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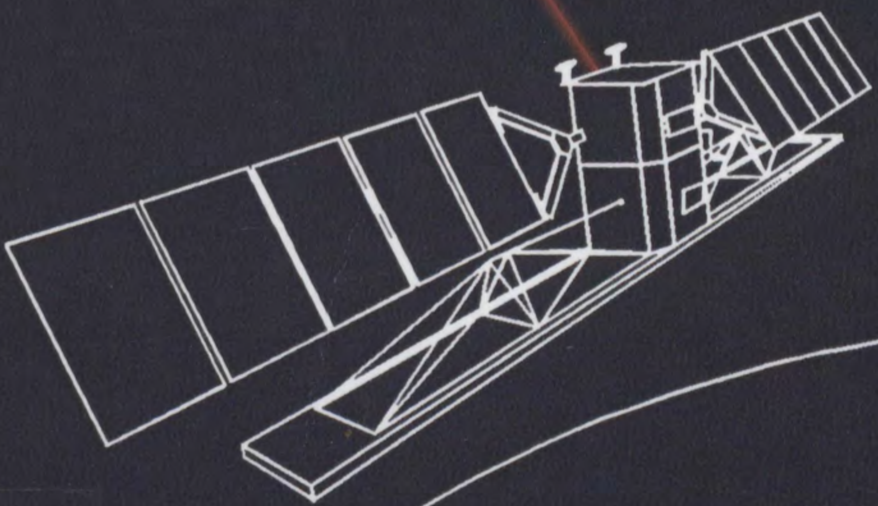
Optical Intersatellite Link System Study

Volume 2
Final Report
Appendices

Prepared for the
Department of Communications
by
Spar Aerospace Limited



SPAR

COVER: The front cover shows a remote sensing satellite relaying data via an optical crosslink to a geostationary data relay satellite and then to a data acquisition facility on the far side of the earth

Spar Program 3670-F

Optical Intersatellite Link System Study

Volume 2 - Appendices

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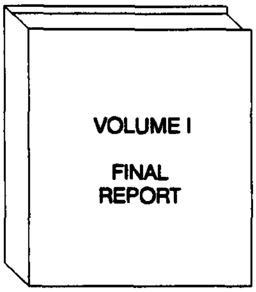

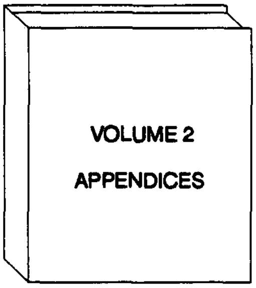

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List of Acronyms

A

AGC Automatic Gain Control
AlGaAs Aluminum Gallium Arsenide
AM Amplitude Modulation
APD Avalanche Photodiode
ASIC Application Specific Integrated Circuit
ASK Amplitude-Shift Keying
ATSG Advanced Technology Systems Group

B

BER Bit Error Rate

C

CAD Computer-Aided Design
CAE Computer-Aided Engineering
CASE Computer Aided Software Engineering
CDH Constricted Double-Heterostructure
cm centimeter
CO_2 Carbon Dioxide
CP Circular Polarization
CRC Communications Research Centre
CSA Canadian Space Agency
CTS Communications Technology Satellite

D

dB Decibel
dBW Decibels relative to 1 watt
DND Department of National Defence
DOC Department of Communications
DREV Defence Research Establishment Valcartier

E

e.g. *exampli gratia* (for example)
EHF Extremely High Frequency
EMP Electromagnetic Pulse
EOSD Electro-Optical Systems Division
ESA European Space Agency

F

FM Frequency Modulation
FSK Frequency-Shift Keying

G

Gbps gigabit per second
GEO Geostationary Orbit
GHz Gigahertz

H

HeNe Helium Neon
HF High Frequency

I

I.e. *id est* (that is)
IF Intermediate Frequency
InGaAs Indiuym Gallium Arsenide
InGaAsP Indiuym Gallium Arsenide Phosphide

J

J Joule

K

kbps kilobit per second
km kilometer

L

LD Laser Diode
LED Light Emitting Diode
LEO Low Earth Orbit
LO Local Oscillator
LOC Large Optical Cavity

M

M Millions
Mbps Megabit per second

MCS	Mission Control System
MHz	Megahertz
MMIC	Monolithic Microwave Integrated Circuit
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
MSAT	Mobile Satellite

N

NASA	National Aeronautics and Space Administration
Nd	Neodinium
NEA	Noise Equivalent Angle
nm	nanometer
nsec	nanosecond

O

OISL	Optical Inter-Satellite Link
OOK	On-Off Keying

P

PC	Printed Circuit
PCB	Printed Circuit Board
PCM	Pulse-Code Modulation
Ph.D.	Doctorate Degree
PIN	Positive-Intrinsic-Negative

Q

QA	Quality Assurance

R

R&D	Research and Development

S

s	second
SAR	Synthetic Aperture Radar
SARSAT	Search and Rescue Satellite Assisted Tracking
SCOE	Subsystem Checkout Equipment
SSOC	Solid State Optical Consortium

T

TEM	Transverse Electromagnetic
TT&C	Telemetry Tracking and Command
TV	Television

U

U.S.	United States

V

VSAT	Very Small Aperture Terminal

Y

YAG	Yttrium Aluminum Garnet

APPENDIX A

OPERATIONAL PARAMETERS OVER A 24 HOUR PERIOD FOR GEO-GEO, GEO-INCLINED AND GEO-LEO LINKS

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A.1.0 GEOSTATIONARY TO GEOSTATIONARY

Orbital parameters for the GEO to GEO link are presented in this section. Since the spacing is fixed the range is constant between the two satellites and depends only on the angle between them as shown in Figure A.1-1. The range rate is zero and since the pointing angles are fixed the angular rates are also zero. However, since the satellites are in motion the terminals must point ahead in order to close the loop with the other terminals. The point ahead angle varies with the angle between the two satellites as shown in Figure A.1-2.

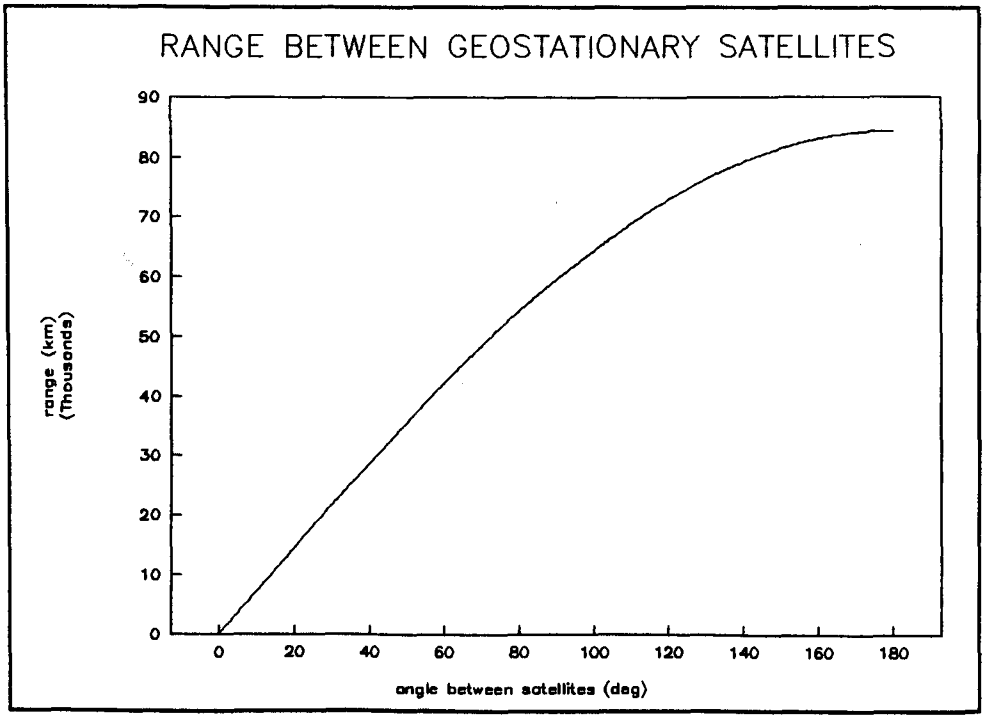


Figure A.1-1 The Range Between Two Satellites in Geostationary Orbit as a Function of the Angle Between Them

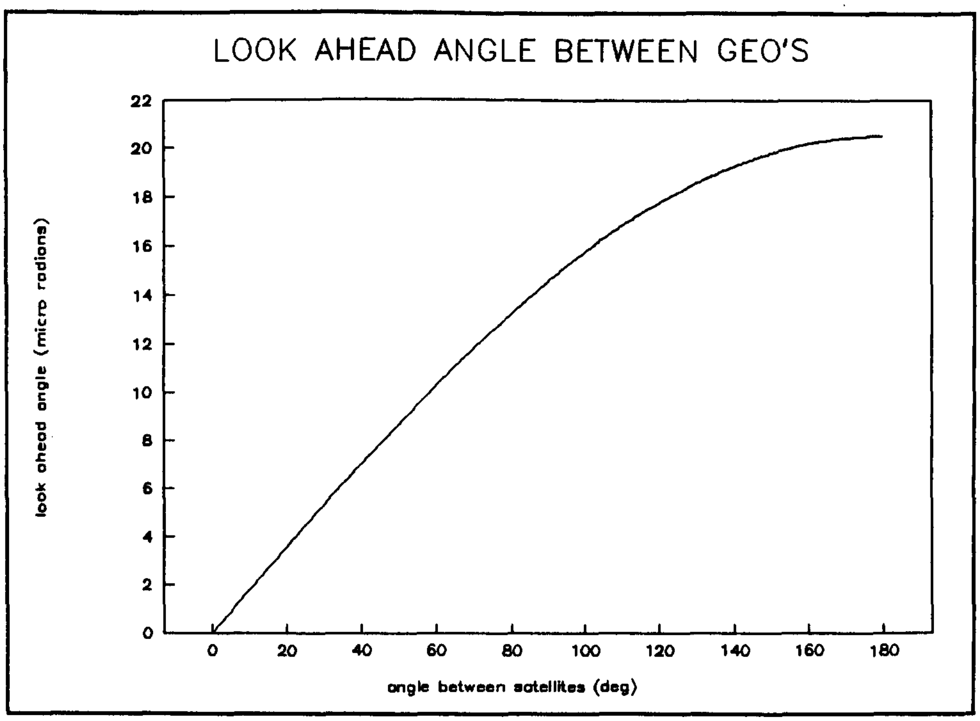


Figure A.1-2 The Look Ahead Angle for a Link Between Satellites in Geostationary Orbit as a Function of the Angle Between Them

A.2.0 GEOSTATIONARY TO INCLINED GEOSYNCHRONOUS LINKS

A.2.1 Molniya Type Orbit

The molniya orbit is a 12 hour highly elliptic geosynchronous inclined orbit which can be used for communications for a period of eight hours centered on apogee. Parameters for the orbit are given in Table 2.0-1. During the 24 hour daily cycle, there are two apogees located 180° apart in earth coordinates. Figure A.2.1-1 shows the ground trace of a molniya orbit with an apogee at -90 deg. longitude.

An intersatellite link between the molniya orbit and a geostationary orbit can occur during either of the periods around apogee. Figure A.2.1-2 shows the range, over a 24 hour period, between the molniya orbit and a geostationary satellite at -90 deg. longitude. The location of the two apogees and the limits of the 8 hour operating period are identified. The first apogee is the one at -90 deg. longitude which is the location of the cooperating geostationary satellite. As expected, the range to the first apogee is much less than that to the second apogee.

Figure A.2.1-3 shows the range rate for the link to the geostationary satellite. The range rate is very similar for the two apogees, with a maximum of less than 2 km/sec. over the eight hour period.

Figure A2.2.1-4a gives the angles in azimuth and elevation on the geostationary satellite required to point at the molniya satellite. Figure A.2.1-4b gives the time line of azimuth and Figure A.2.1-4c the time line for elevation over a 24 hour period.

Figure A.2.1-5a, b and c are similar for azimuth and elevation on the molniya type satellite.

The rate of change of angle on the geostationary satellite is given in Figure A.2.1-6 and on the molniya satellite in Figure A.2.1-7.

The look ahead angle over a 24 hour period is given in Figure A.2.1-8 for the geostationary satellite and in Figure A.2.1-9 for the molniya satellite.

Figures A.2.1-10 to A.2.1-17 present similar data for the same molniya orbit but for a geostationary satellite of zero degrees longitude while Figures A.2.1-18 to A.2.1-25 are for a geostationary satellite at +90 degrees longitude.

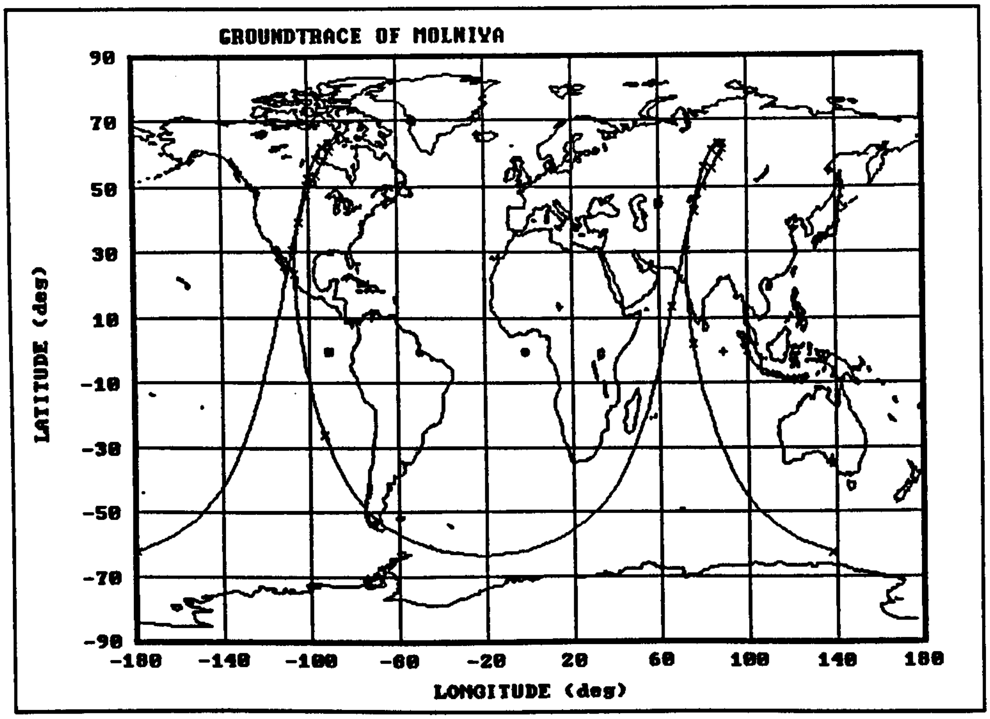


Figure A.2.1-1 *Ground Trace of the Molniya Type Orbit with the First Apogee at -90° and the Second Apogee at +90° Longitude*

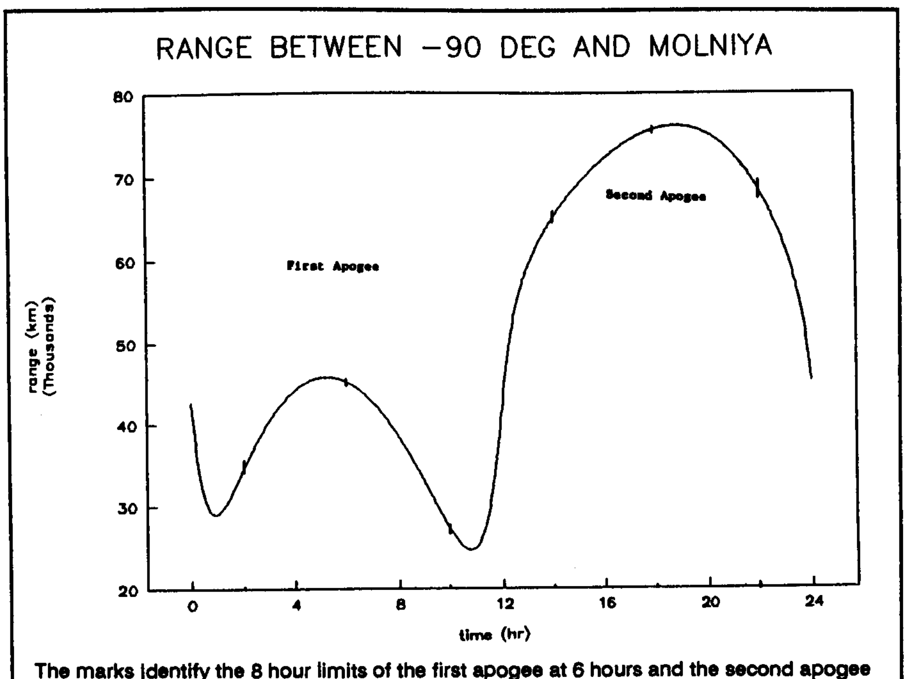
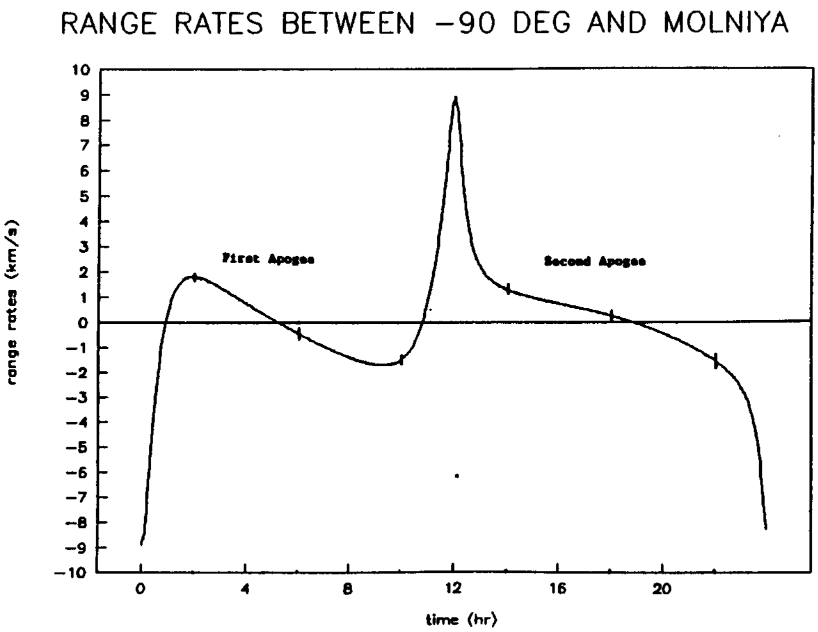


Figure A.2.1-2 *Range Between the Molniya Type Satellite and a Geostationary Satellite at -90° Longitude*



The marks identify the 8 hour limits of the first apogee at 6 hours and the second apogee at 18 hours

Figure A.2.1-3 The Range Rate Between the Molniya Type Satellite and a Geostationary Satellite at -90° Longitude

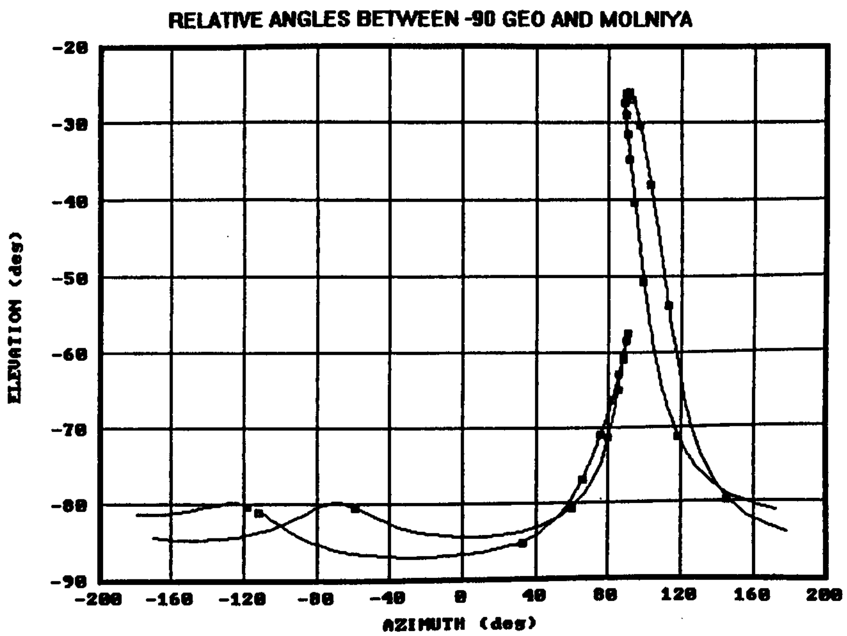


Figure A.2.1-4a Pointing Angles over a 24 Hour Period of the Terminal on the Geostationary Satellite at -90o Longitude Required to Point at the Molniya Type Satellite

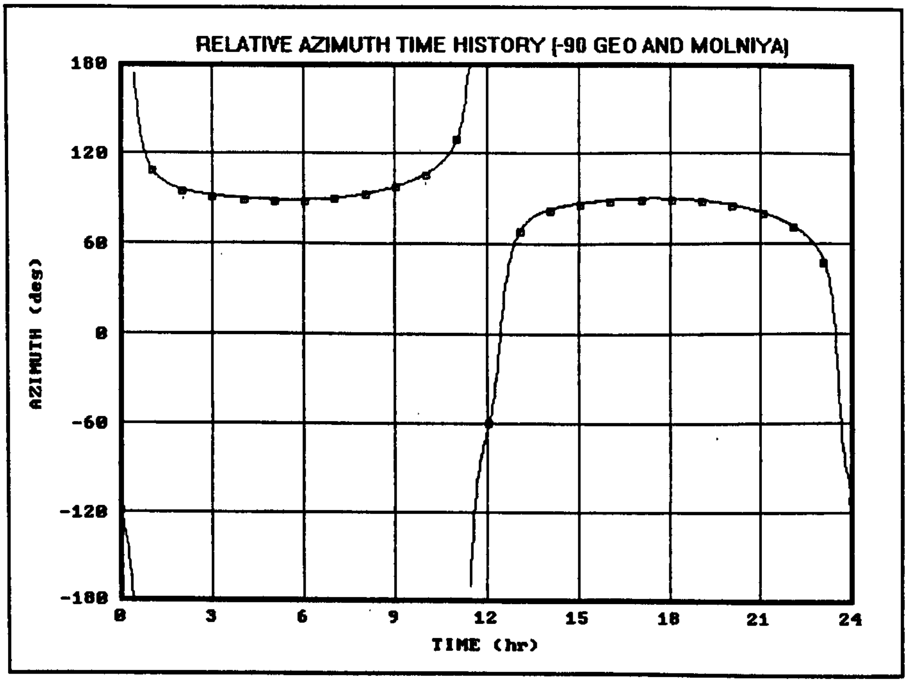


Figure A.2.1-4b *Azimuth Angle Measured from the Velocity Vector, on the Geostationary Satellite at -90 Degrees Longitude Required to Point at the Molniya Type Satellite*

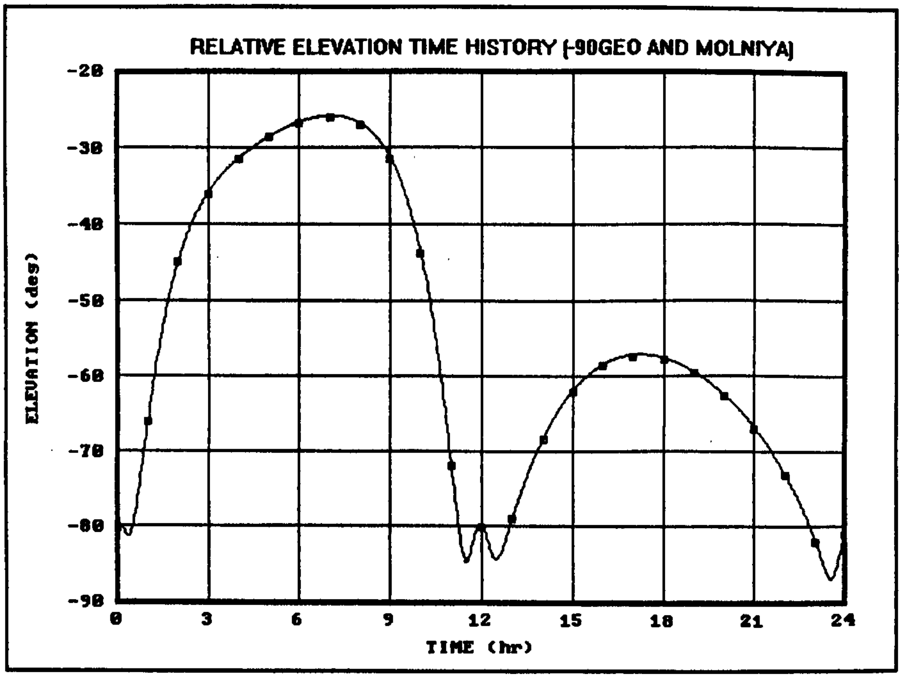


Figure A.2.1-4c *Elevation Angle on the Geostationary Satellite at -90 Degrees Longitude Required to Point at the Molniya Type Satellite*

