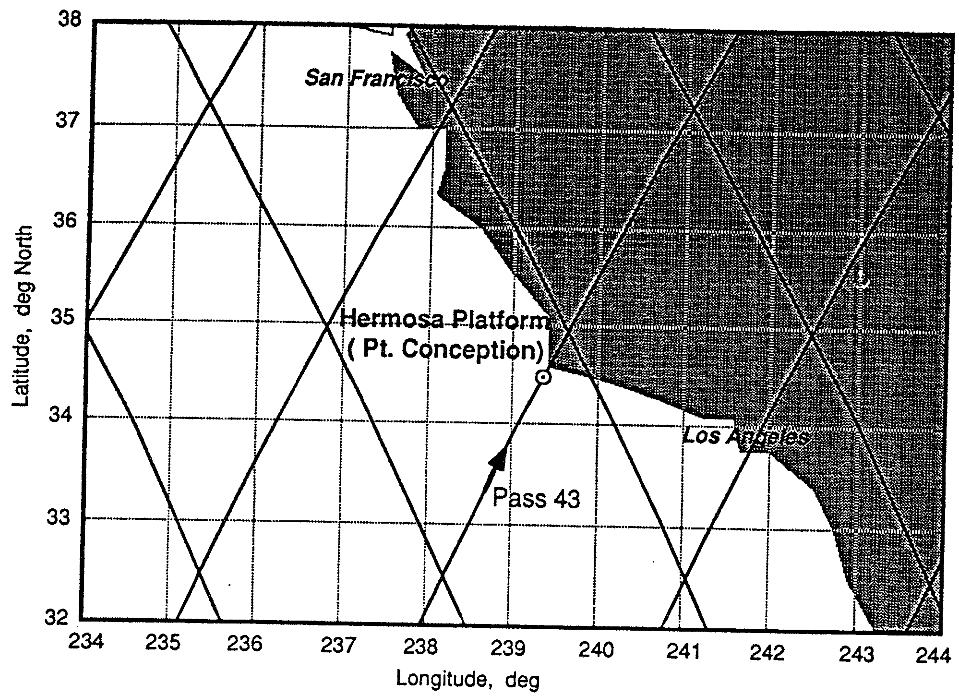
The planned orbital parameters for TOPEX/POSEIDON mission as of October 1989 are shown in Table 5-1. Figure 5-1 shows the ground-track for the satellite. Figure 5-2 shows the ground-track in the vicinity of the Pt. Conception calibration site, and Figure 5-3 the ground-track in the vicinity of the Lampedusa calibration site.

Table 5-1
TOPEX/POSEIDON ORBITAL PARAMETERS

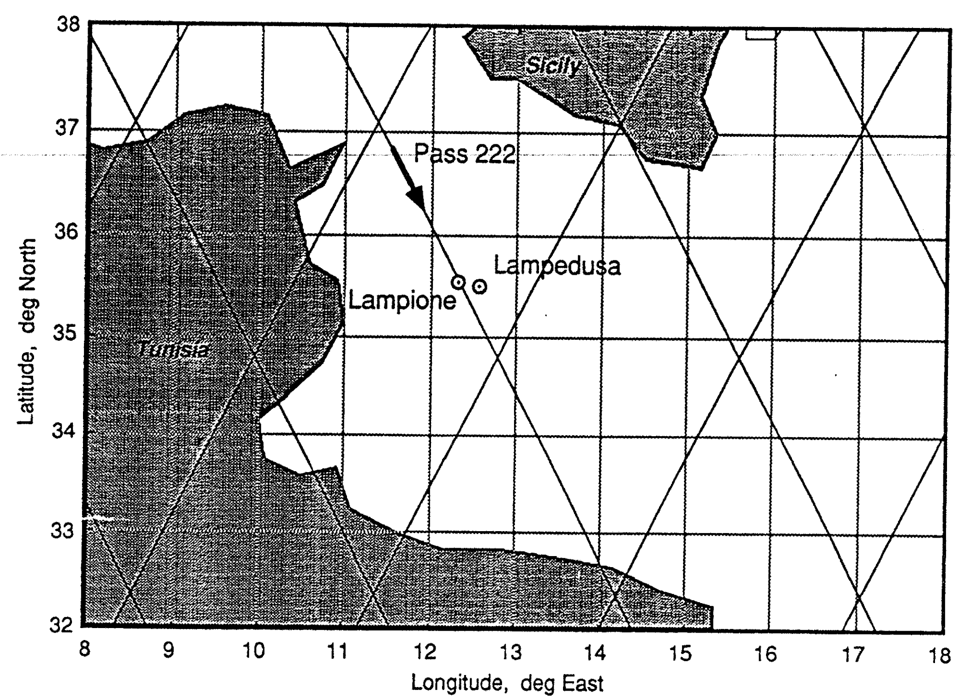
Semimajor axis:	7714 km
Altitude (mean):	1335 km
Eccentricity:	0.0
Inclination:	66 degrees
Orbit repeat cycle	127 orbits