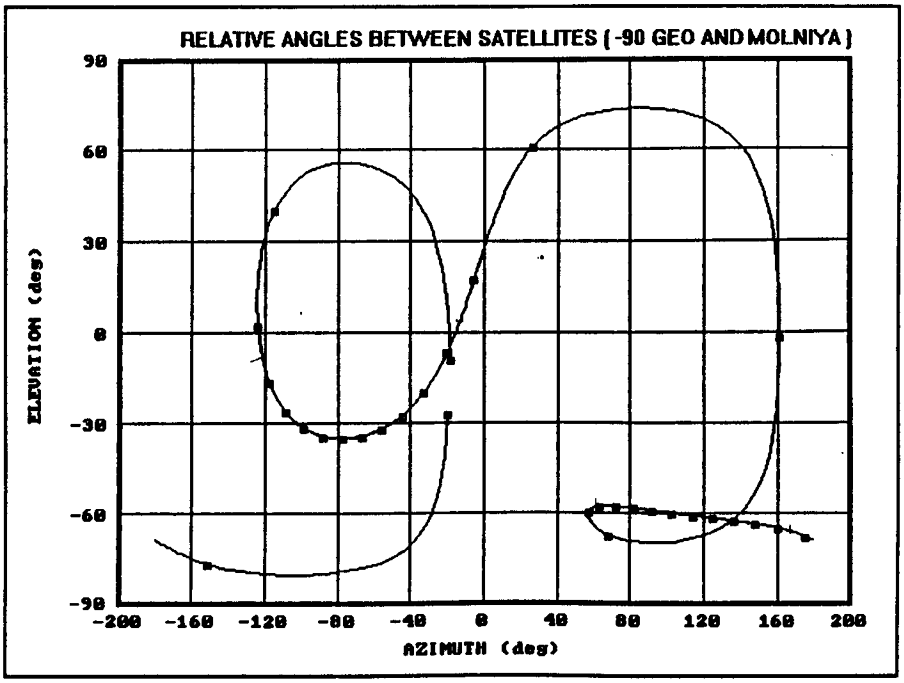


Figure A.2.1-5a *Pointing Angles over a 24 Hour Period of the Terminal on the Molniya Type Satellite Required to Point at a Geostationary Satellite at -90° Longitude*

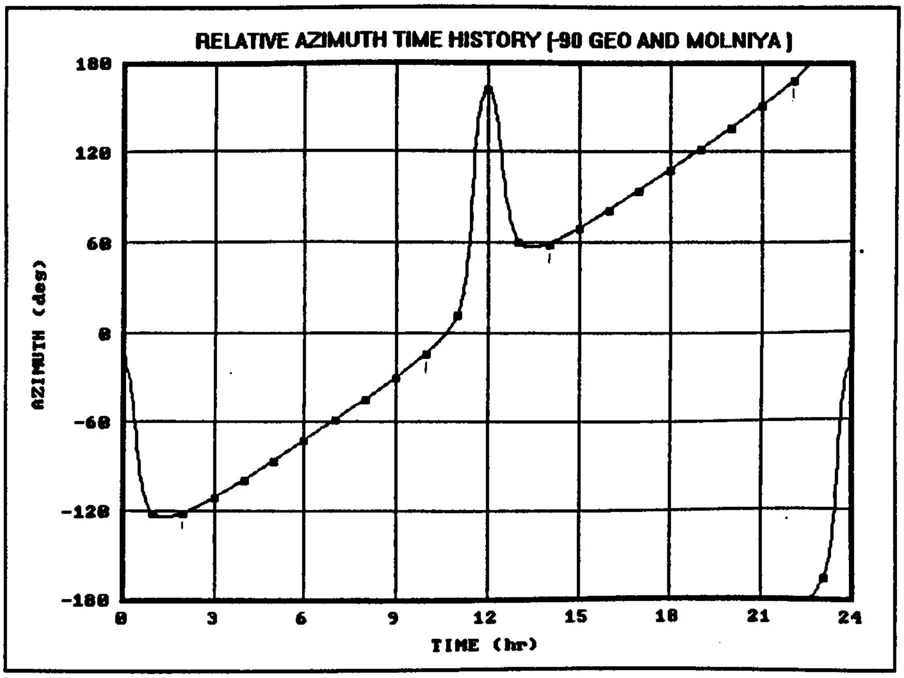


Figure A.2.1-5b *Aximuth Angle on a Molniya Type Satellite, as Measured from the Velocity Vector, Required to Point at a Geostationary Satellite at -90° Longitude*

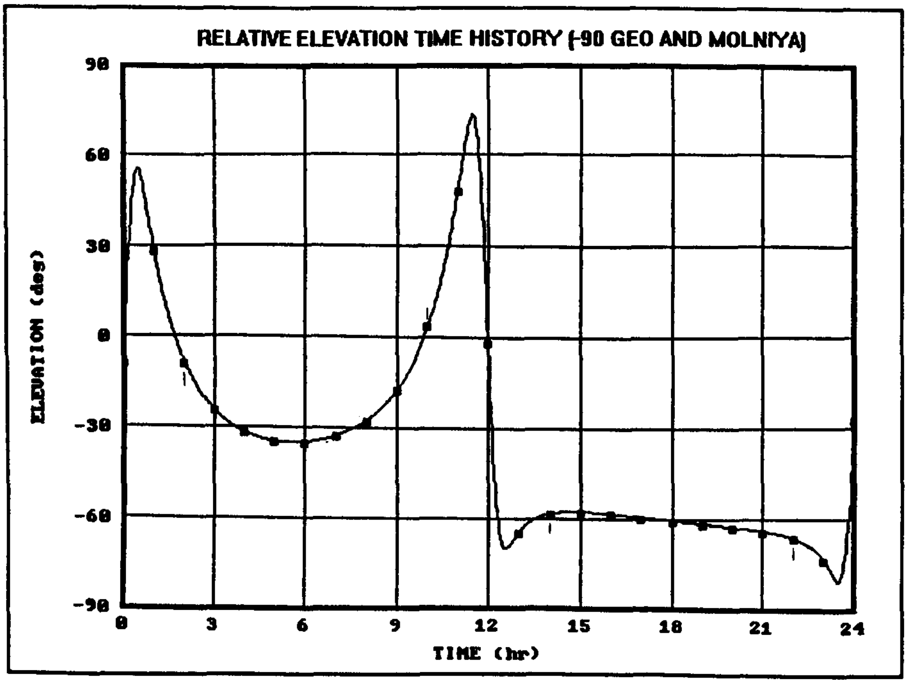


Figure A.2.1-5c *Elevation Angle on a Molniya Type Satellite Required to Point at a Geostationary Satellite at -90 Deg. Longitude*

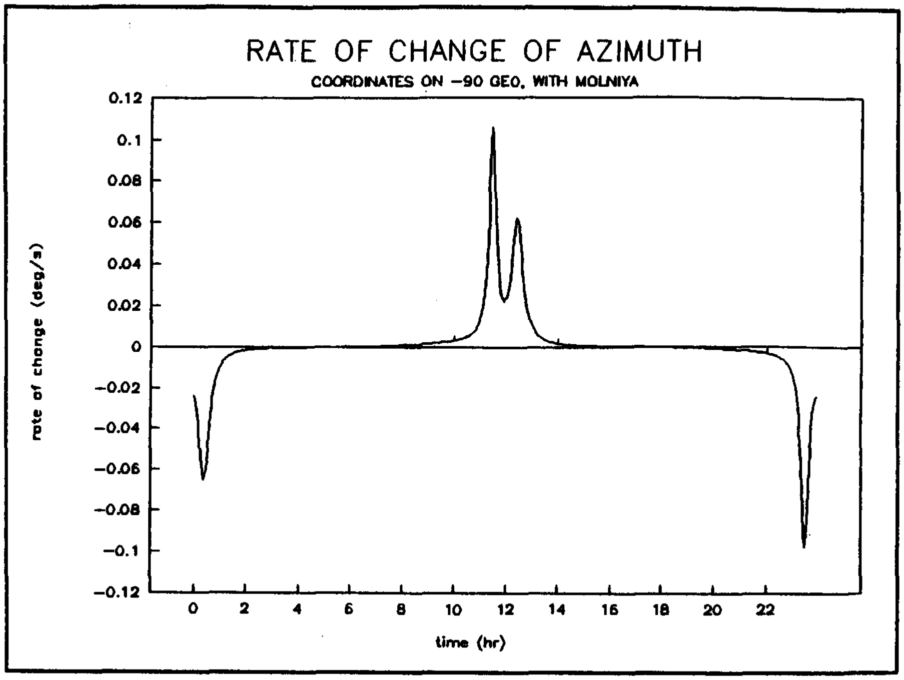


Figure A.2.1-6a *Rate of Change of Azimuth for the Terminal on the Geostationary Satellite at -90° Longitude when Pointing at the Molniya Type Satellite*

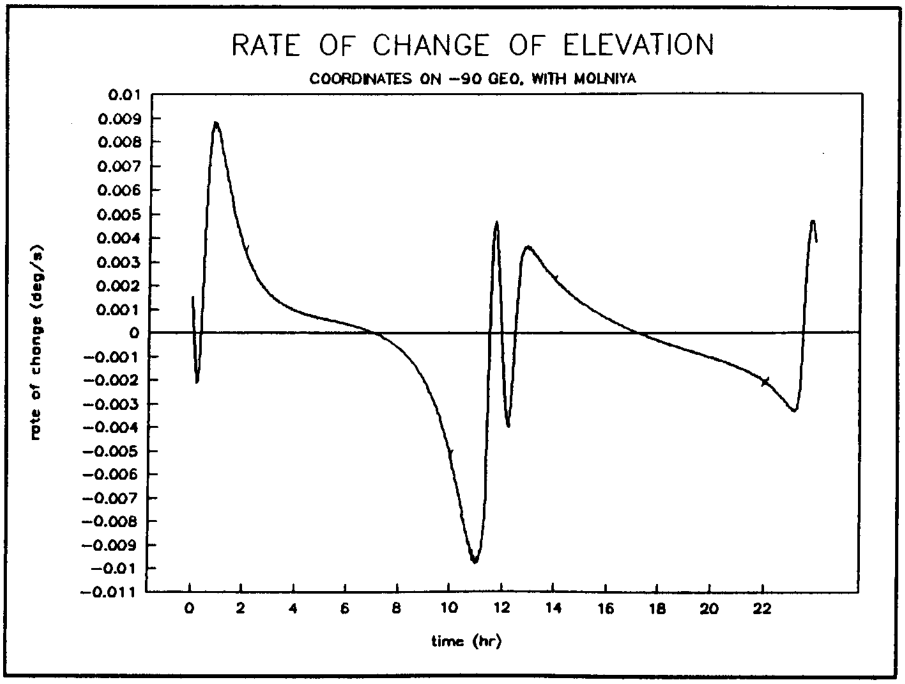


Figure A.2.1-6b *Rate of Change of Elevation for the Terminal on the Geostationary Satellite at -90 Degrees Longitude when Pointing at a Molniya Type Satellite*

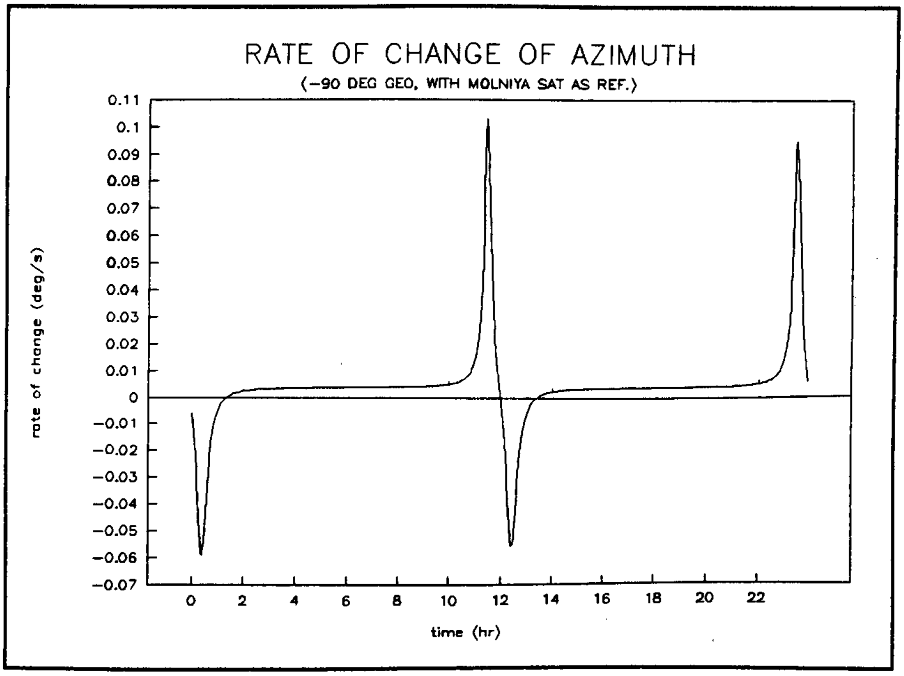


Figure A.2.1-7a *Rate of Change of Azimuth of the Terminal on the Molniya Type Satellite when Pointing at the Geostationary Satellite at -90° Longitude*

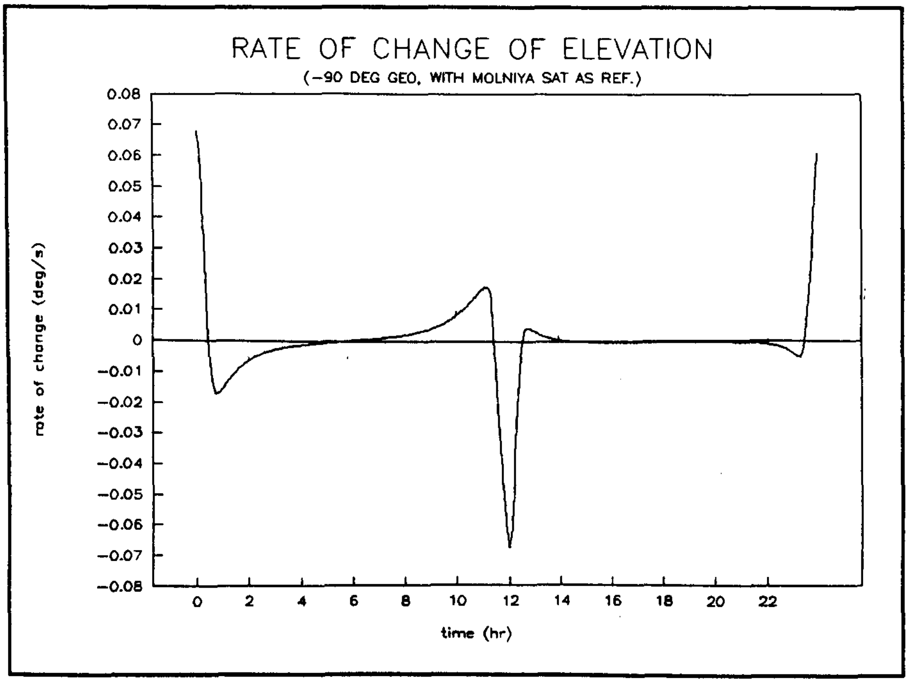


Figure A.2.1-7b Rate of Change of Elevation of the Terminal on a Molniya Type Satellite when Pointing of a Geostationary Satellite at 90 Deg. Longitude

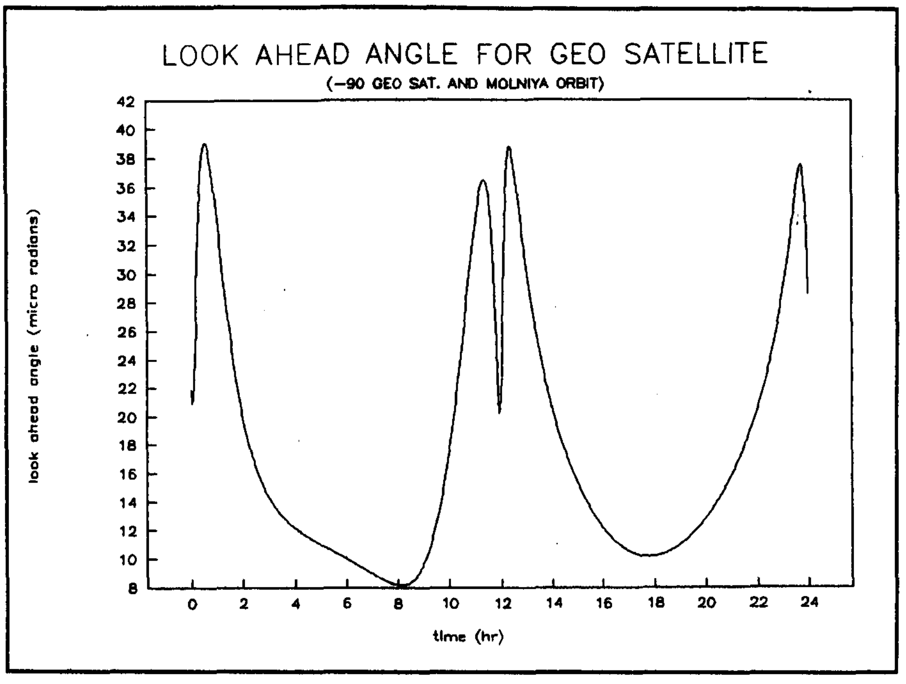


Figure A.2.1-8 Look Ahead Angle over a 24 Hour Period for the Terminal on the Geostationary Satellite at -90° Longitude when Pointing at the Molniya Type Satellite

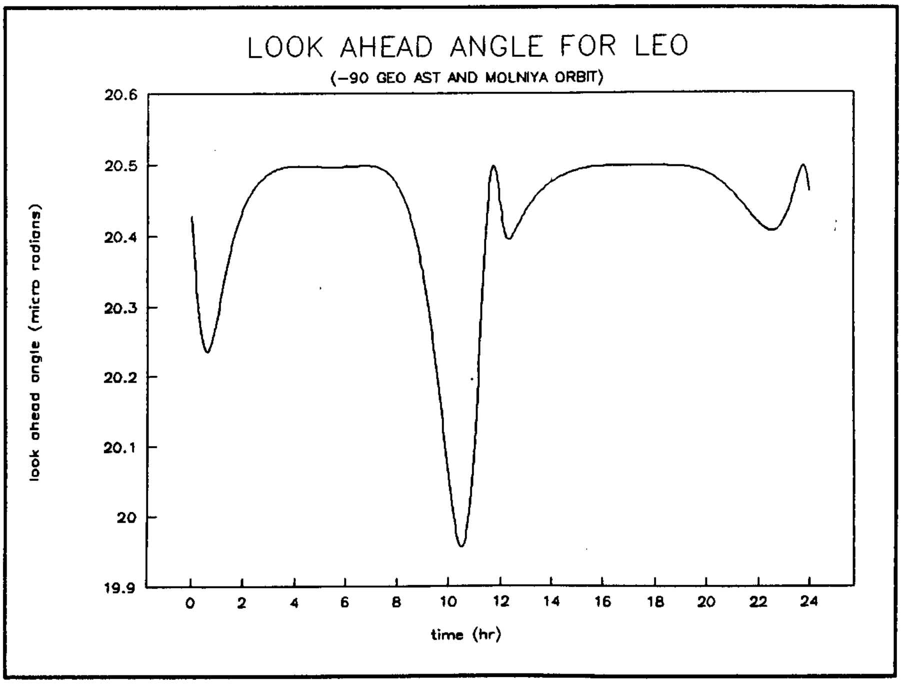
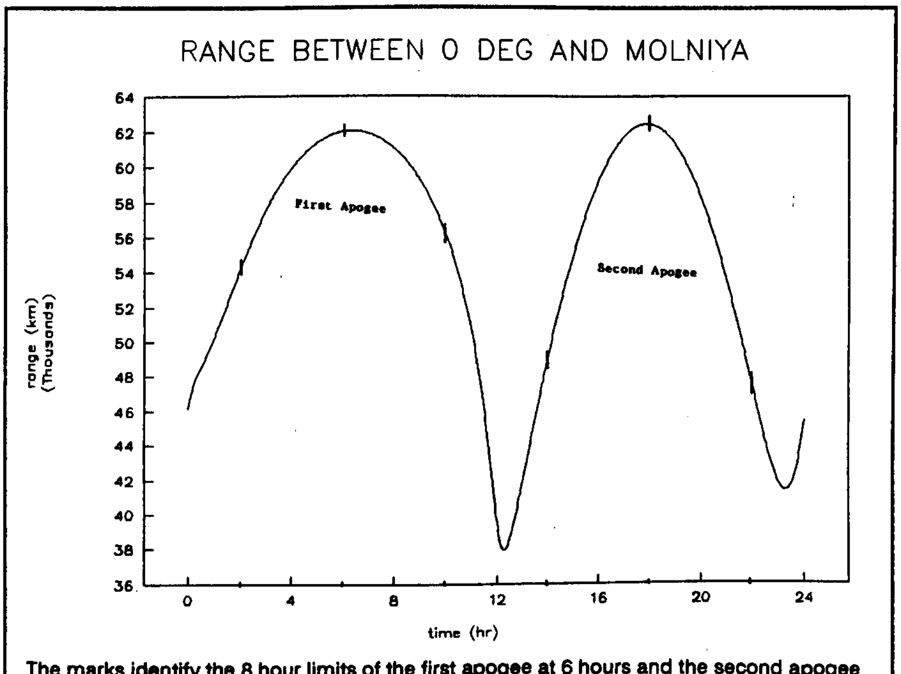
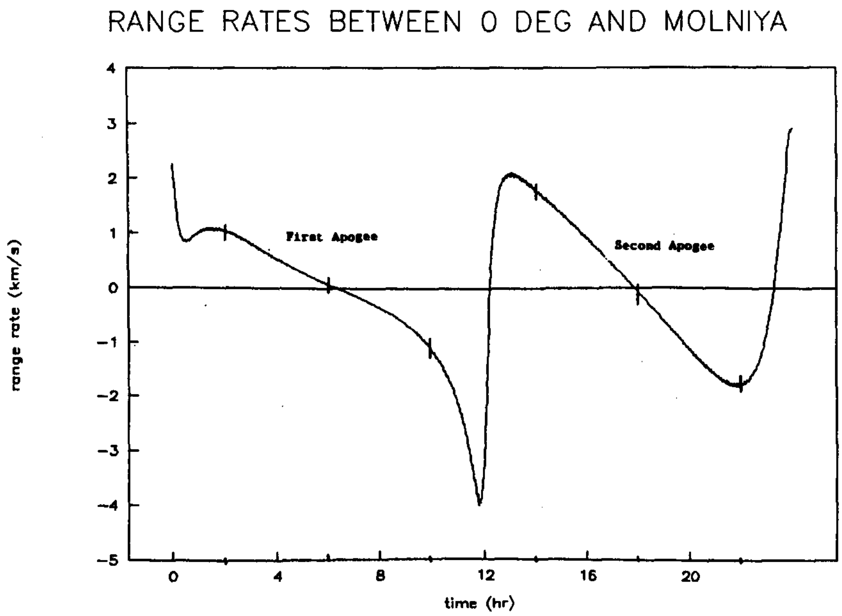


Figure A.2.1-9 Look Ahead Angle over a 24 Hour Period for the Terminal on the Molniya Type Satellite when Pointing at the Geostationary Satellite at -90° Longitude



The marks identify the 8 hour limits of the first apogee at 6 hours and the second apogee at 18 hours

Figure A.2.1-10 Range Between the Molniya Type Satellite and a Geostationary Satellite at Zero Degree Longitude



The marks identify the 8 hour limits of the first apogee at 6 hours and the second apogee at 18 hours

Figure A.2.1-11 *The Range Rate Between the Molniya Type Satellite and a Geostationary Satellite at Zero Degree Longitude*

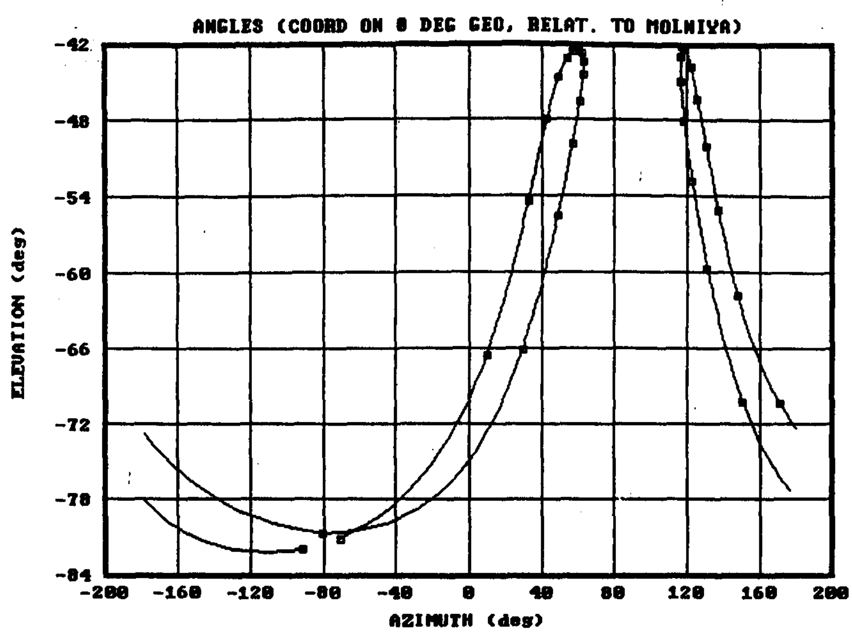


Figure A.2.1-12a *Pointing Angle over a 24 Hour Period of the Terminal on the Geostationary Satellite at Zero Deg. Longitude Required to Point at the Molniya Type Satellite*

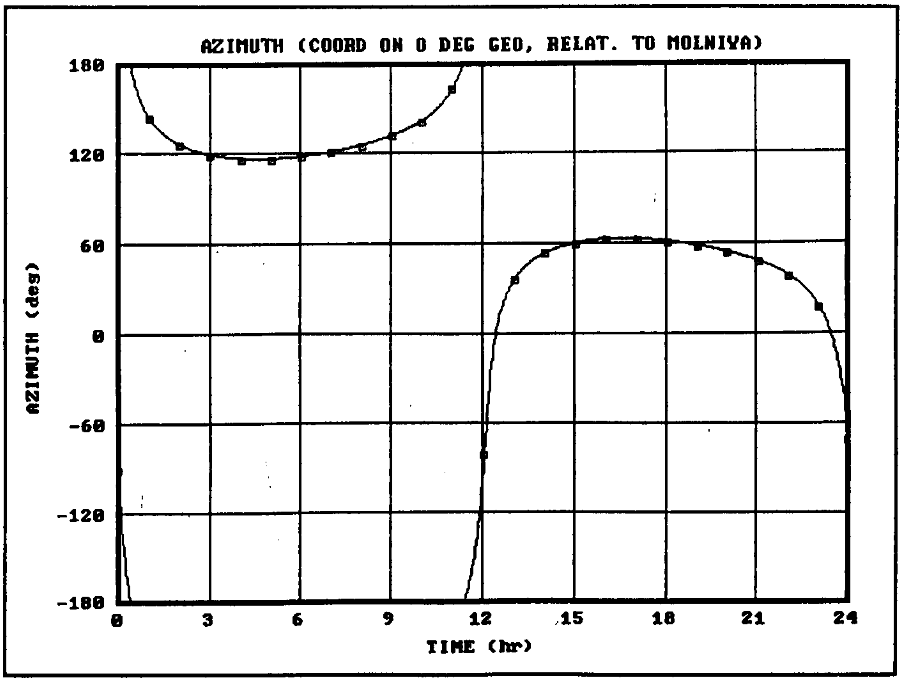


Figure A.2.1-12b *Azimuth Angle Measured from the Velocity Vector on the Geostationary Satellite at Zero Degree Longitude Required to Point at the Molniya Type Satellite*

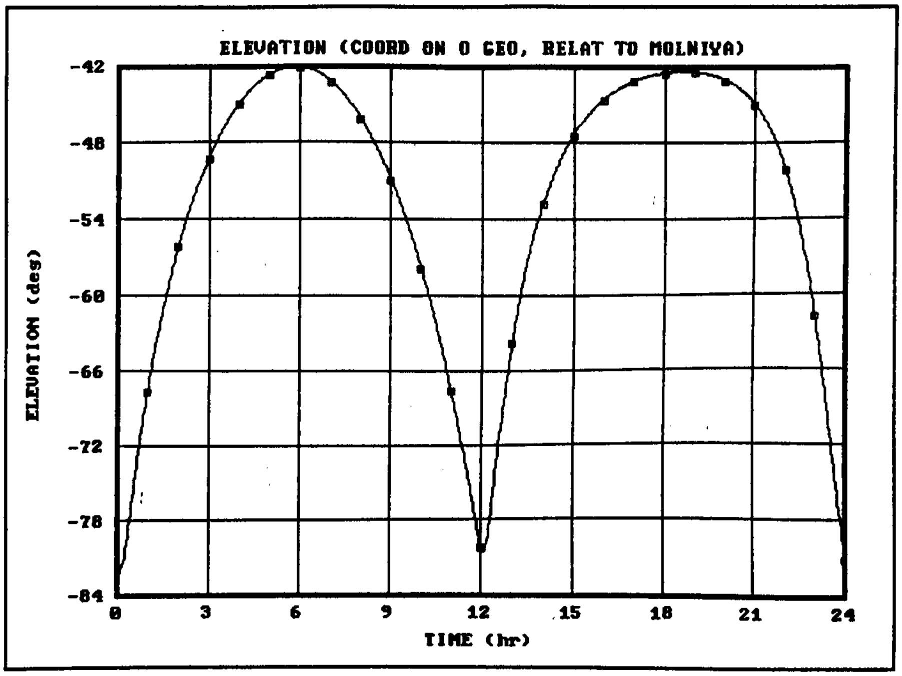


Figure A.2.1-12c *Elevation Angle on the Geostationary Satellite at Zero Degrees Longitude Required to Point at the Molniya Type Satellite*

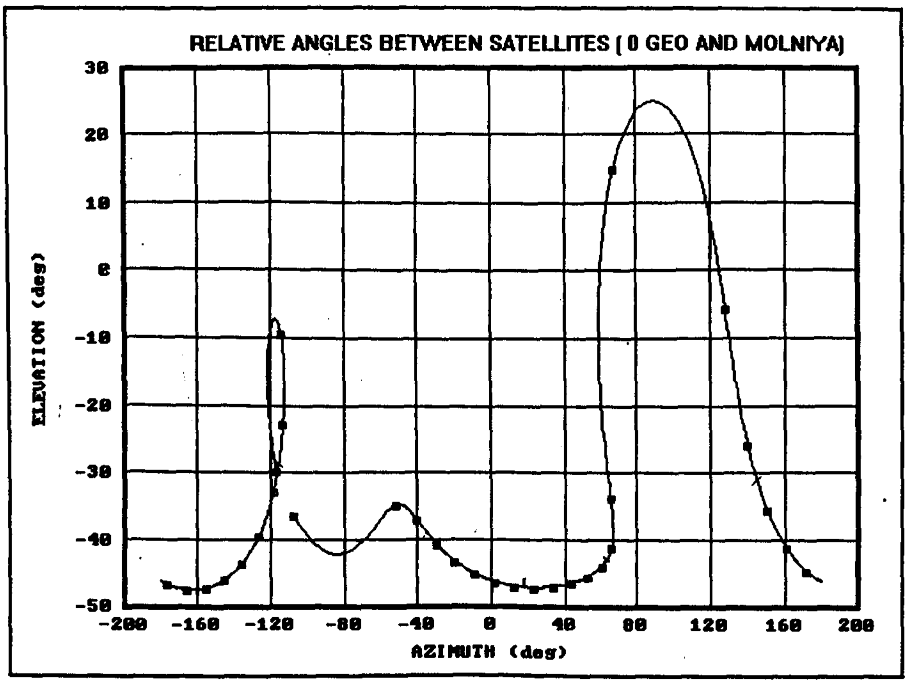


Figure A.2.1-13a Pointing Angle over a 24 Hour Period of the Terminal on the Molniya Type Satellite Required to Point at a Geostationary Satellite at Zero Degree Longitude

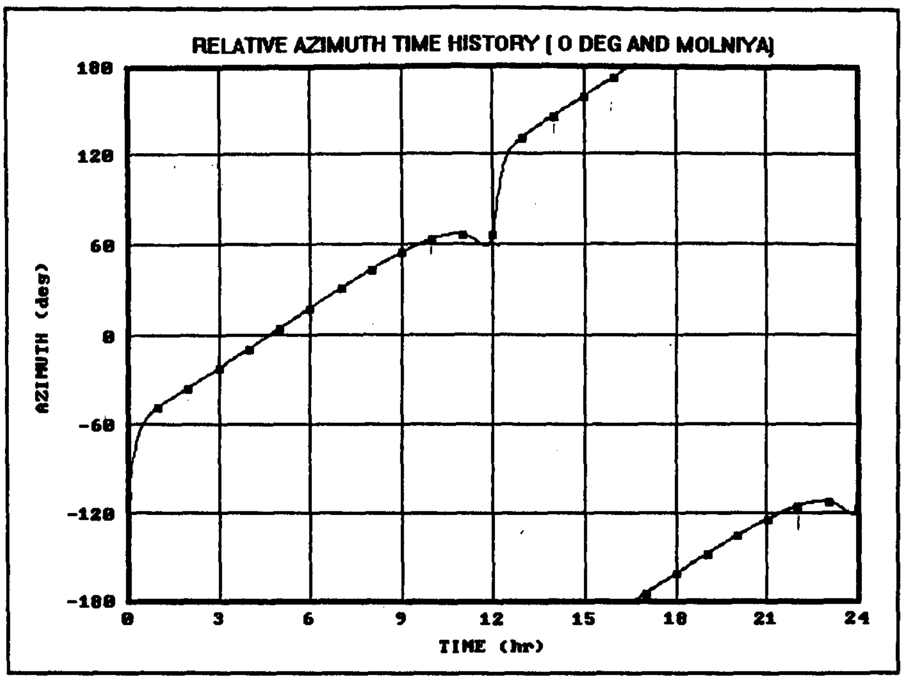


Figure A.2.1-13b Azimuth Angle on a Molniya Type Satellite, as Measured from the Velocity Vector, Required to Point at a Geostationary Satellite at Zero Degree Longitude

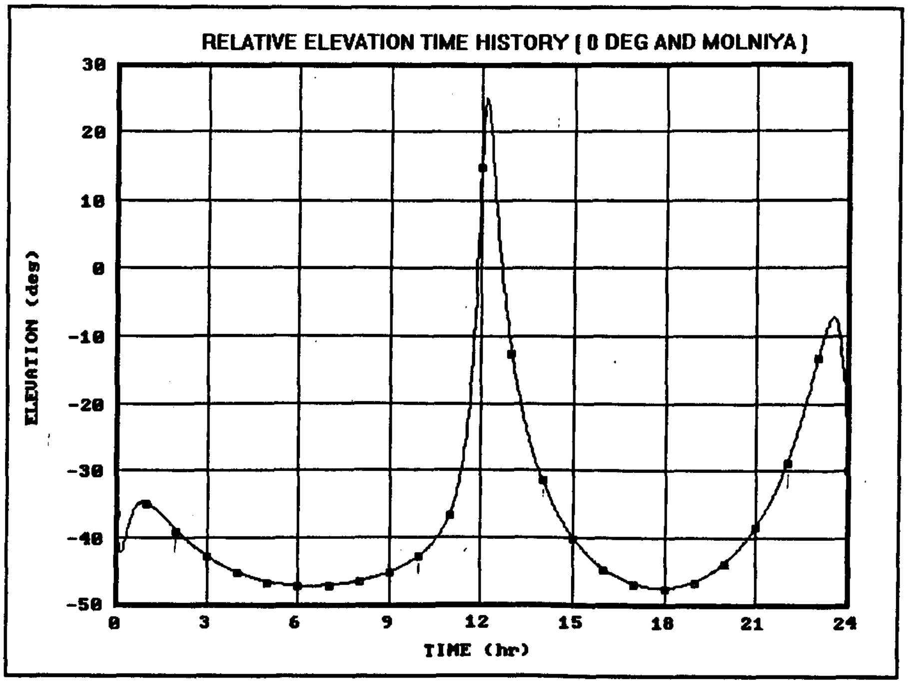


Figure A.2.1-13c *Elevation Angle on a Molniya Type Satellite Required to Point at a Geostationary Satellite at Zero Degree Longitude*

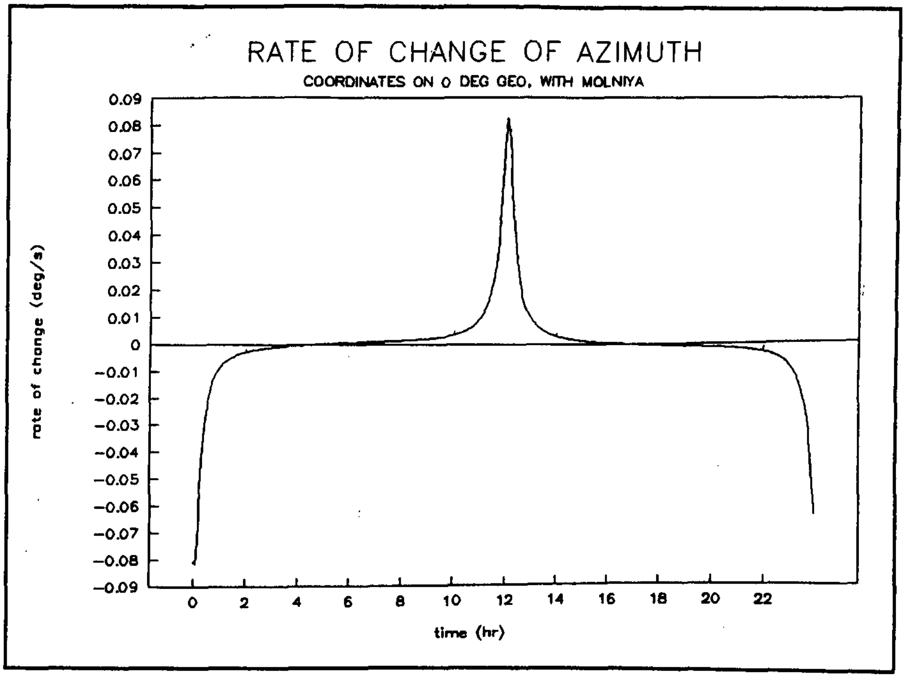


Figure A.2.1-14a *Rate of Change of Azimuth for the Terminal on the Geostationary Satellite at Zero Degree Longitude when Pointing at the Molniya Type Satellite*

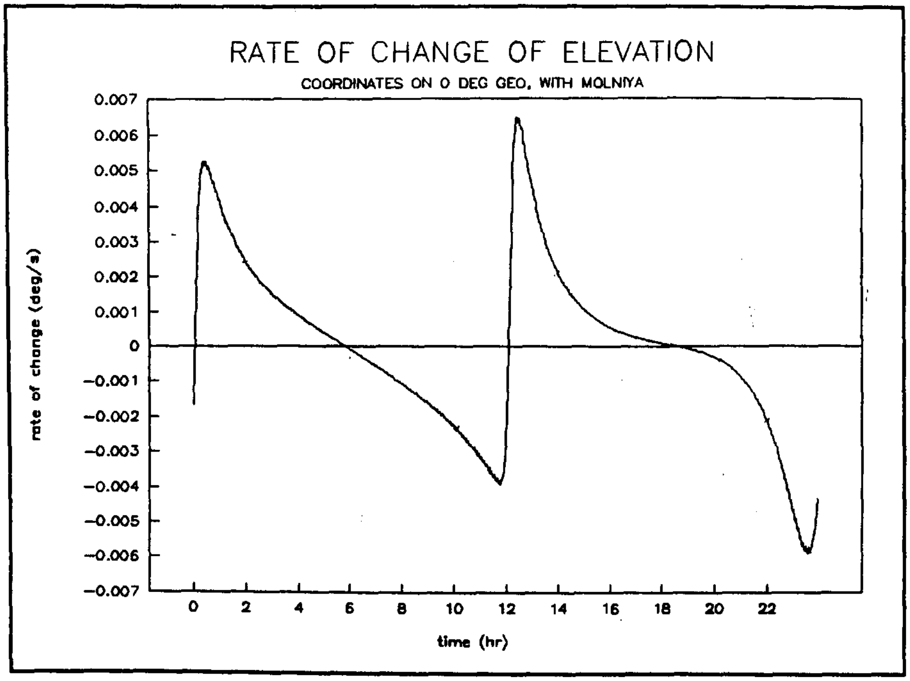


Figure A.2.1-14b *Rate of Change of Elevation for the Terminal on the Geostationary Satellite at Zero Degrees Longitude when Pointing at a Molniya Type Satellite*

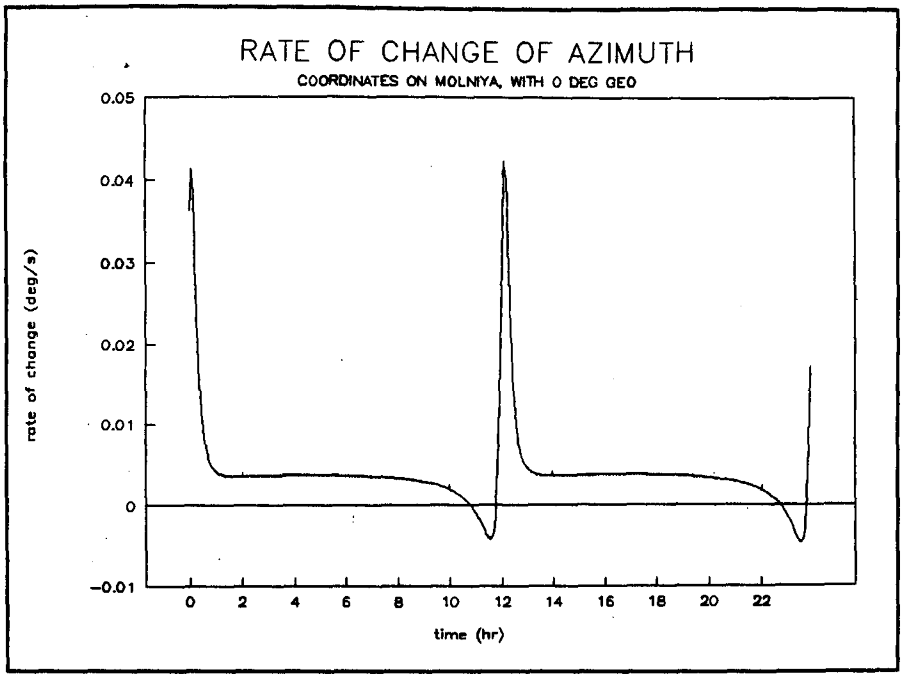


Figure A.2.1-15a *Rate of Change of Azimuth for the Terminal on the Molniya Type Satellite when Pointing at the Geostationary Satellite at Zero Degree Longitude*

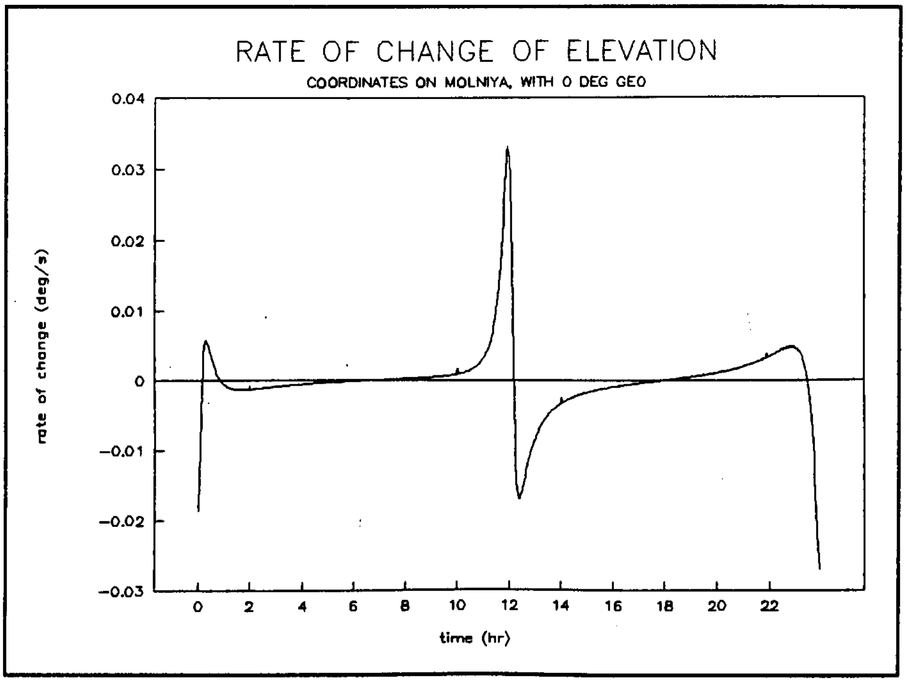


Figure A.2.1-15b Rate of Change of Elevation for the Terminal on the Molniya Type Satellite when Pointing at a Geostationary Satellite at Zero Degrees Longitude

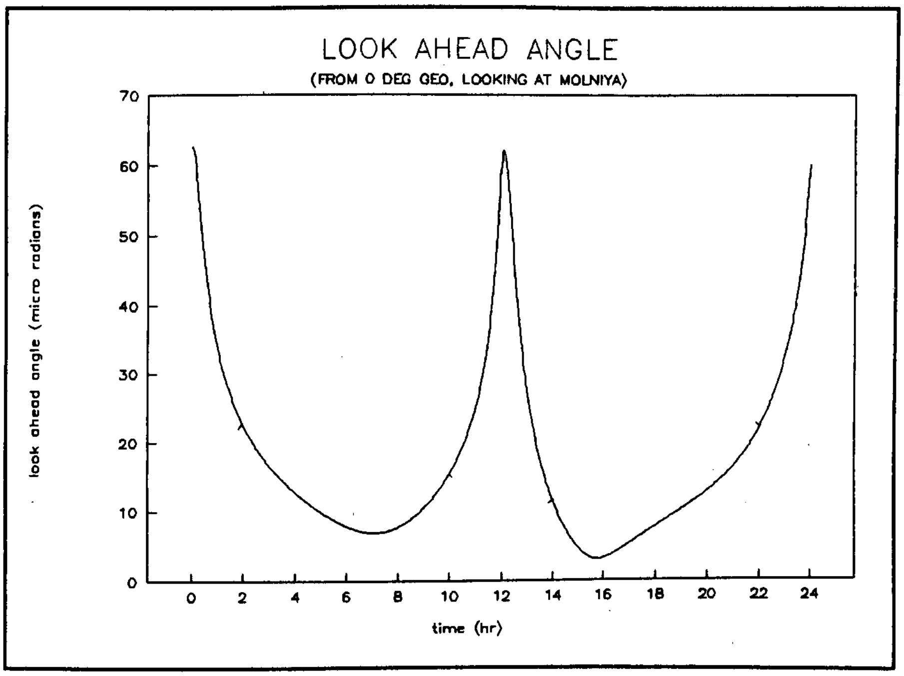


Figure A.2.1-16 Look Ahead Angle over a 24 Hour Period for the Terminal on the Geostationary Satellite at Zero Degree Longitude when Pointing at the Molniya Type Satellite

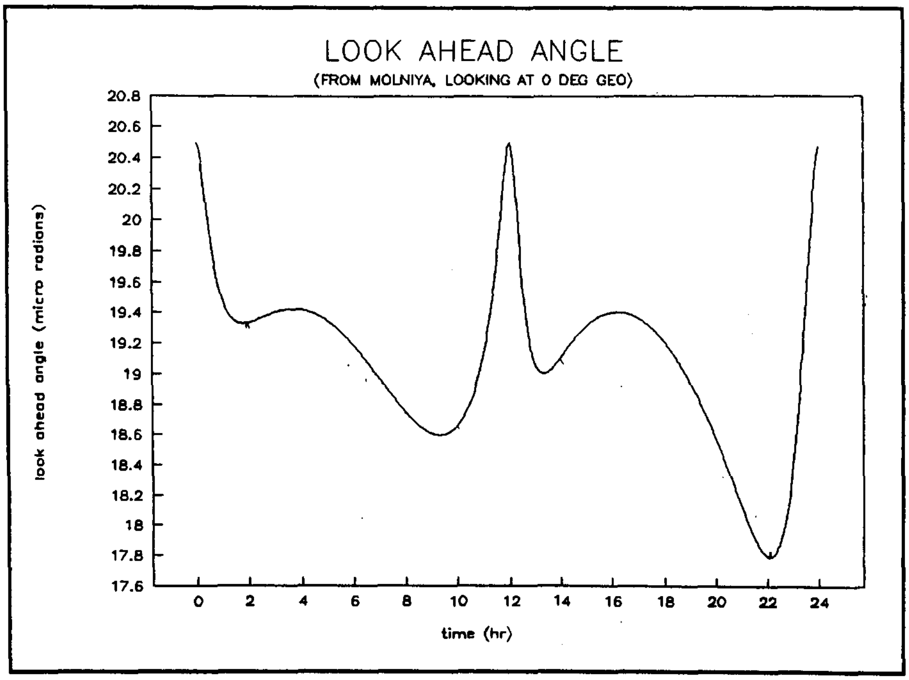
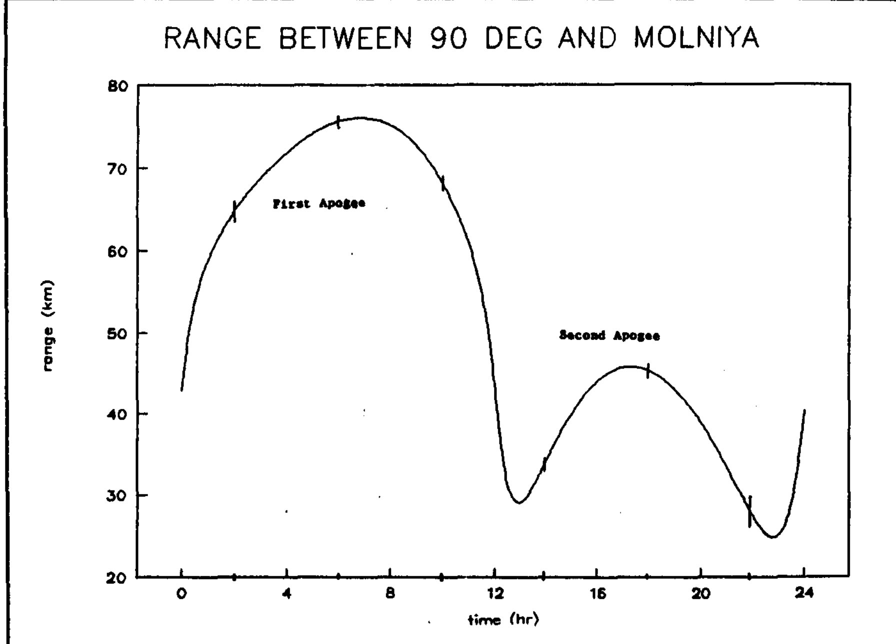
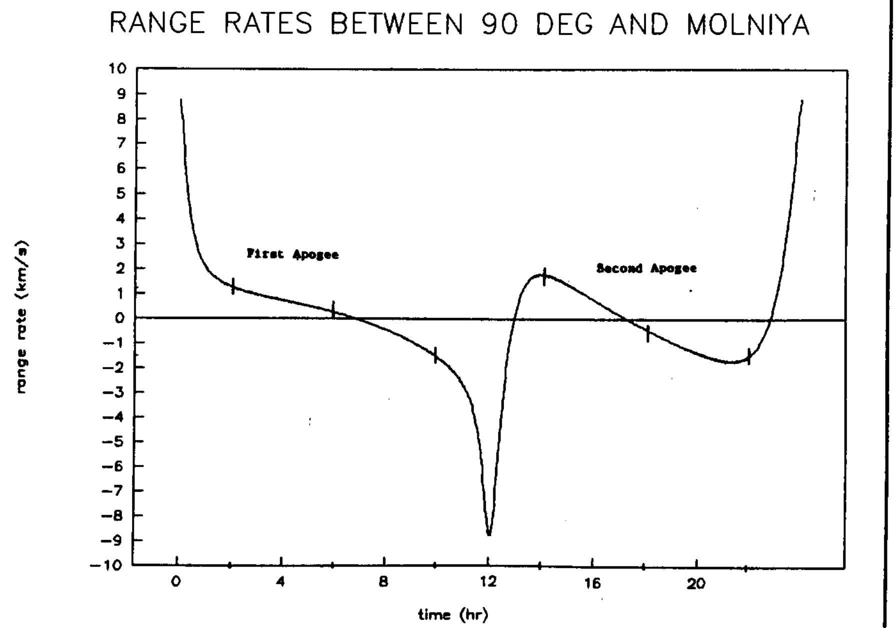