TOPEX/POSEIDON ground track
Figure 5-1



Ground-track in the vicinity of the Pt. Conception calibration site
Figure 5-2



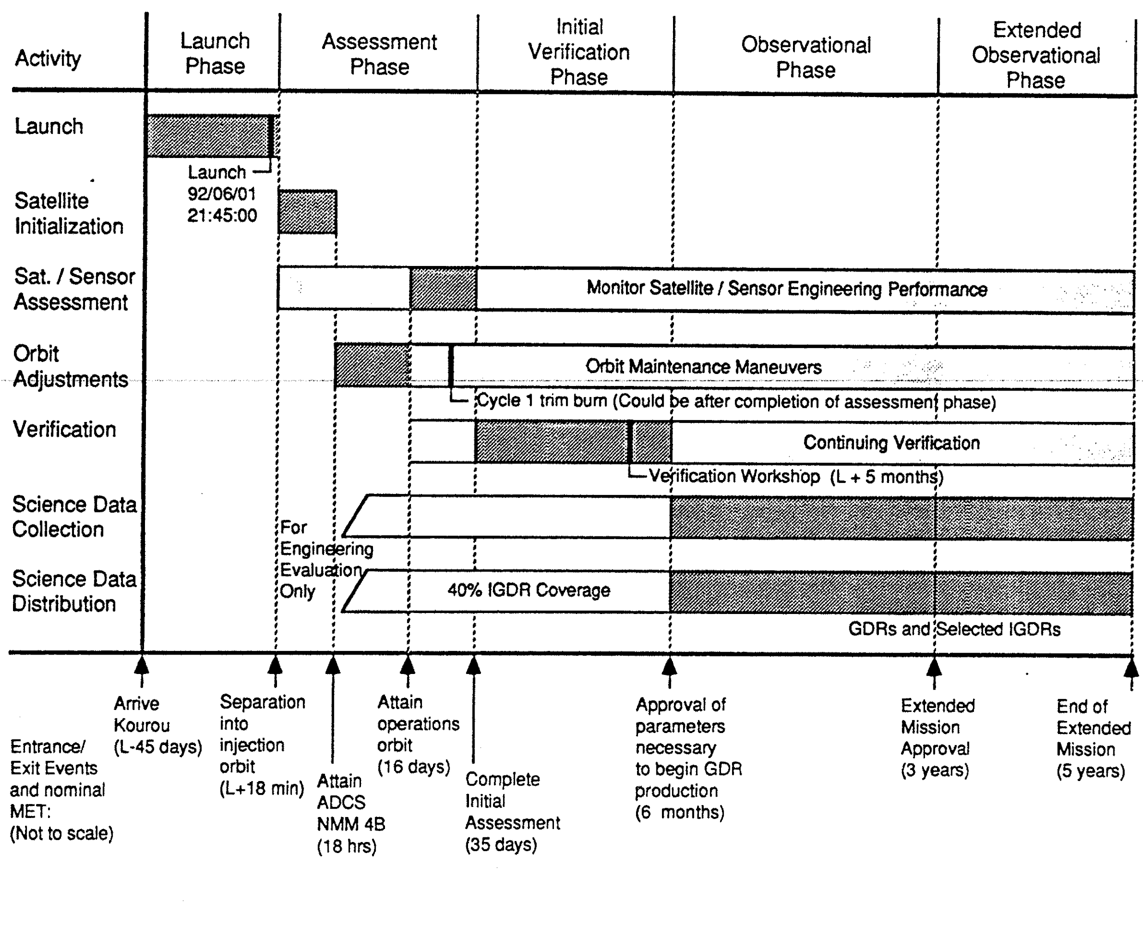
Ground-track in the vicinity of the Lampedusa calibration site
Figure 5-3

6) Mission time line

The TOPEX/POSEIDON mission has been designed for a 3-year life, but with enough margin of expendable resources to allow extension of the duration to 5 years.

The mission is divided into phases during which different kinds of mission operations are being conducted. The First Phase is the Launch Phase which begins several weeks before launch (presently scheduled for June 1992) and ends at the injection of the satellite into a bias orbit very near the mission orbit. The Second Phase consists of a 30-day Assessment Phase during which all systems are deployed and activated and engineering assessment is made of the satellite bus systems and sensor systems. A Data Verification Phase begins at sensor turn-on during the Assessment Phase and continues until 6 months after launch.

The Operation Phase begins 6 months after launch and extends to the end-of-mission, nominally launch plus 3 years. Data processing will continue for 3 months past the end-of-mission to complete processing of the acquired data [5]. Figure 5-1 graphs the TOPEX/POSEIDON mission timeline.



TOPEX/POSEIDON mission timeline
Figure 6-1

7) References

[1] R.H. Parrish, "Laser Retroreflector Array Interface Description", Jet Propulsion Laboratory document 633-461, March 1985.

[2] J.A. Schwartz, "TOPEX retroreflector link analysis model development", JPL-IOM 331-86.6-129, 3 April 1986.

[3] P.O. Minott, "Reader's guide to the "RETRO" program output", Publication X-722-76-267, Goddard Space Flight Center, September 1976.

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[5] A. Murdoch, "Crustal Dynamics Satellite Laser Ranging Network Preliminary TOPEX/POSEIDON Laser Network Support Plan", Goddard Space Flight Center document CDSLR-03-0002, December 1989.