Figure A.2.1-17 Look Ahead Angle over a 24 Hour Period for the Terminal on the Molniya Type Satellite when Pointing at the Geostationary Satellite at Zero Degree Longitude



The marks identify the 8 hour limits of the first apogee at 6 hours and the second apogee at 18 hours

Figure A.2.1-18 Range Between the Molniya Type Satellite and a Geostationary Satellite at +90° Degree Longitude



The marks identify the 8 hour limits of the first apogee at 6 hours and the second apogee at 18 hours

Figure A.2.1-19 The Range rate Between the Molniya Type Satellite and a Geostationary Satellite at +90° Longitude

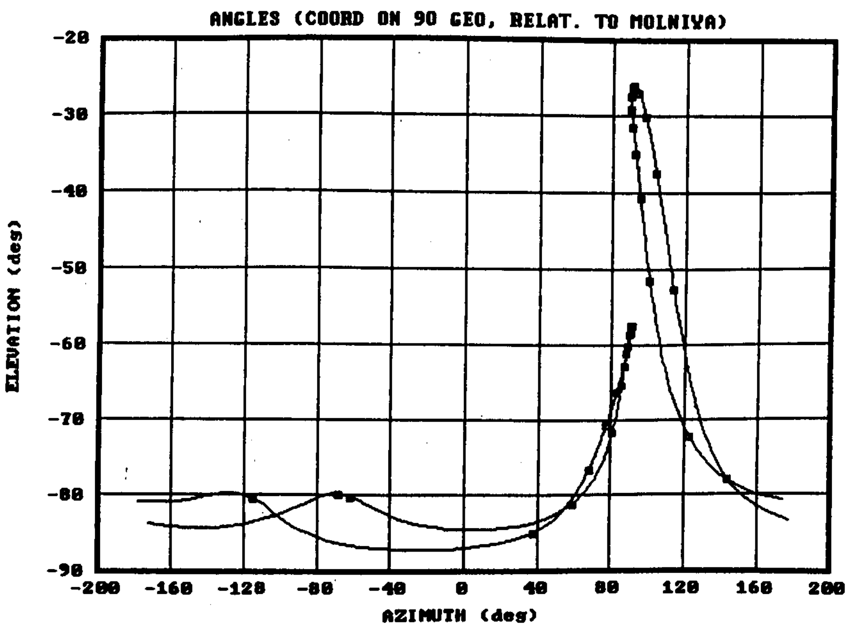


Figure A.2.1-20a Pointing Angle over a 24 Hour Period of the Terminal on the Geostationary Satellite at +90° Longitude Required to Point at the Molniya Type Satellite

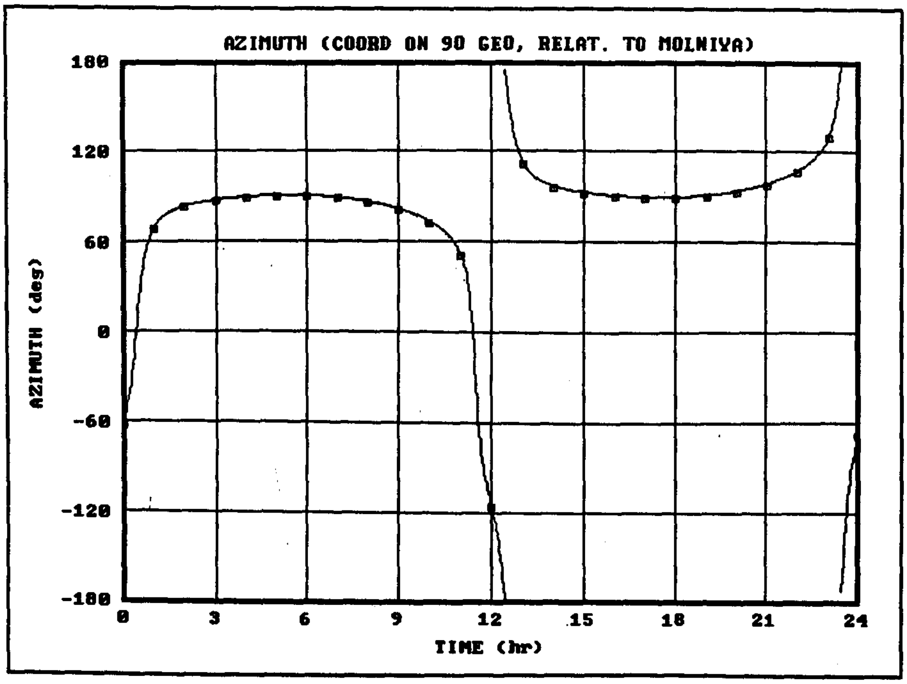


Figure A.2.1-20b *Azimuth Angle, Measured from the Velocity Vector on the Geostationary Satellite at +90 Degrees Longitude Required to Point the Molniya Type Satellite*

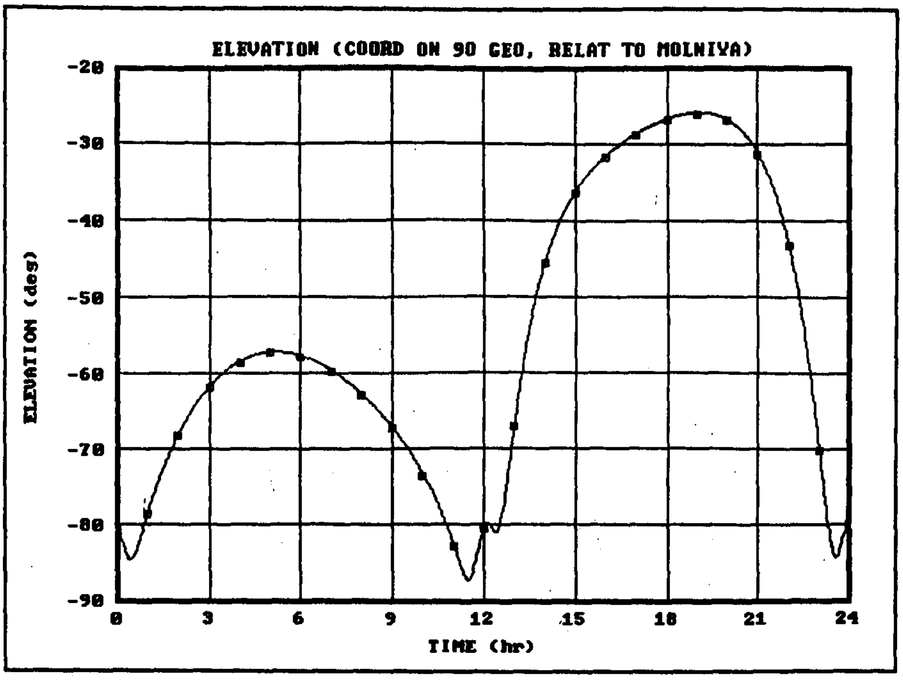


Figure A.2.1-20c *Elevation Angle on the Geostationary Satellite at +90 Degrees Longitude Required to Point at the Molniya Type Satellite*

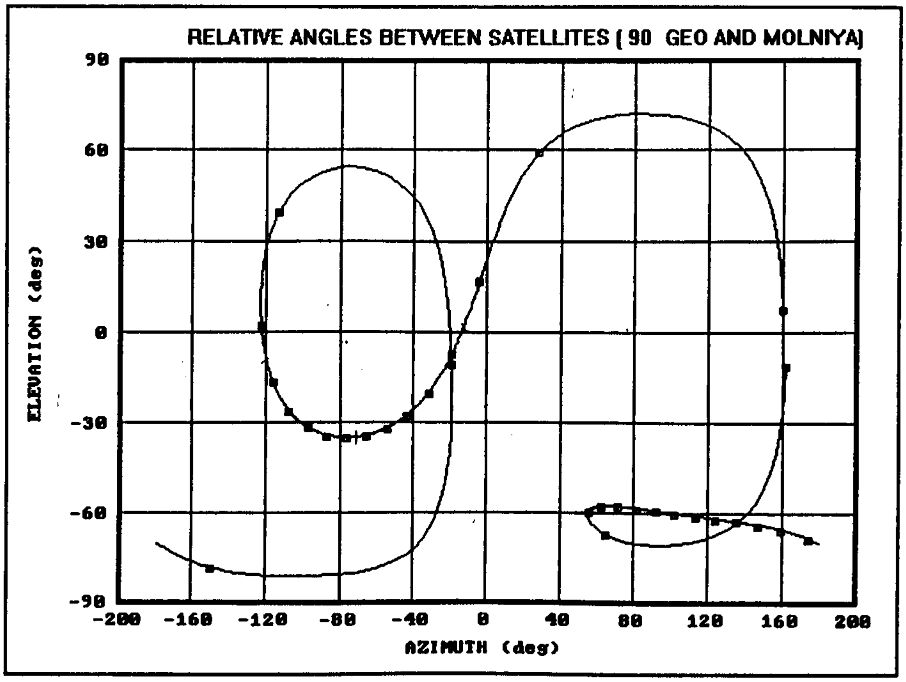


Figure A.2.1-21a *Pointing Angle over a 24 Hour Period of the Terminal on the Molniya Type Satellite Required to Point at a Geostationary Satellite at +90° Longitude*

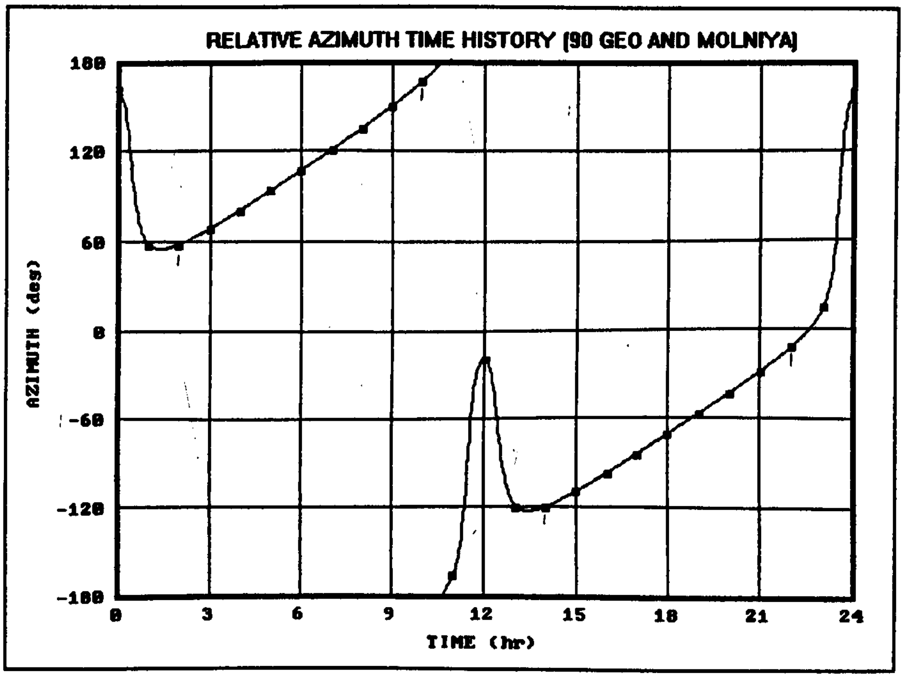


Figure A.2.1-21b *Azimuth Angle on a Molniya Type Satellite, as Measured from the Velocity Vector, Required to Point at a Geostationary Satellite at + 90° Longitude*

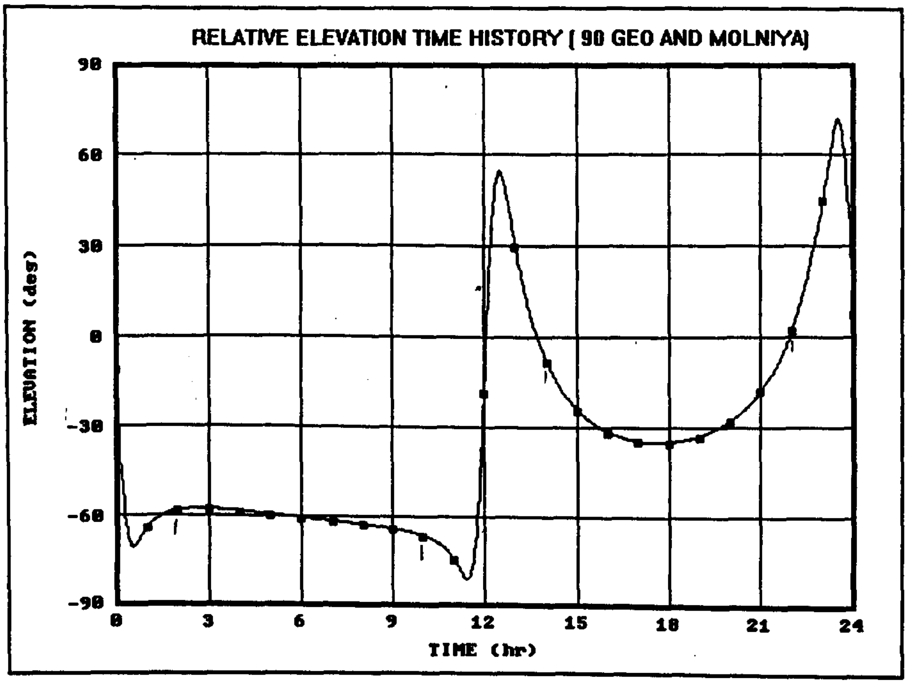


Figure A.2.1-21c *Elevation Angle on a Molniya Type Satellite Required to Point at a Geostationary Satellite at +90° Longitude*

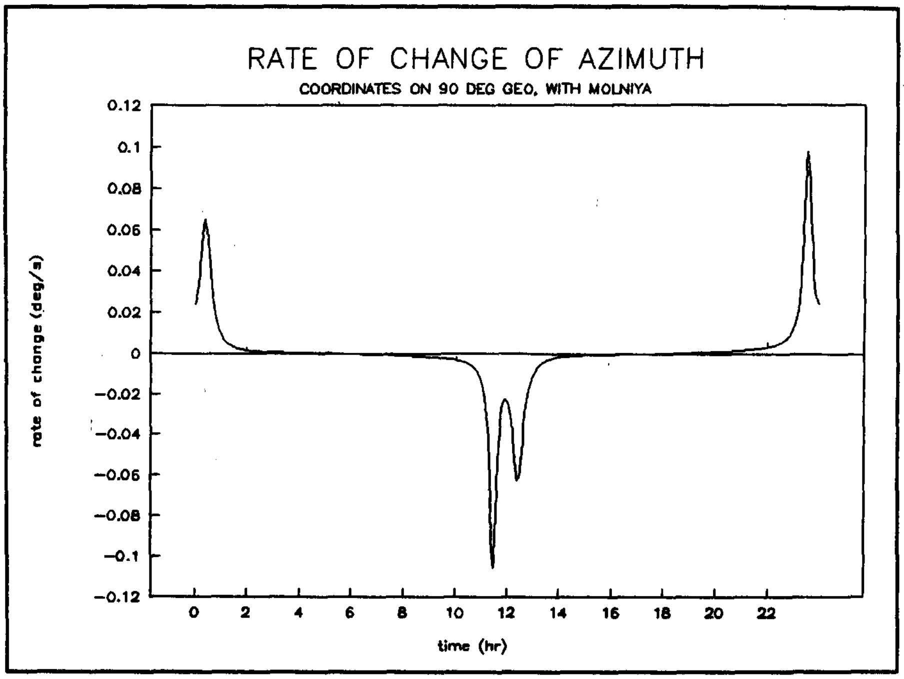


Figure A.2.1-22a *Rate of Change of Azimuth for the Terminal on the Geostationary Satellite at +90° Longitude when Pointing at the Molniya Type Satellite*

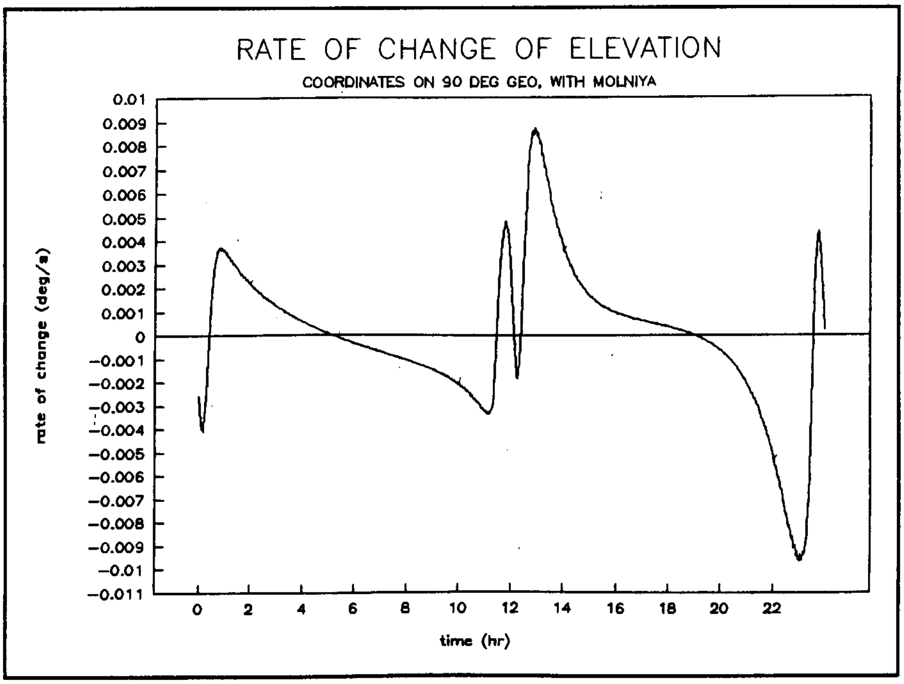


Figure A.2.1-22b *Rate of Change of Elevation for the Terminal on the Geostationary Satellite at +90 Degrees Longitude when Pointing at a Molniya Type Satellite*

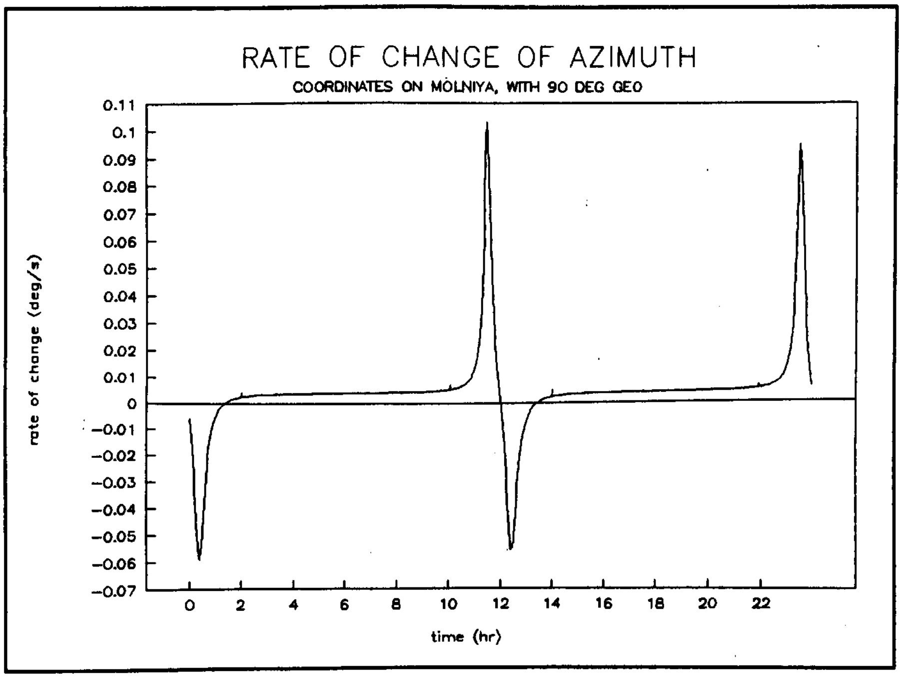


Figure A.2.1-23a *Rate of Change of Azimuth for the Terminal on the Molniya Type Satellite when Pointing at the Geostationary Satellite at +90° Longitude*

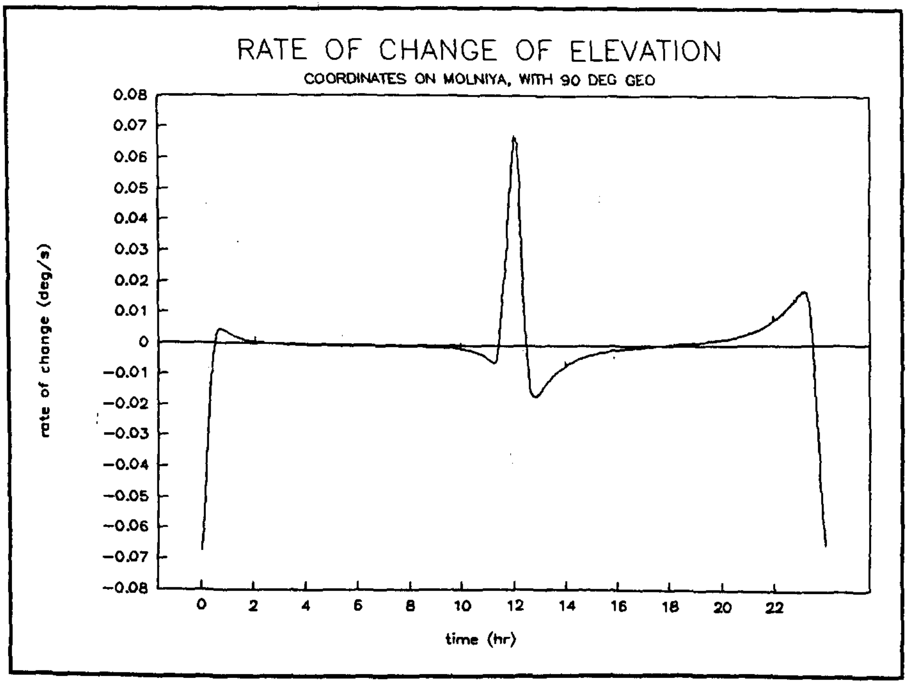


Figure A.2.1-23b ***Rate of Change of Elevation for the Terminal on the Molniya Type Satellite when Pointing at a Geostationary Satellite at +90 Degrees Longitude***

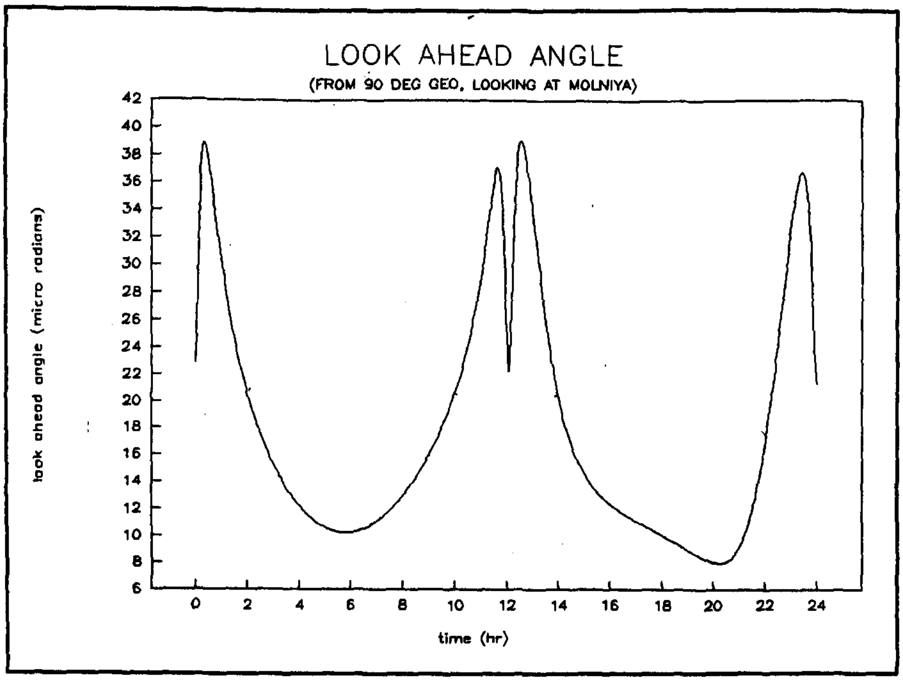


Figure A.2.1-24 ***Look Ahead Angle over a 24 Hour Period for the Terminal on the Geostationary Satellite at +90° Longitude when Pointing at the Molniya Type Satellite***

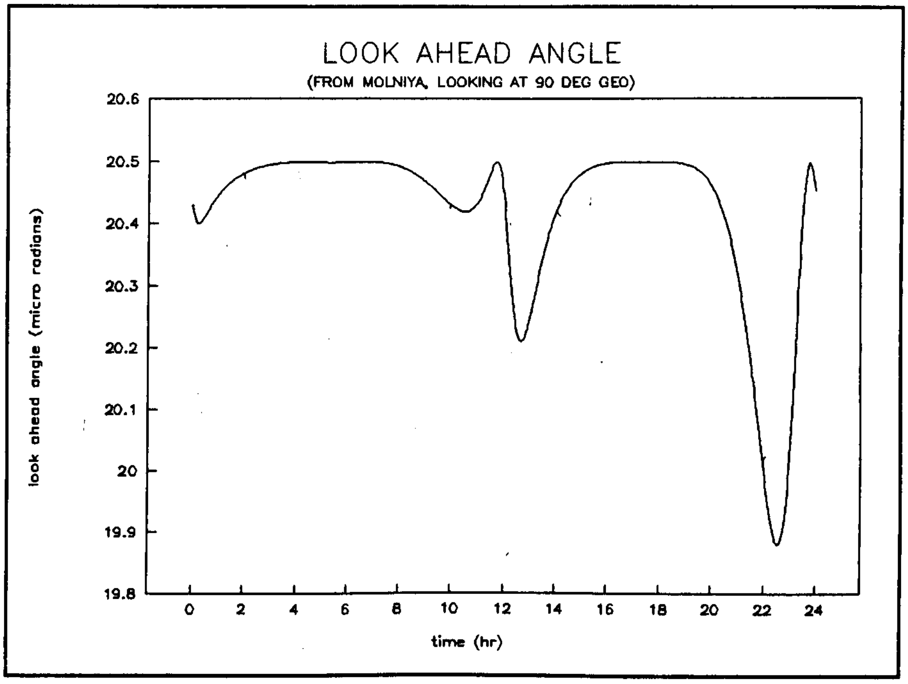


Figure A.2.1-25 Look Ahead Angle over a 24 Hour Period for the Terminal on the Molniya Type Satellite when Pointing at the Geostationary Satellite at +90° Longitude

A.2.2 Tundra Type Orbits

The Tundra orbit is a 24 hour inclined geosynchronous orbit with parameters given in Table 2.0-1. It is moderately elliptical and can be used for communications for a 12 hour period centered on apogee. Figure A.2.2-1 shows the ground trace of the orbit with an apogee at -90° longitude.

In Figures A.2.2-2 to A.2.2-25 the same performance parameters are presented as for the Molniya orbit and for the same three locations of geostationary satellite.

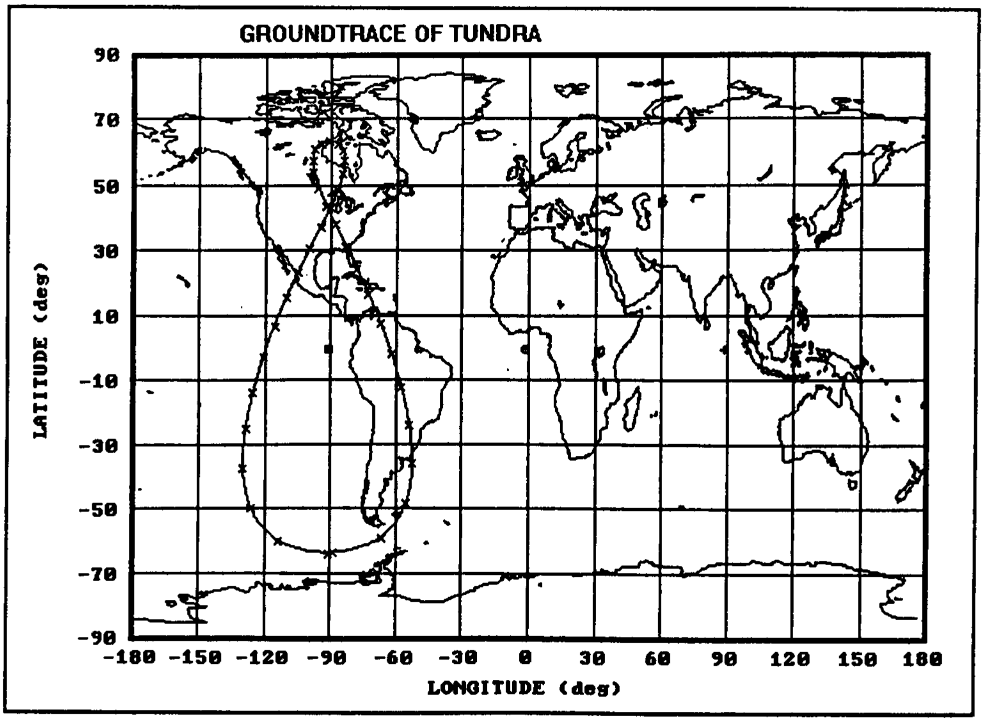
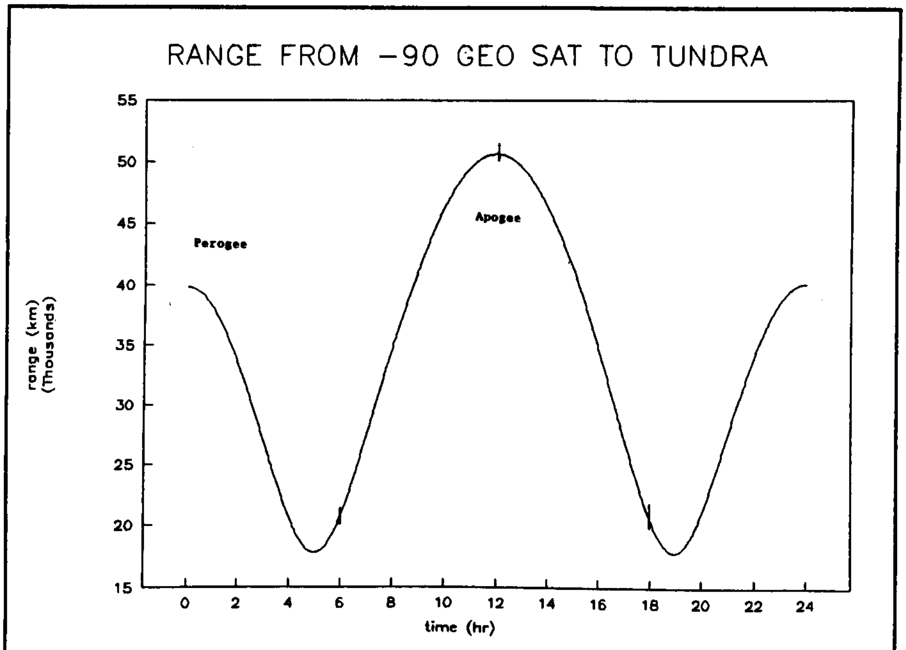
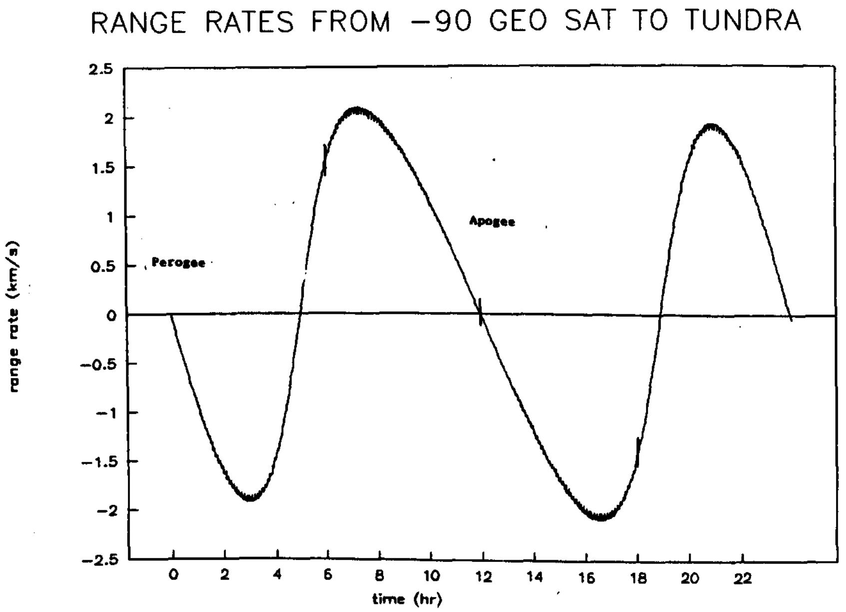


Figure A.2.2-1 Ground Trace of the Tundra Type Orbit with Apogee at -90° Longitude



The marks identify the limits between the 12 hour apogee pass and the 12 hour period around perogee.

Figure A.2.2-2 Range Between the Tundra Type Satellite and a Geostationary Satellite at -90° Longitude



The marks identify the limits between the 12 hour apogee pass and the 12 hour period around perogee.

Figure A.2.2-3 Range Rate Between the Tundra Type Satellite and a Geostationary Satellite at -90° Longitude

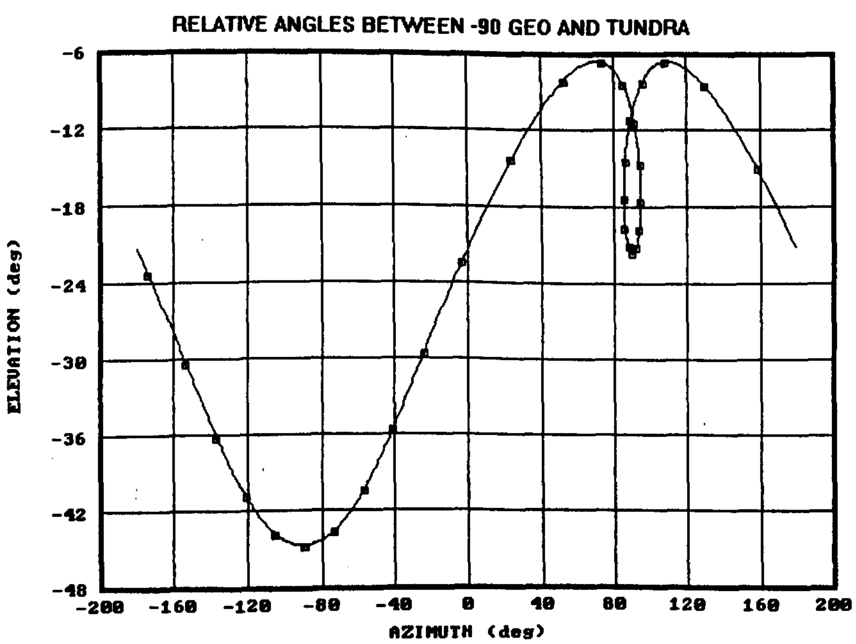


Figure A.2.2-4a Pointing Angle over a 24 Hour Period of the Terminal on the Geostationary Satellite at -90° Longitude Required to Point at the Tundra Type Satellite

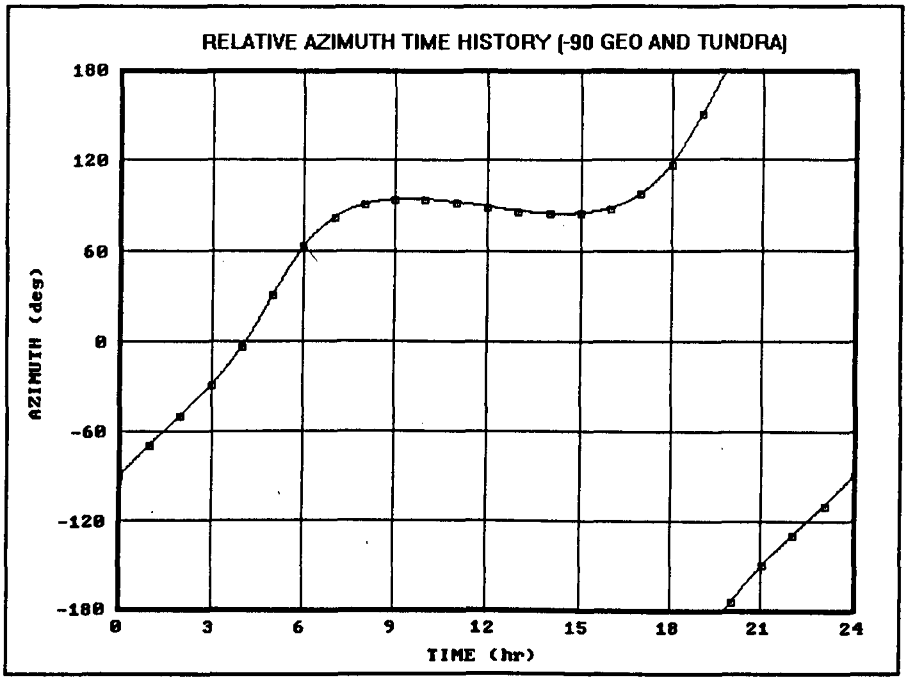


Figure A.2.2-4b Azimuth Angle Measured from the Velocity Vector on the Geostationary Satellite at -90 Degrees Longitude Required to Point at the Tundra Type Satellite

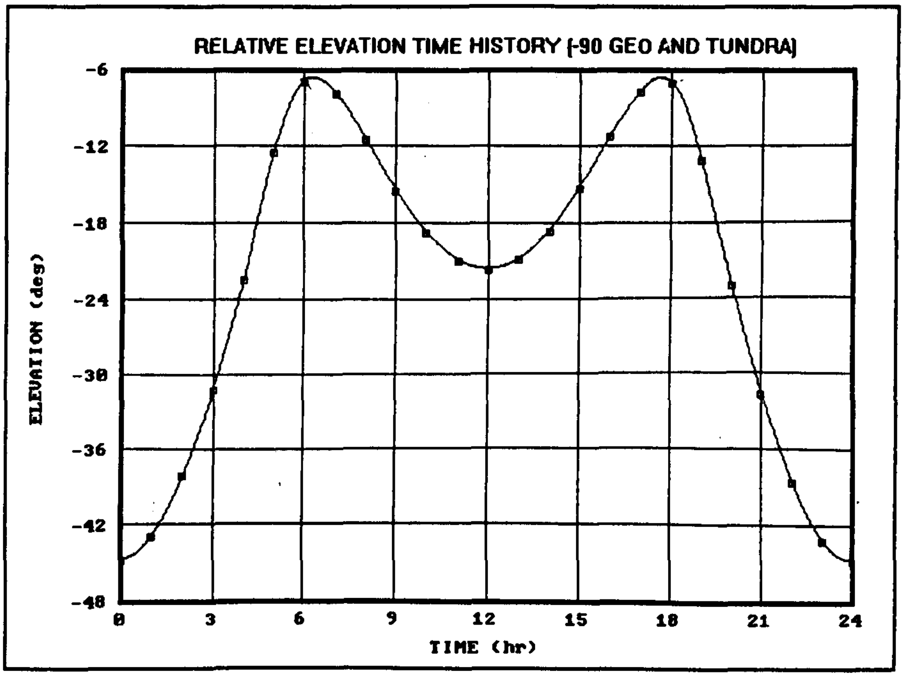


Figure A.2.2-4c Elevation Angle on the Geostationary Satellite at -90 Degrees Longitude Required to Point at the Tundra Type Satellite

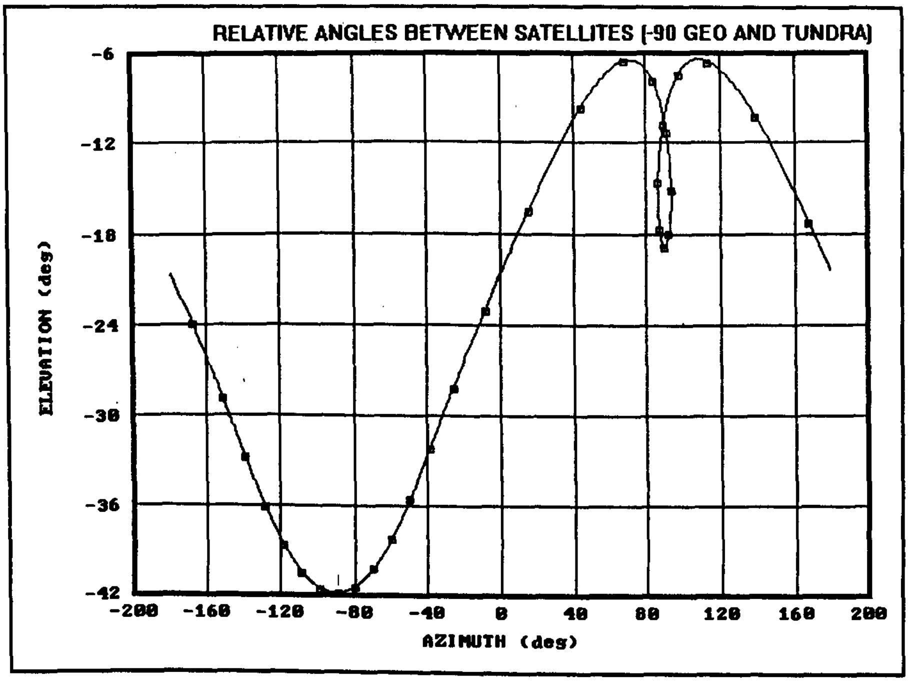


Figure A.2.2-5a *Pointing Angle over a 24 Hour Period of the Terminal on the Tundra Type Satellite Required to Point at a Geostationary Satellite at -90° Longitude*

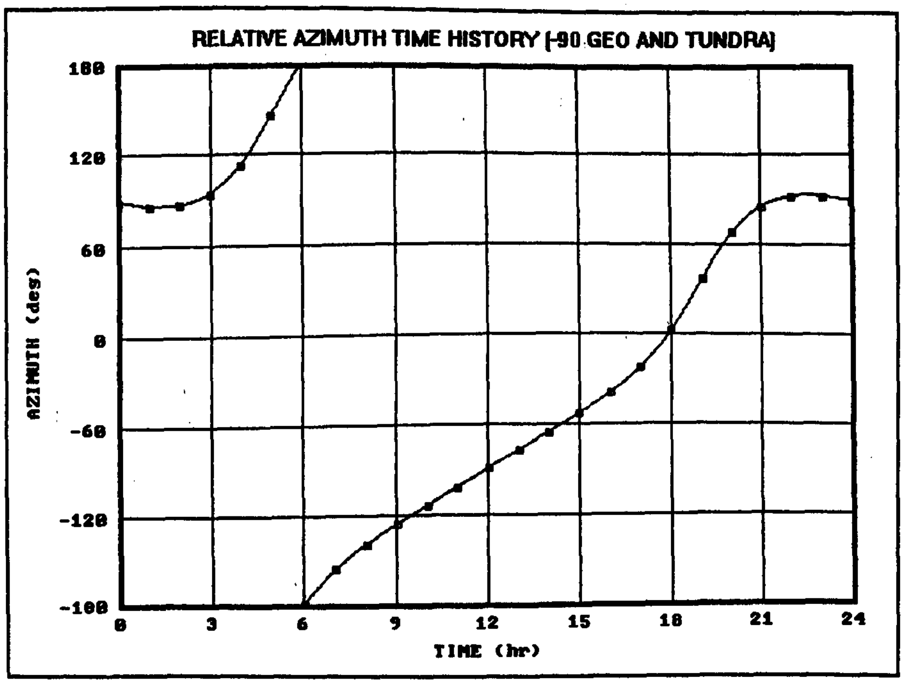


Figure A.2.2-5b *Azimuth Angle on a Tundra Type Satellite, as Measured from the Velocity Vector, Required to Point at a Geostationary Satellite at -90° Longitude*

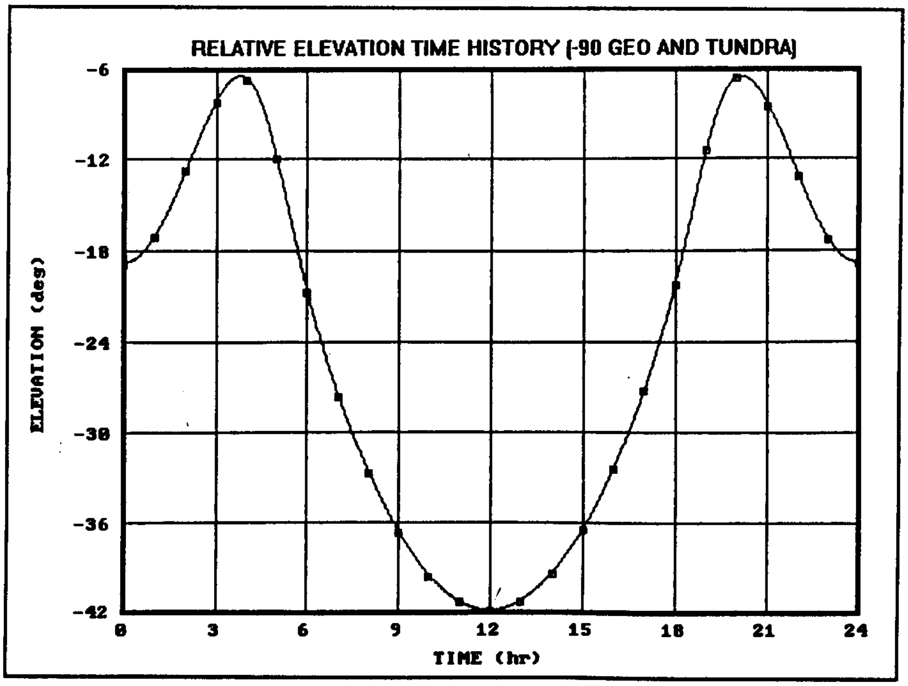


Figure A.2.2-5c *Elevation Angle on a Tundra Satellite Required to Point at a Geostationary Satellite at 90° Longitude*

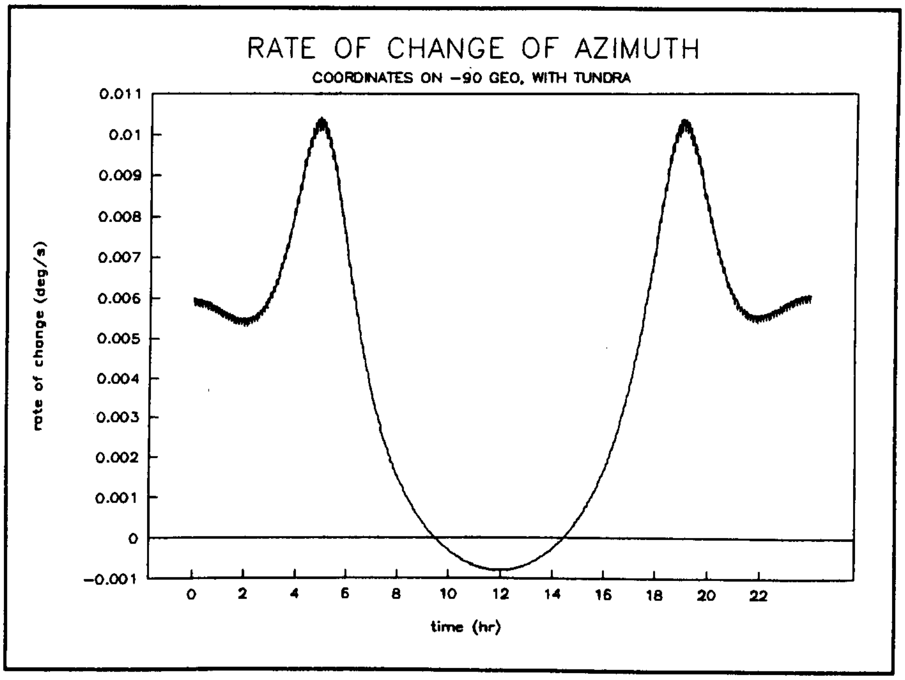


Figure A.2.2-6a *Rate of Change of Azimuth for the Terminal on the Geostationary Satellite at -90° Longitude when Pointing at the Tundra Type Satellite*

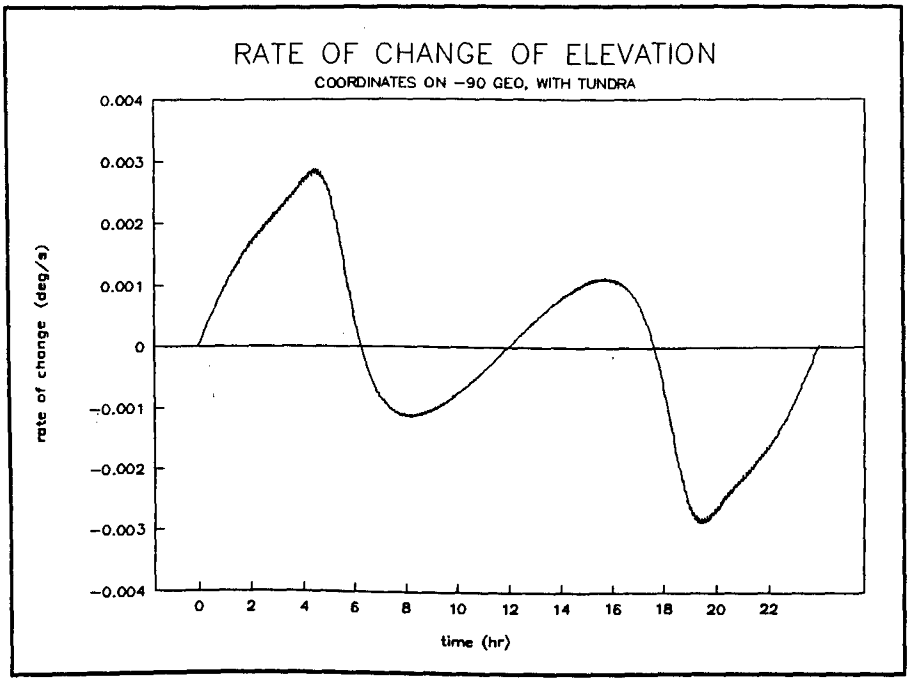


Figure A.2.2-6b *Rate of Change of Elevation for the Terminal on the Geostationary Satellite at -90 Degrees Longitude when Pointing at the Tundra Type Satellite*

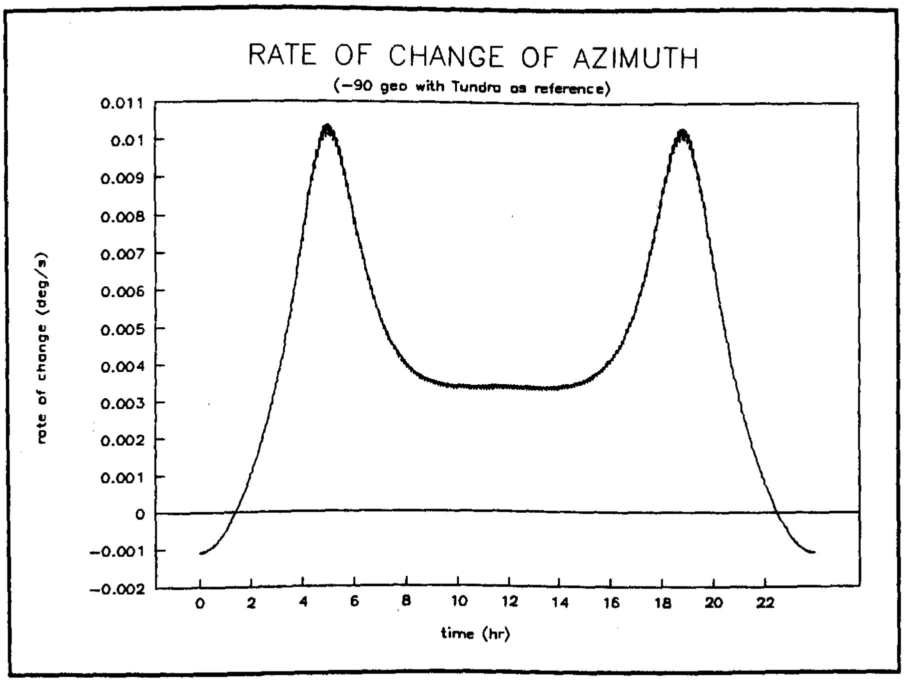


Figure A.2.2-7a *Rate of Change of Azimuth of the Terminal on the Tundra Type Satellite when Pointing at the Geostationary Satellite at -90° Longitude*

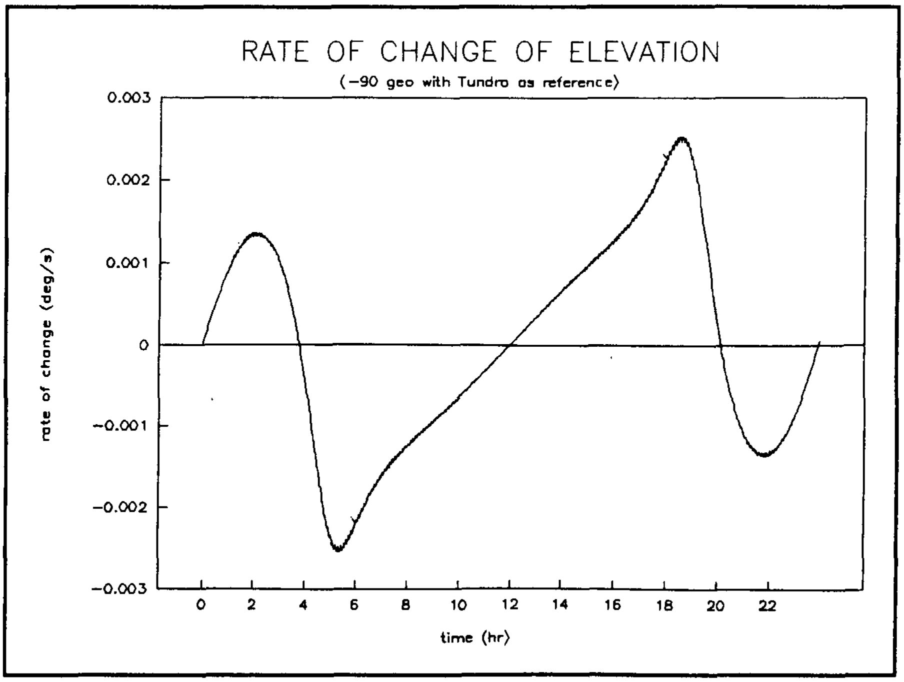


Figure A.2.2-7b ***Rate of Change of Elevation of the Terminal on a Tundra Type Satellite when Pointing at a Geostationary Satellite at -90° Longitude***

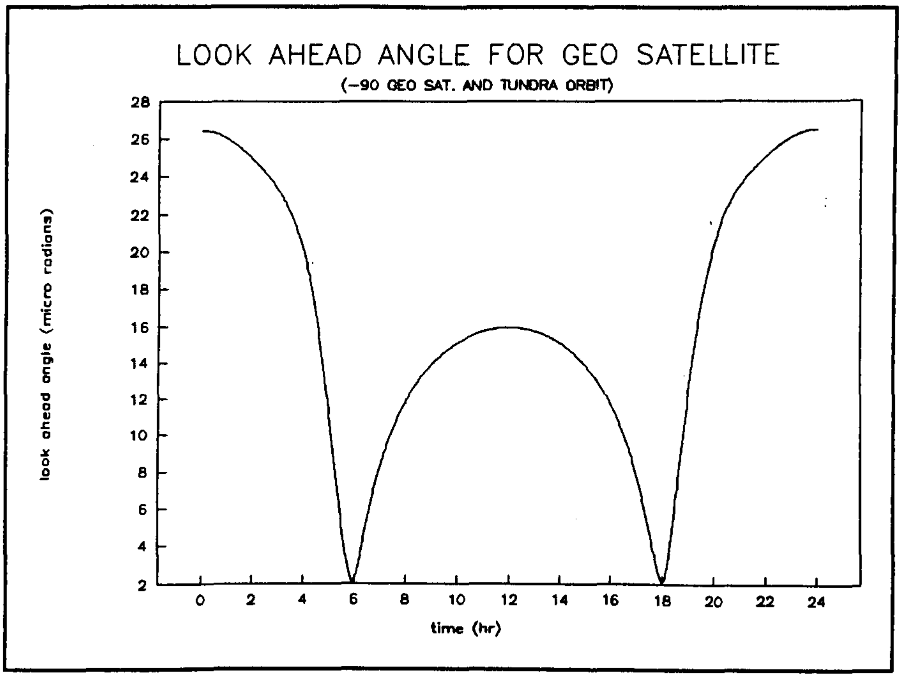


Figure A.2.2-8 ***Look Ahead Angle over a 24 Hour Period for the Terminal on the Geostationary Satellite at -90 Degree Longitude when Pointing at the Tundra Type Satellite***

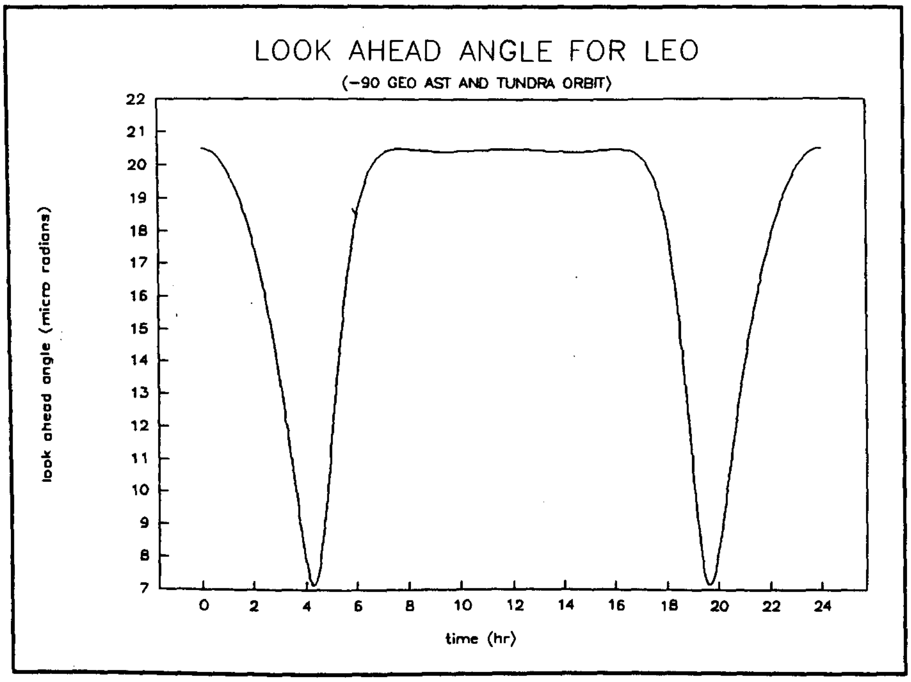
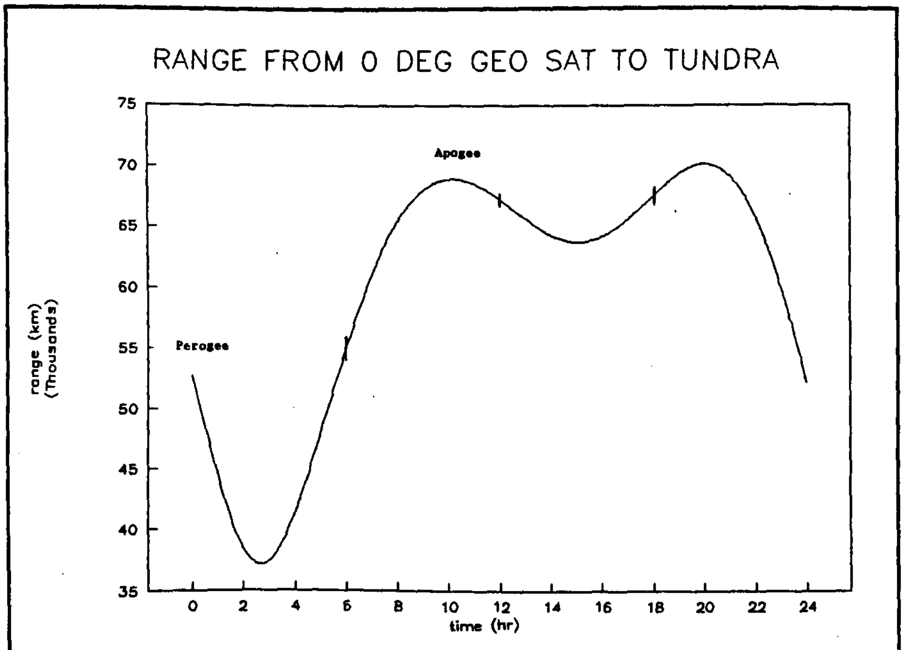


Figure A.2.2-9 Look Ahead Angle over a 24 Hour Period for the Terminal on the Tundra Type Satellite when Pointing at the Geostationary Satellite at -90° Longitude



The marks identify the limits between the 12 hour apogee pass and the 12 hour period around perogee.

Figure A.2.2-10 Range Between the Tundra Type Satellite and a Geostationary Satellite at Zero Degree Longitude

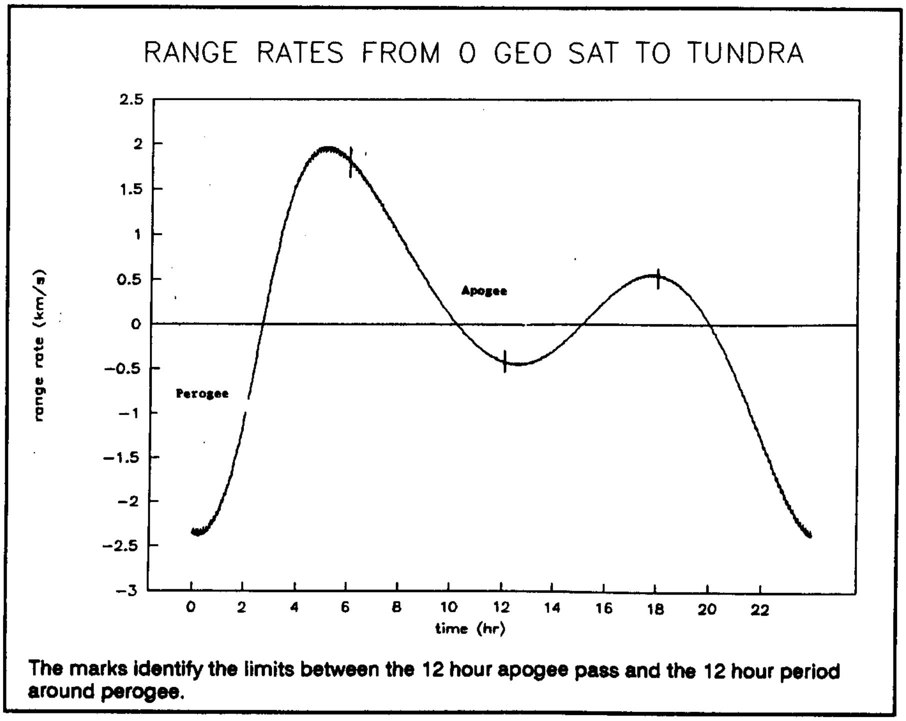


Figure A.2.2-11 *Range Rate Between the Tundra Type Satellite and a Geostationary Satellite at Zero Degree Longitude*

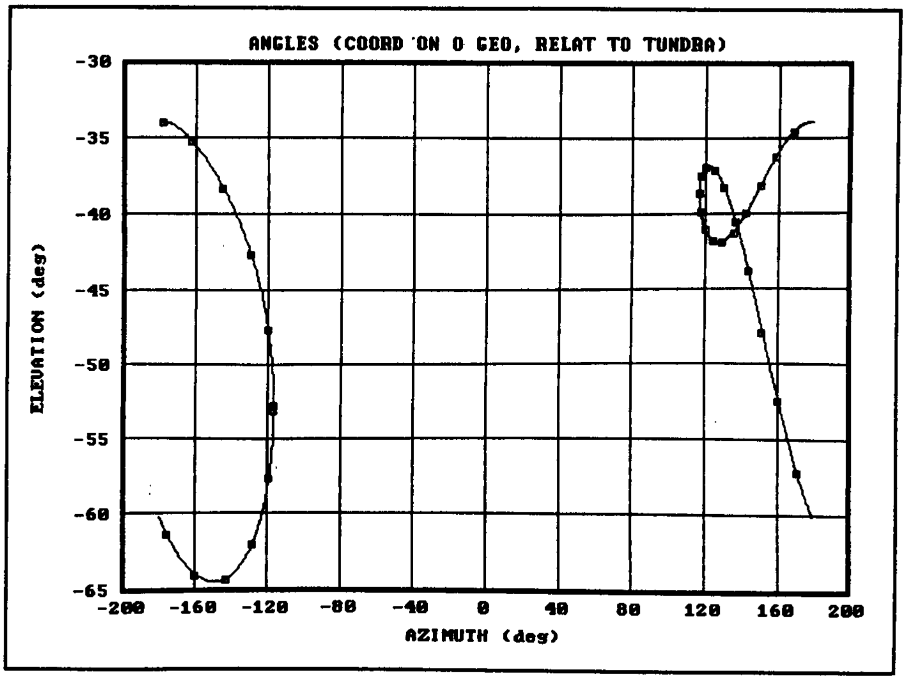


Figure A.2.2-12a *Pointing Angle over a 24 Hour Period of the Terminal on the Geostationary Satellite at Zero Deg.Longitude Required to Point at the Tundra Type Satellite*

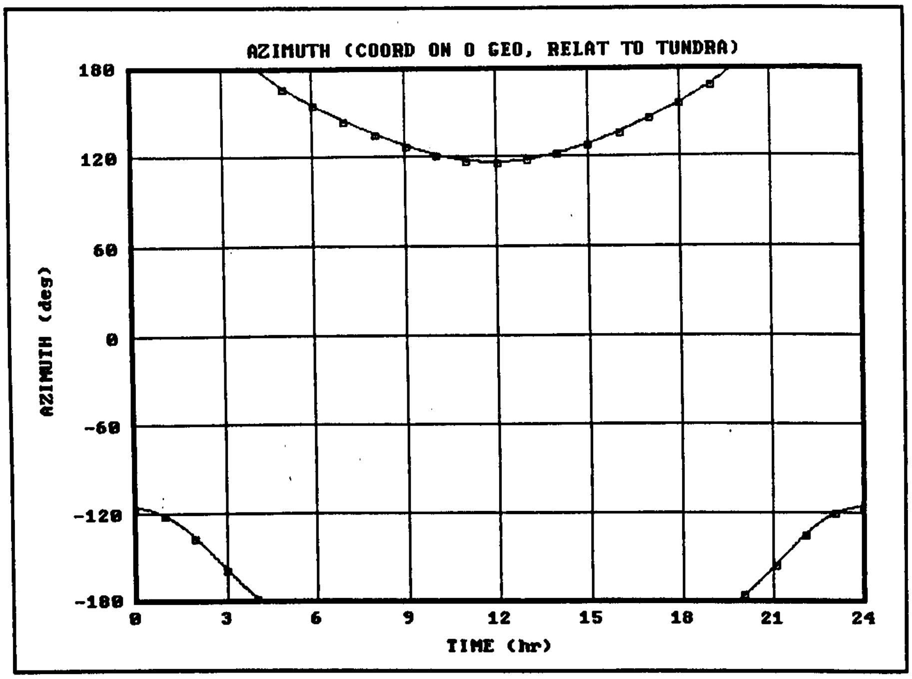


Figure A.2.2-12b Azimuth Angle, Measured from the Velocity Vector, on the Geostationary Satellite at Zero Degrees Longitude Required to Point at the Tundra Type Satellite

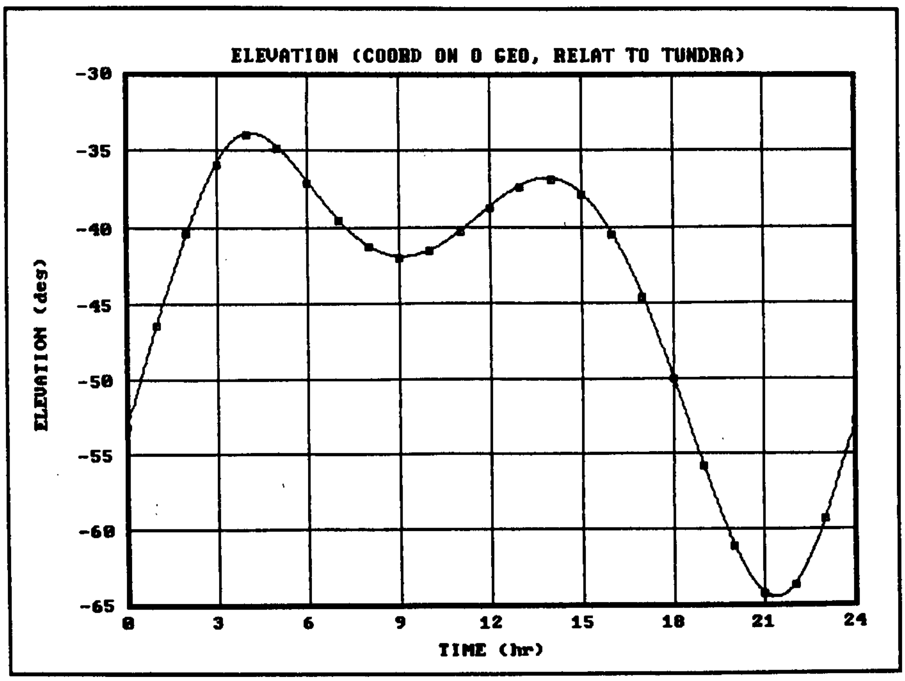


Figure A.2.2-12c Elevation Angle on the Geostationary Satellite at Zero Degrees Longitude Required to Point at the Tundra Type Satellite

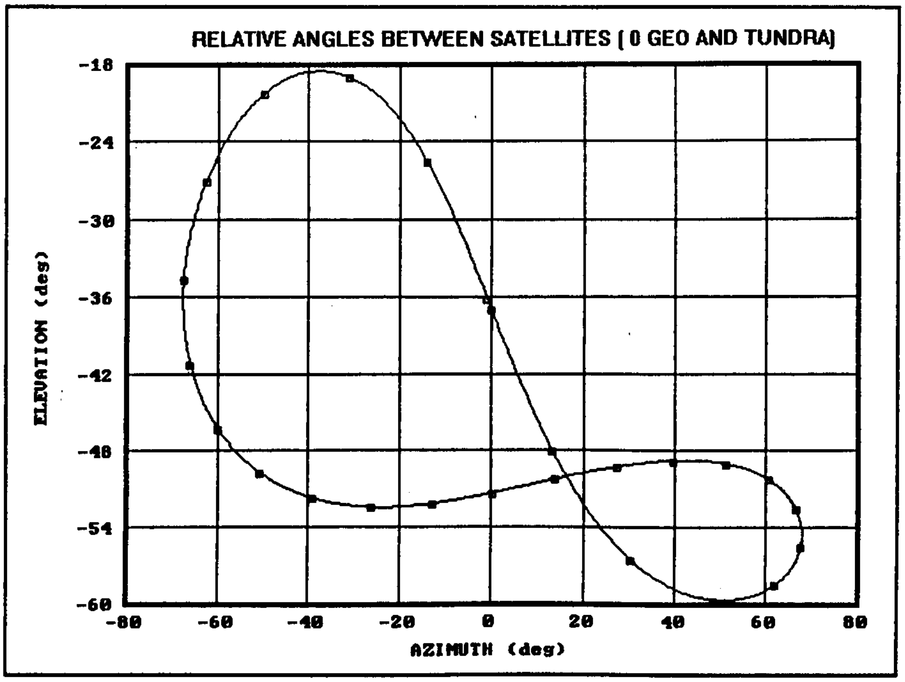


Figure A.2.2-13a *Pointing Angle over a 24 Hour Period of the Terminal on the Tundra Type Satellite Required to Point at a Geostationary Satellite at Zero Longitude*

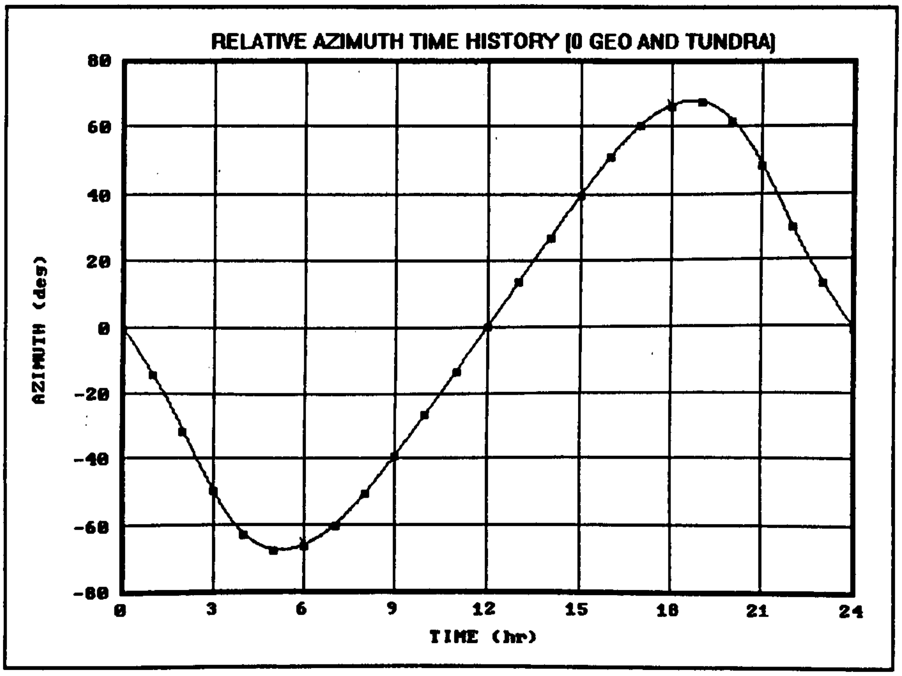


Figure A.2.2-13b *Azimuth Angle on a Tundra Type Satellite, as Measured from the Velocity Vector, Required to Point at a Geostationary Satellite at 0° Longitude*

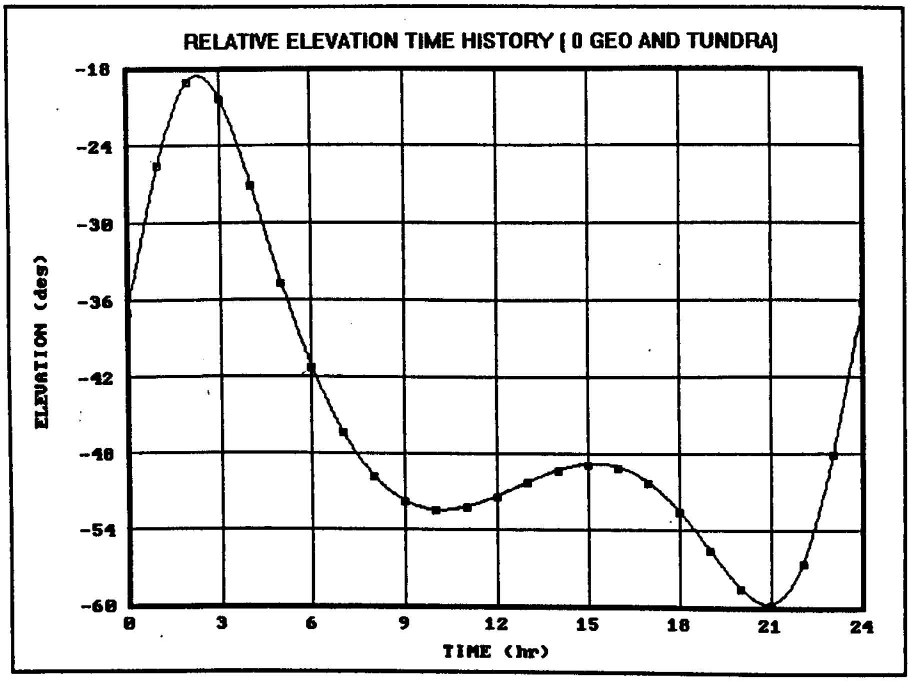


Figure A.2.2-13c *Elevation Angle on a Tundra Type Satellite Required to Point at a Geostationary Satellite at Zero Deg. Longitude*

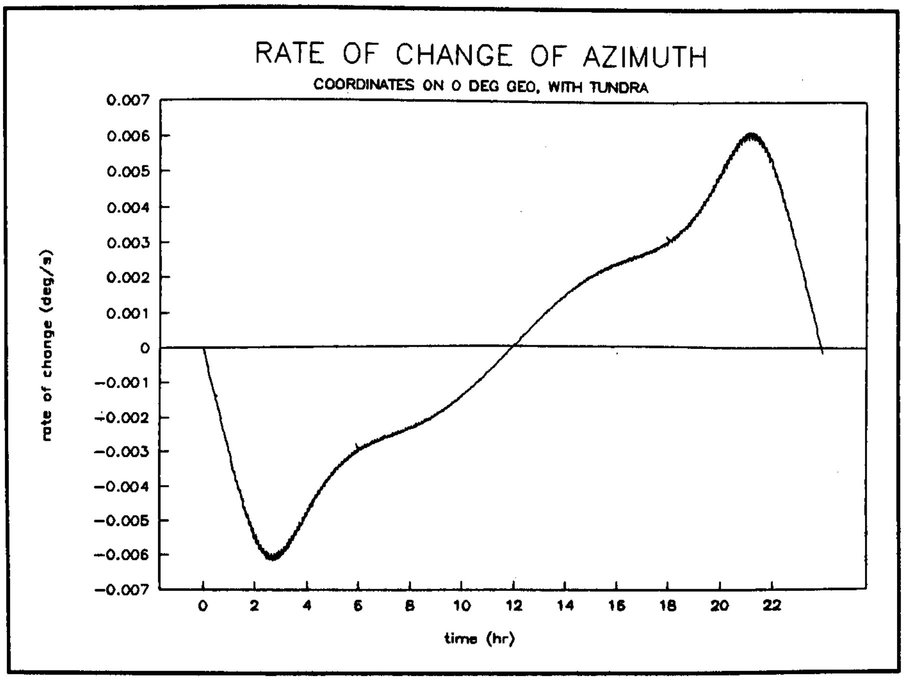


Figure A.2.2-14a *Rate of Change of Azimuth for the Terminal on the Geostationary Satellite at Zero Degree Longitude when Pointing at the Tundra Type Satellite*

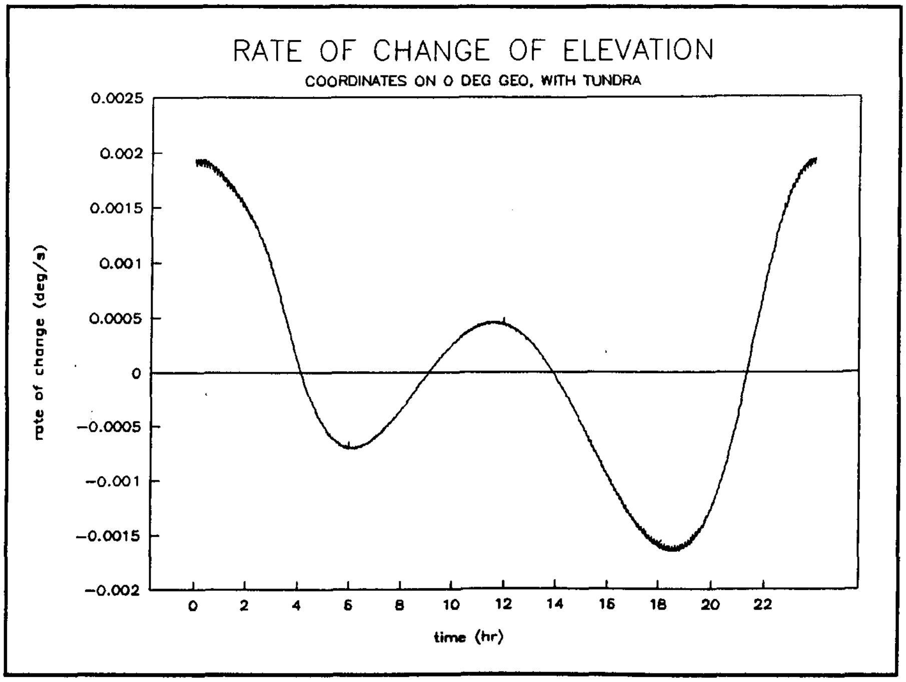


Figure A.2.2-14b Rate of Change of Elevation for the Terminal on the Geostationary Satellite at Zero Degrees Longitude when Pointing at the Tundra Type Satellite

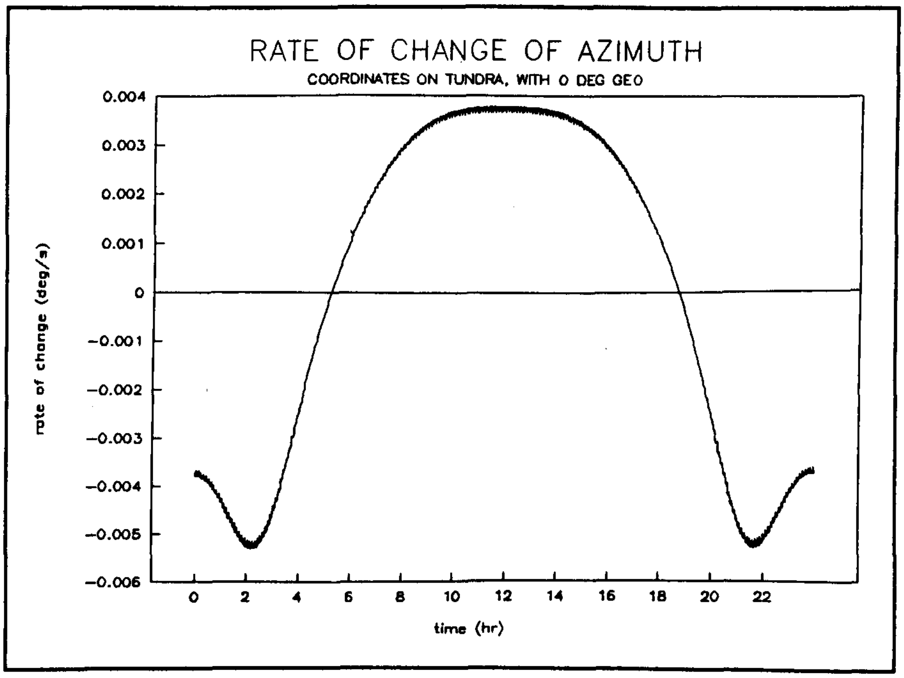


Figure A.2.2-15a Rate of Change of Azimuth for the Terminal on the Tundra Type Satellite when Pointing at the Geostationary Satellite at Zero Degree Longitude

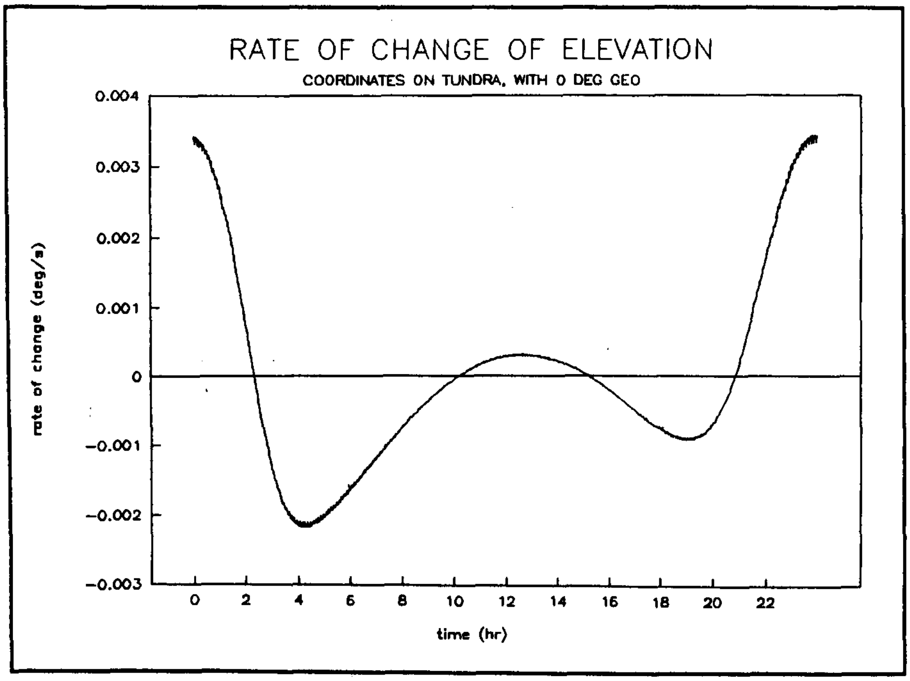


Figure A.2.2-15b Rate of Change of Elevation for the Terminal on the Tundra Type Satellite when Pointing at a Geostationary Satellite at Zero Degrees Longitude

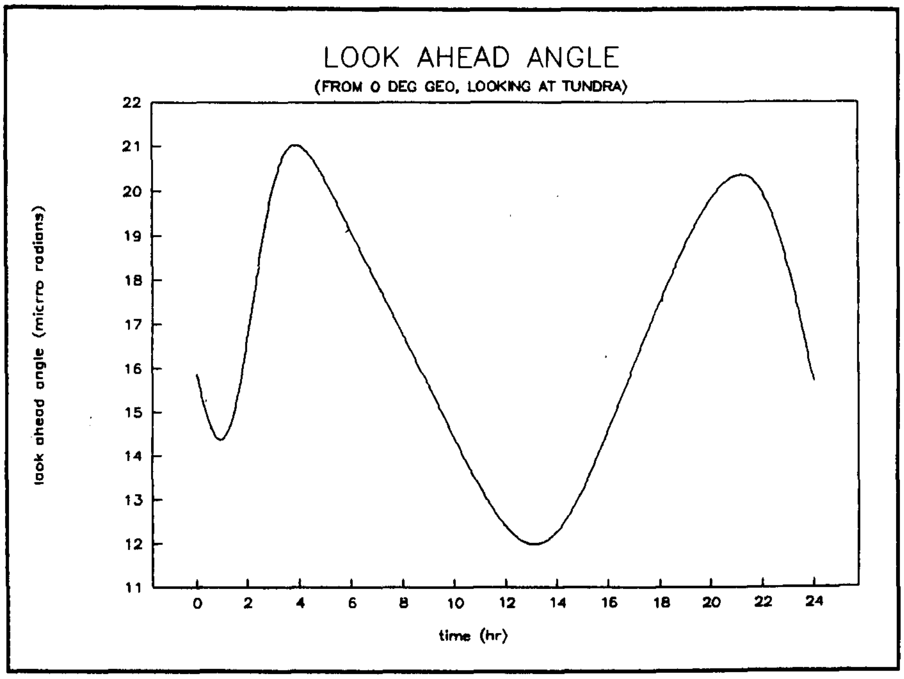


Figure A.2.2-16 Look Ahead Angle over a 24 Hour Period for the Terminal on the Geostationary Satellite at Zero Degree Longitude when Pointing at the Tundra Type Satellite

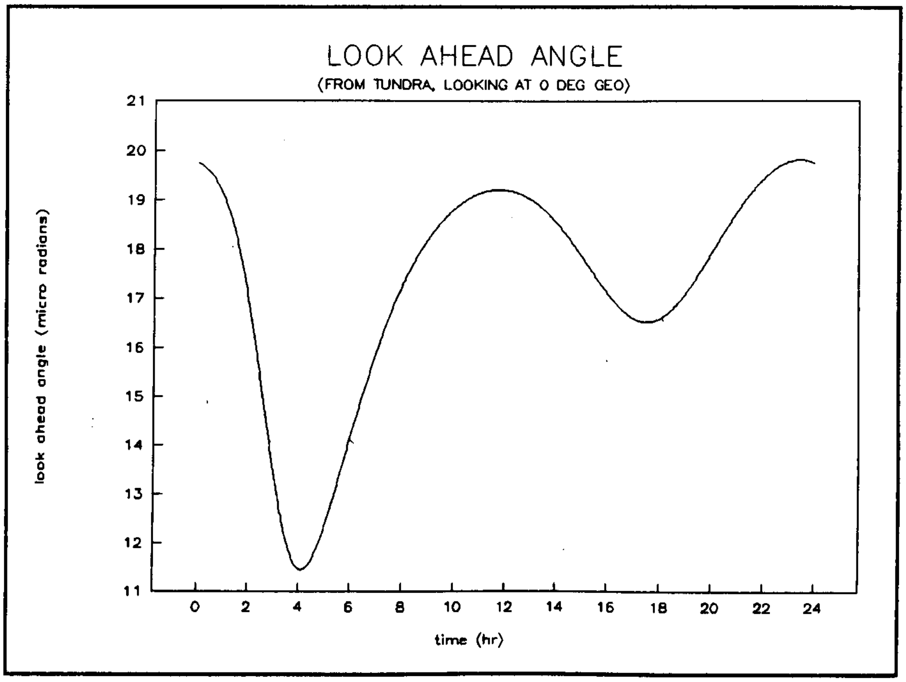
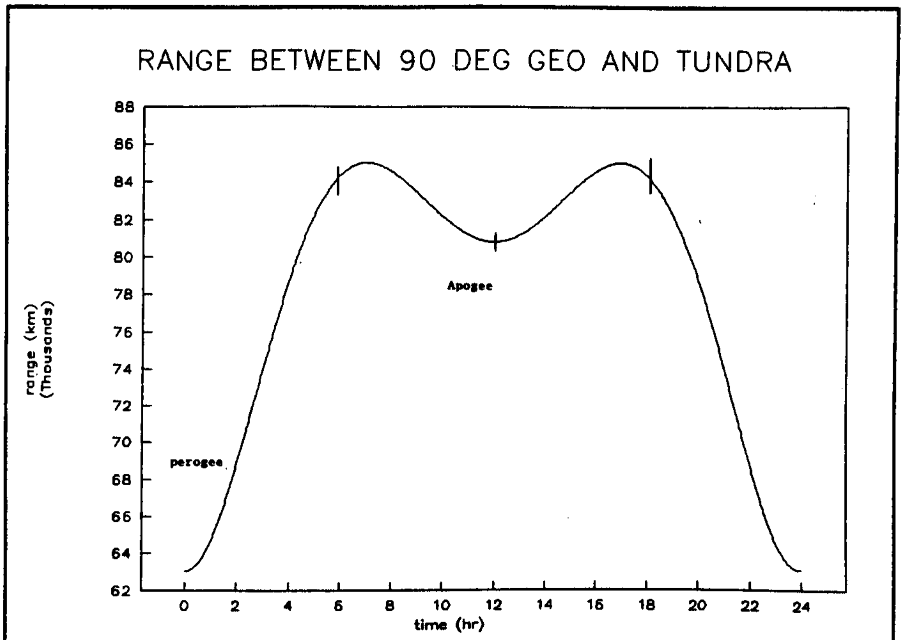


Figure A.2.2-17 Look Ahead Angle over a 24 Hour Period for the Terminal on the Tundra Type Satellite when Pointing at the Geostationary Satellite at Zero Degree Longitude



The marks identify the limits between the 12 hour apogee pass and the 12 hour period around perogee.

Figure A.2.2-18 Range Between the Tundra Type Satellite and a Geostationary Satellite at +90° Longitude

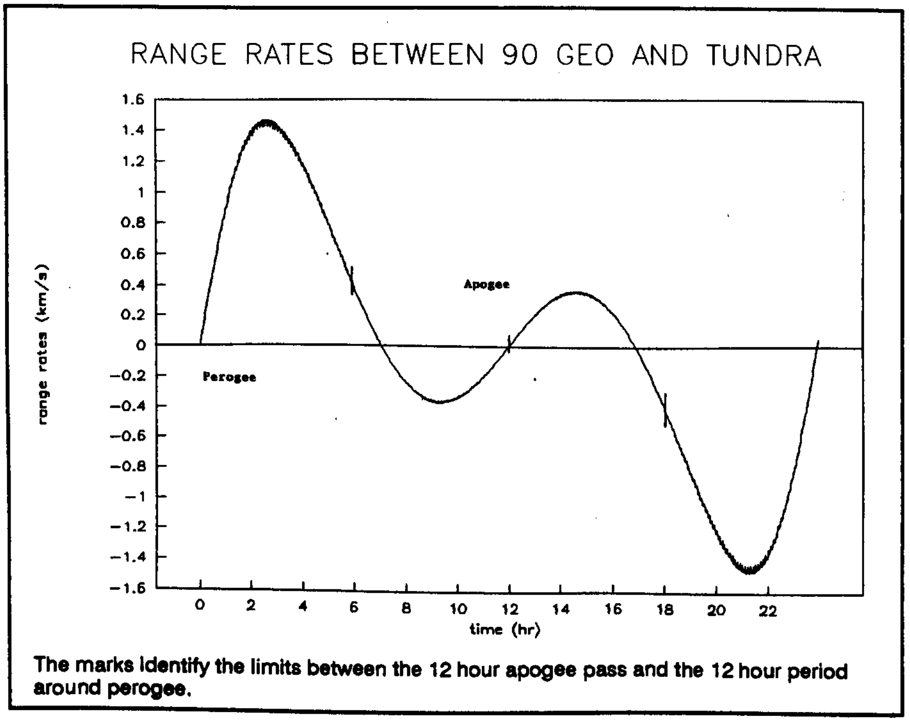


Figure A.2.2-19 Range Rate Between the Tundra Type Satellite and a Geostationary Satellite at +90° Longitude

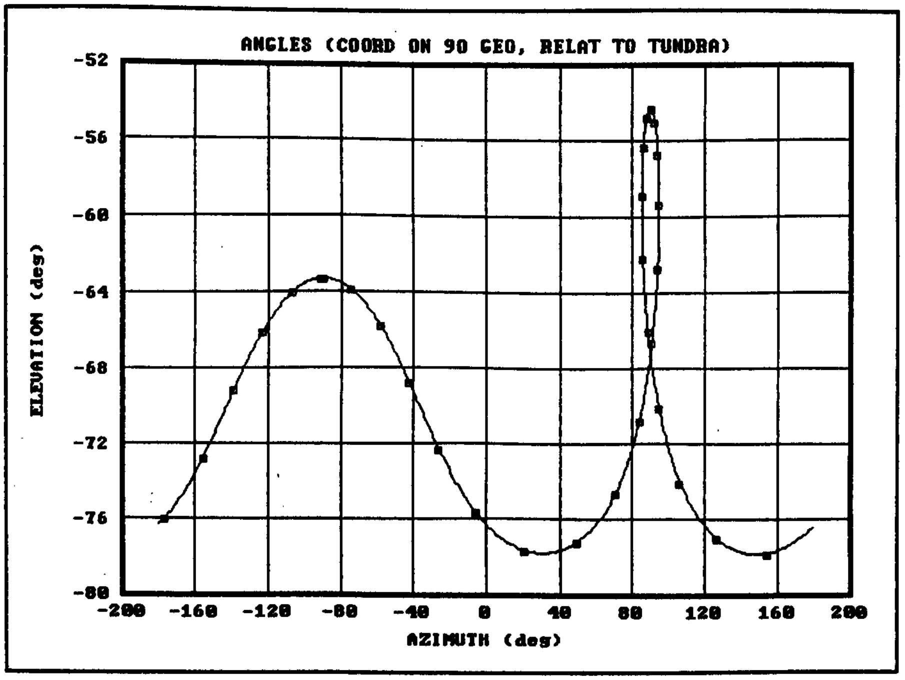


Figure A.2.2-20a Pointing Angle over a 24 Hour Period of the Terminal on the Geostationary Satellite at +90° Longitude Required to Point at the Tundra Type Satellite

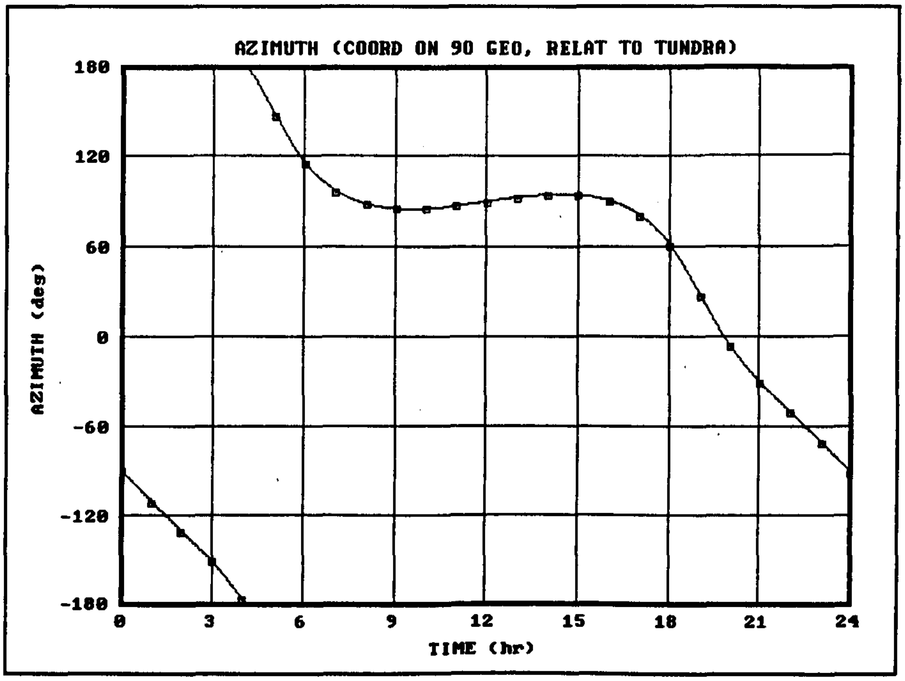


Figure A.2.2-20b Azimuth Angle, Measured from the Velocity Vector, on the Geostationary Satellite at +90 Degrees Longitude Required to Point at the Tundra Type Satellite

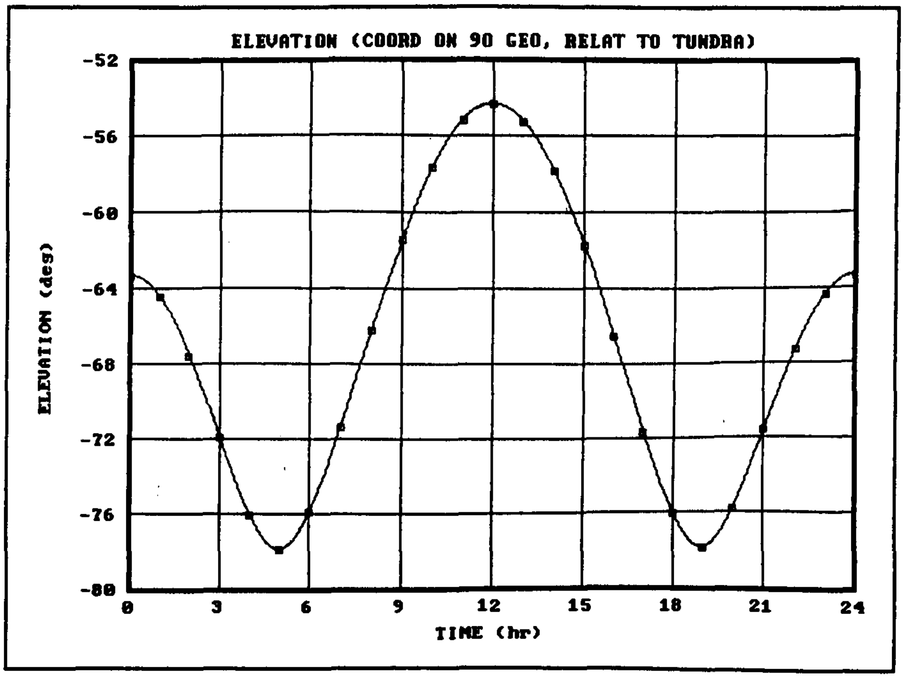


Figure A.2.2-20c Elevation Angle on the Geostationary Satellite at +90 Degrees Longitude Required to Point at the Tundra Type Satellite

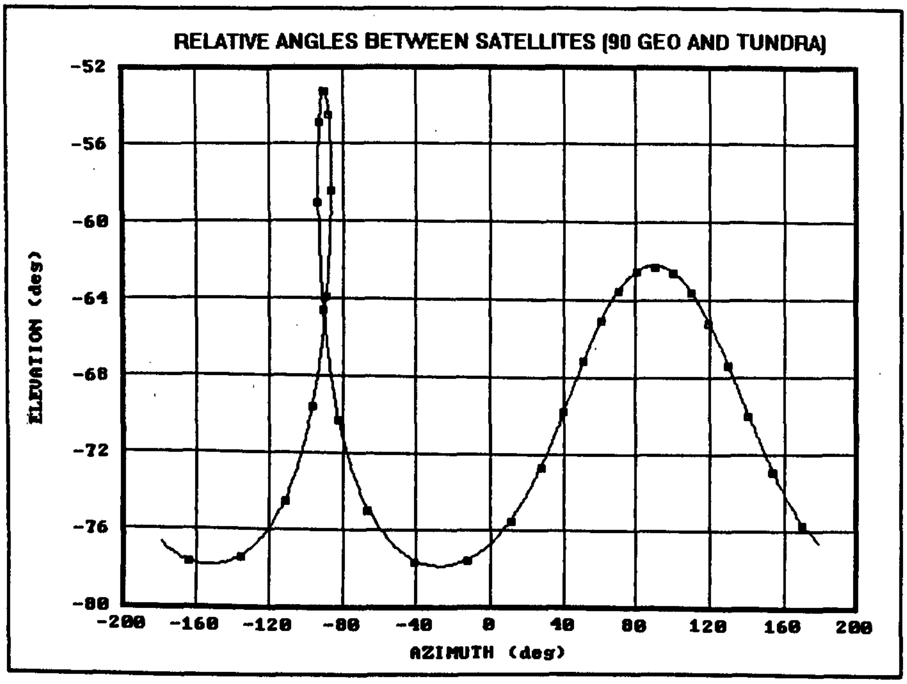


Figure A.2.2-21a *Pointing Angle over a 24 Hour Period of the Terminal on the Tundra Type Satellite Required to Point at a Geostationary Satellite at +90° Longitude*

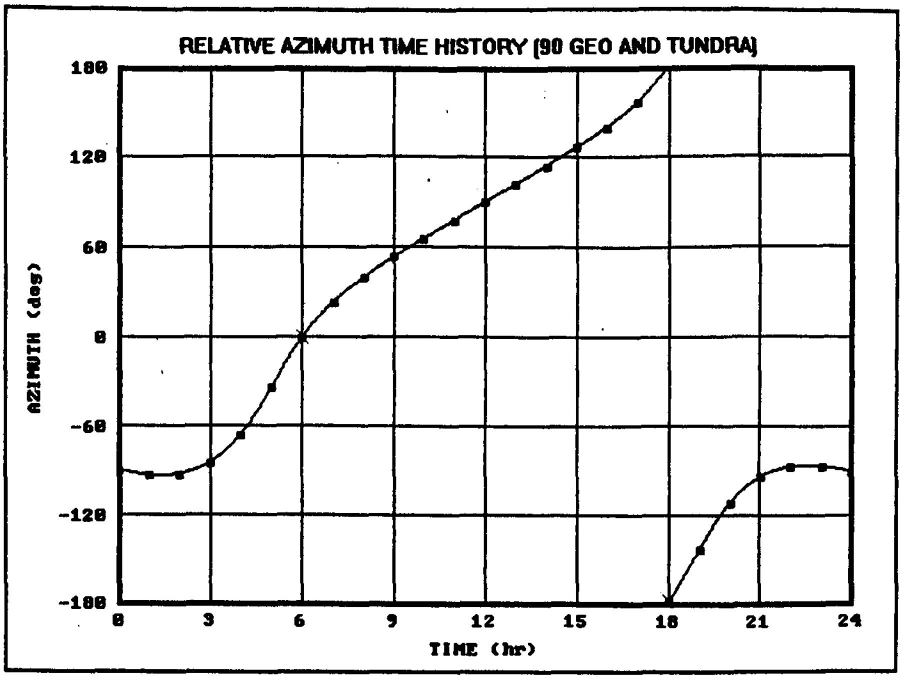


Figure A.2.2-21b *Azimuth Angle on a Tundra Type Satellite, as Measured from the Velocity Vector, Required to Point at a Geostationary Satellite at +90° Longitude*

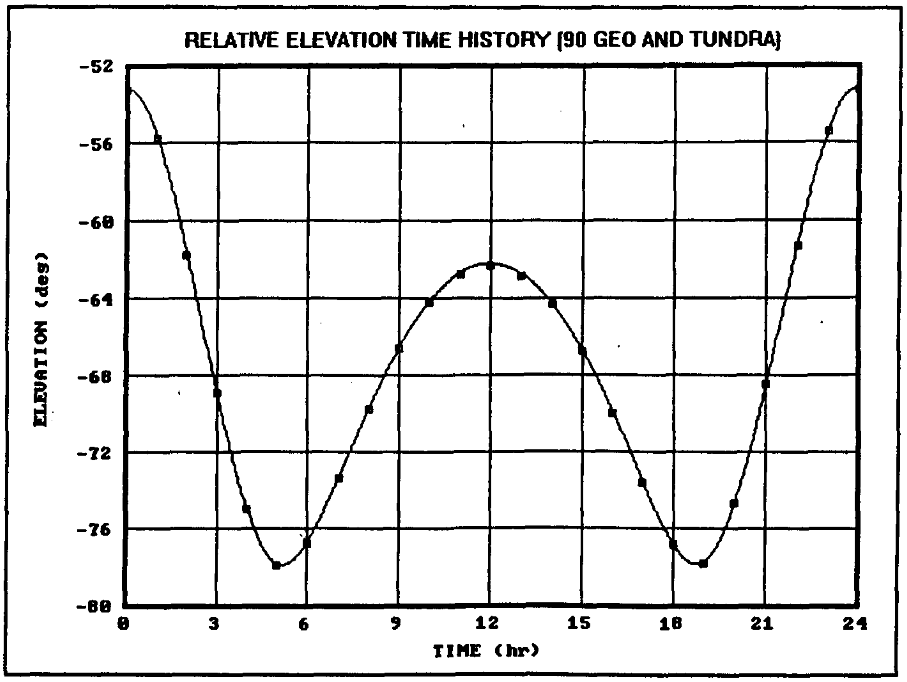


Figure A.2.2-21c Elevation Angle on a Tundra Type Satellite, as Measured from the Velocity Vector, Required to Point at a Geostationary Satellite at +90° Longitude

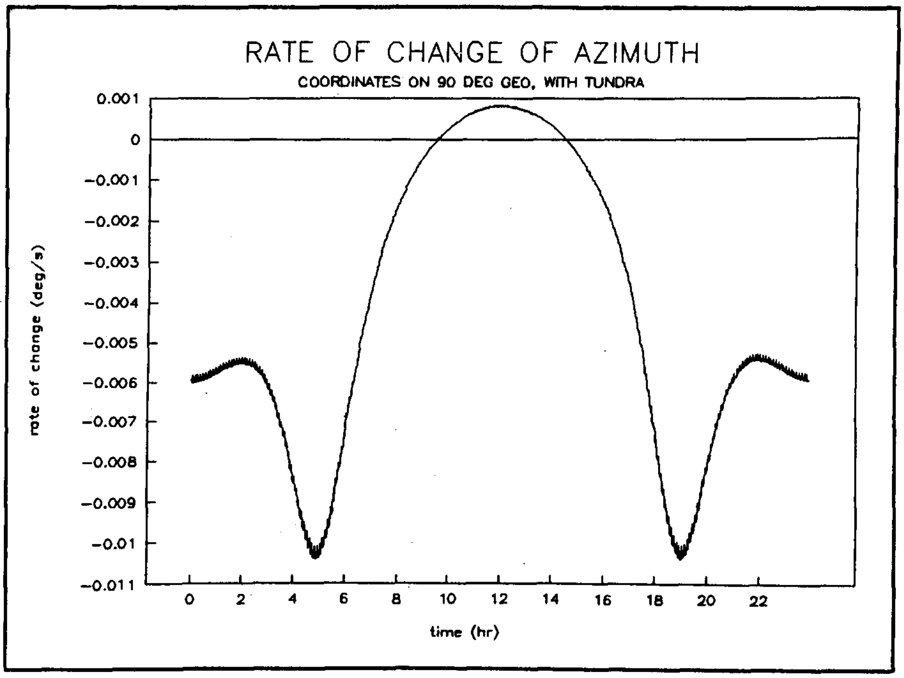


Figure A.2.2-22a Rate of Change of Azimuth for the Terminal on the Geostationary Satellite at +90° Longitude when Pointing at the Tundra Type Satellite

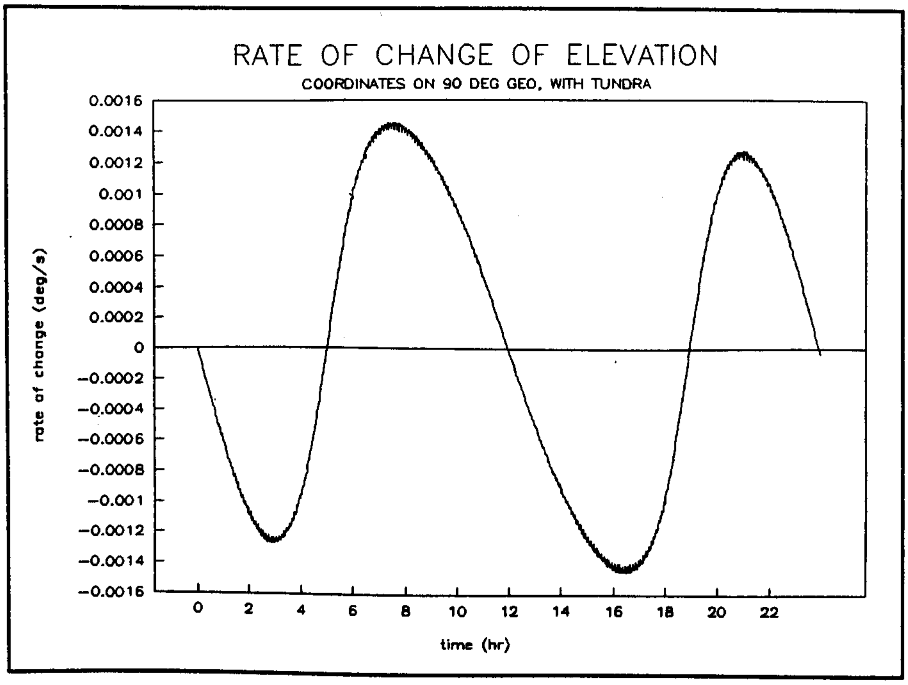


Figure A.2.2-22b ***Rate of Change of Elevation for the Terminal on a Geostationary Satellite at +90 Degrees Longitude when Pointing at a Tundra Type Satellite***

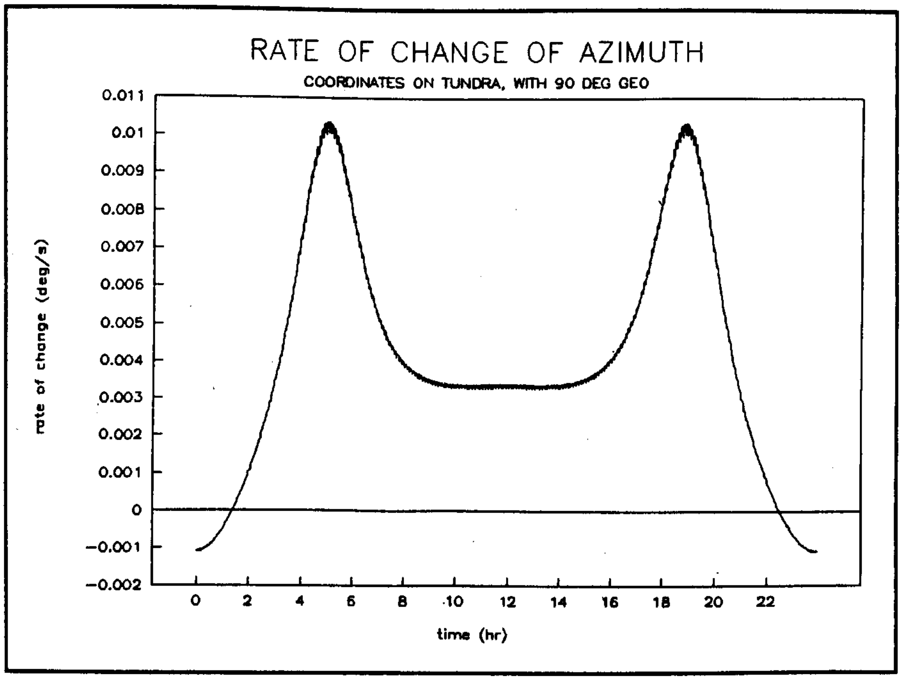


Figure A.2.2-23a ***Rate of Change of Azimuth for the Terminal on the Tundra Type Satellite when Pointing at the Geostationary Satellite at +90° Longitude***

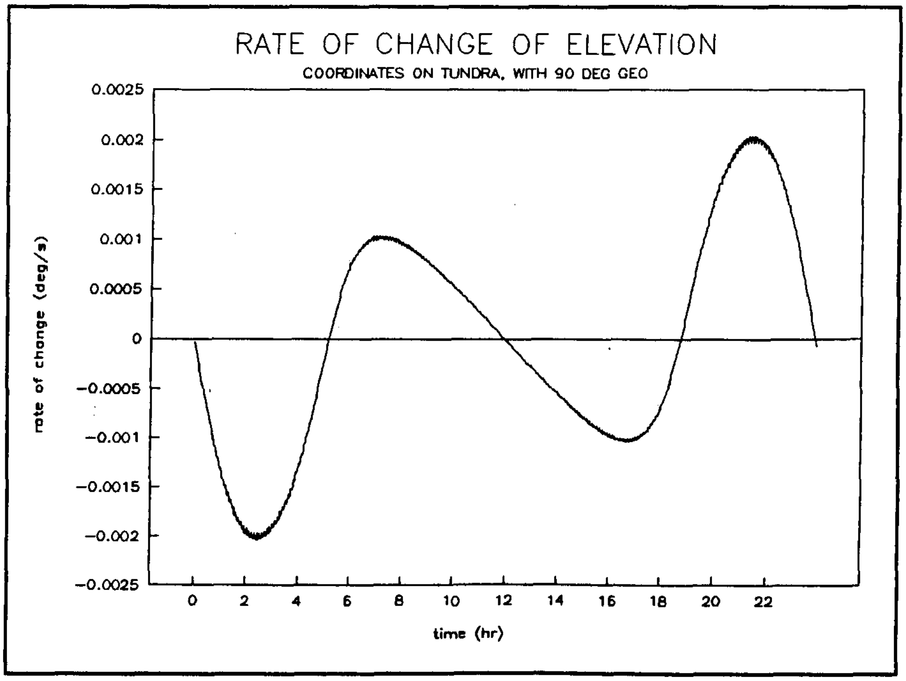


Figure A.2.2-23b ***Rate of Change of Elevation for the Terminal on a Tundra Type Satellite when Pointing at a Geostatinary Satellite at +90 Degrees Longitude***

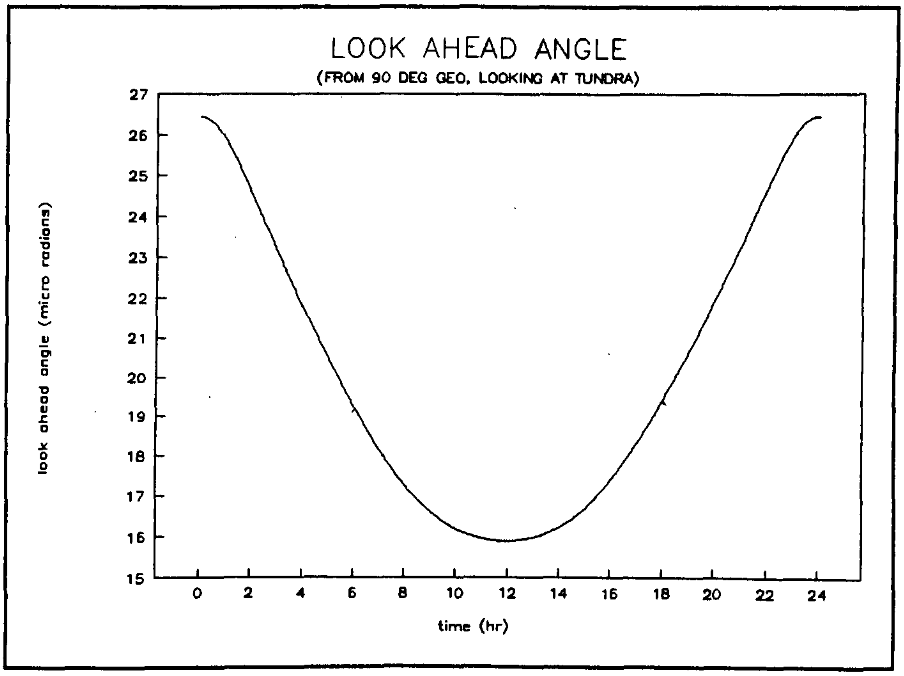


Figure A.2.2-24 ***Look Ahead Angle over a 24 Hour Period for the Terminal on the Geostationary Satellite at +90° Longitude when Pointing at the Tundra Type Satellite***

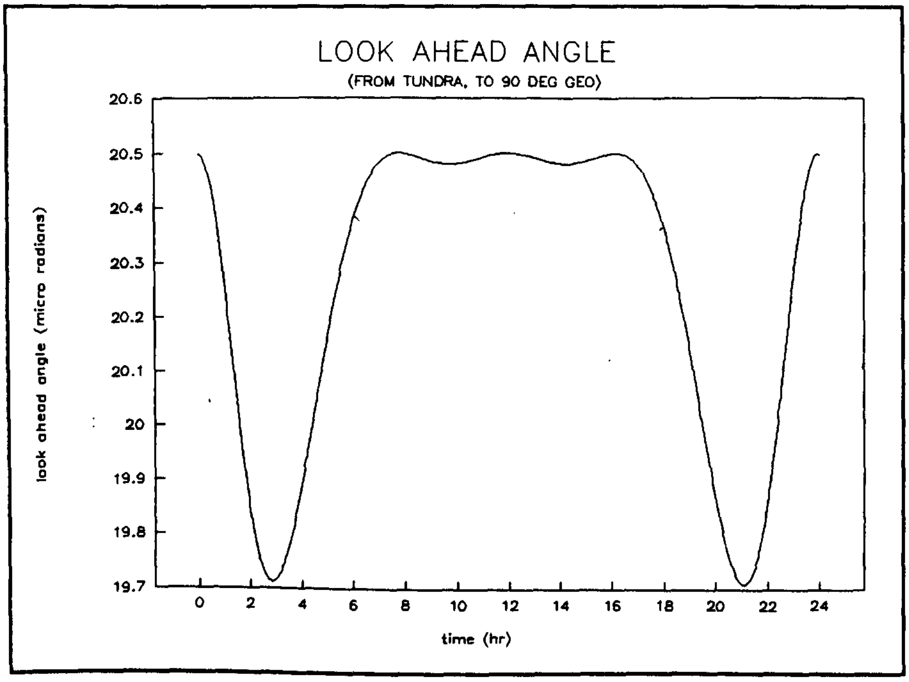


Figure A.2.2-25 Look Ahead Angle over a 24 Hour Period for the Terminal on the Tundra Type Satellite when Pointing at the Geostationary Satellite at +90° Longitude

A.3.0 GEOSTATIONARY TO LOW EARTH ORBIT (LEO) LINKS

A.3.1 Radarsat Orbit

The planned Radarsat orbit is a low altitude near polar orbit and has been selected as representing of that class of satellite. The parameters of the orbit are given in Table 2.0-1. Figure A.3.1-1 gives the ground trace.

Figures A.3.1-2 to A.1.3-9 give the link parameters of range, range rate, pointing angles, and angular rates as well as the look ahead angles when the cooperating terminal is on a geostationary satellite of -90° longitude.

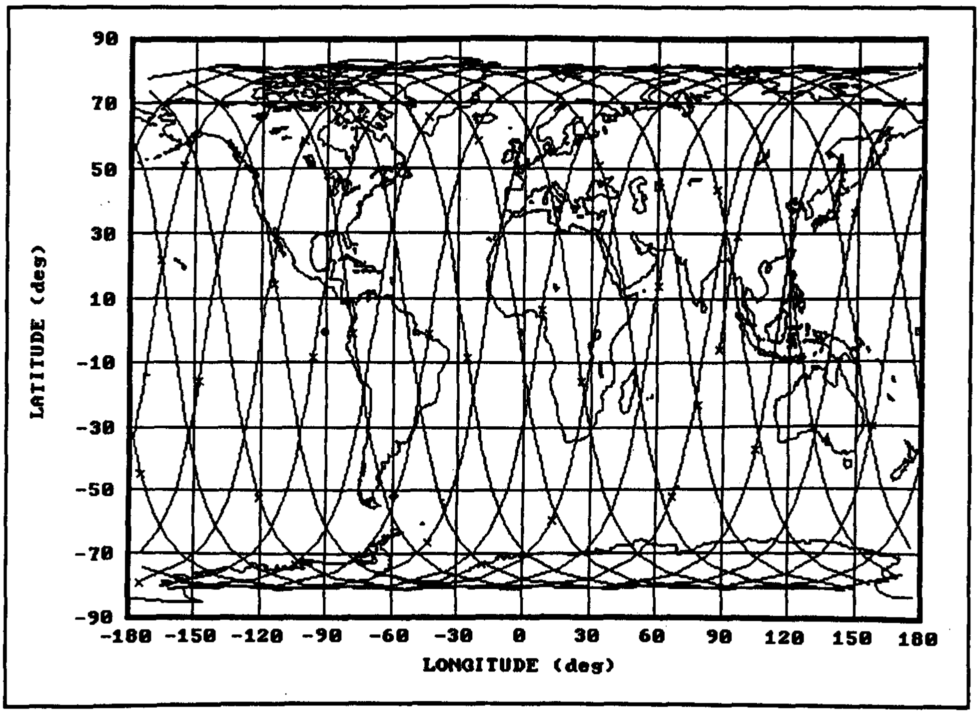


Figure A.3.1-1 The Ground Trace of Radarsat over a 24 Hour Period

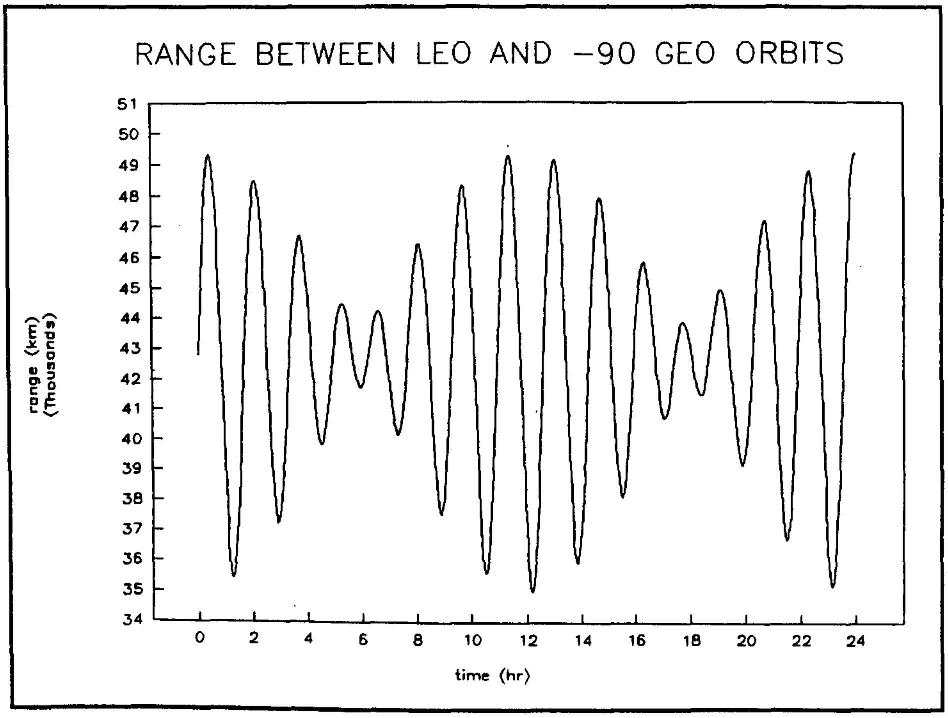


Figure A.3.1-2 ***Range Between Radarsat and a Geostationary Satellite at -90° Longitude***

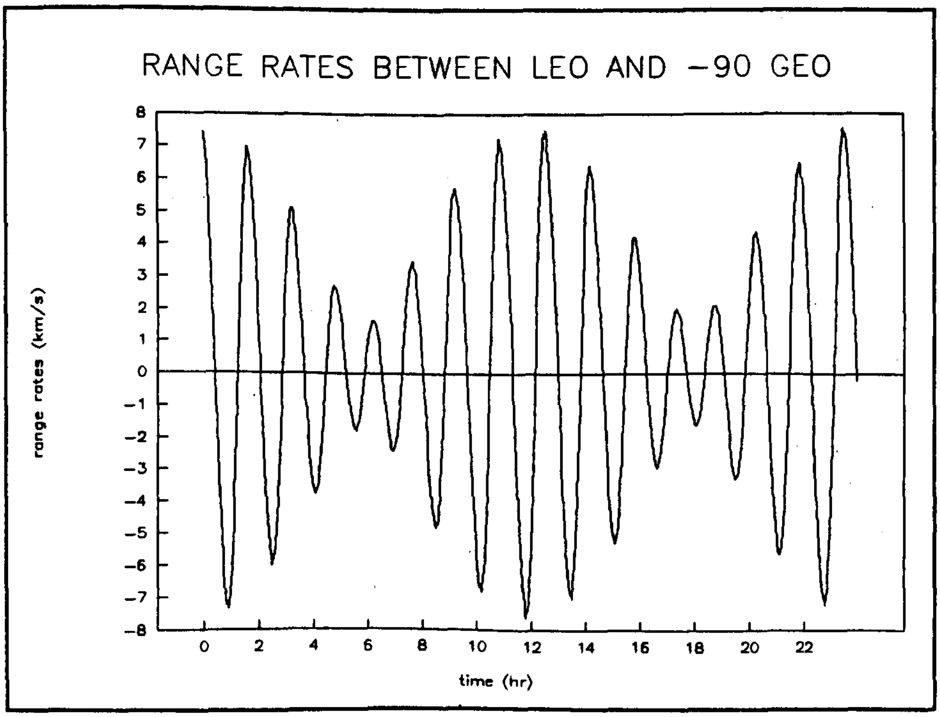


Figure A.3.1-3 ***Range Rate Between Radarsat and a Geostationary Satellite at -90° Longitude***

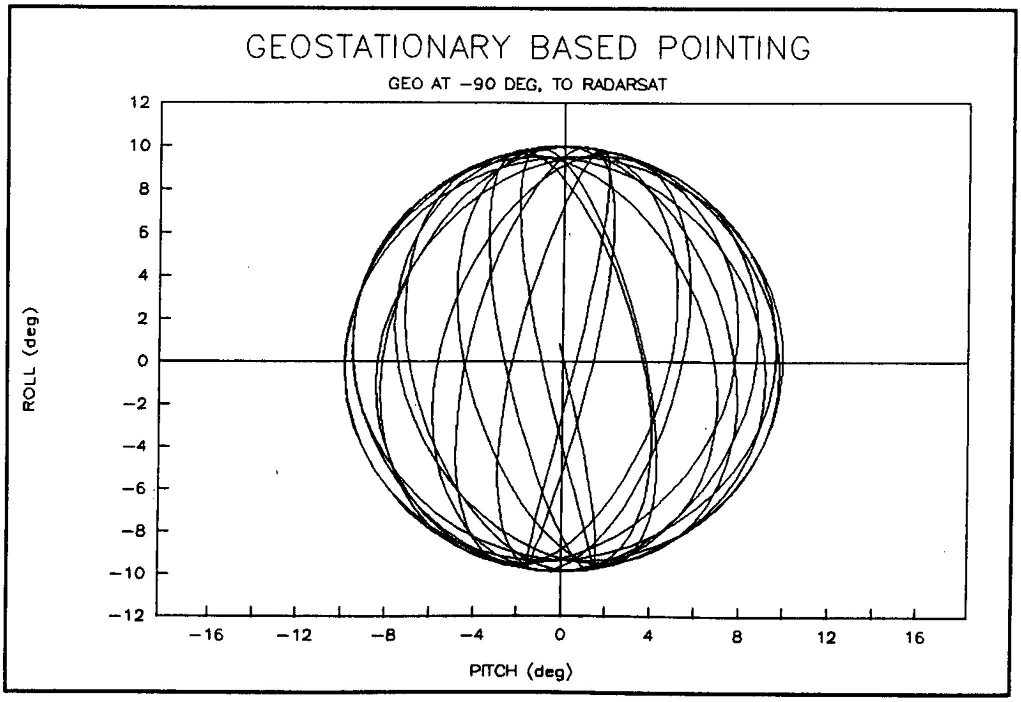


Figure A.3.1-4a *Pointing Angles over a 24 Hour Period of the Terminal on the Geostationary Satellite at -90° Longitude Required to Point at Radarsat*

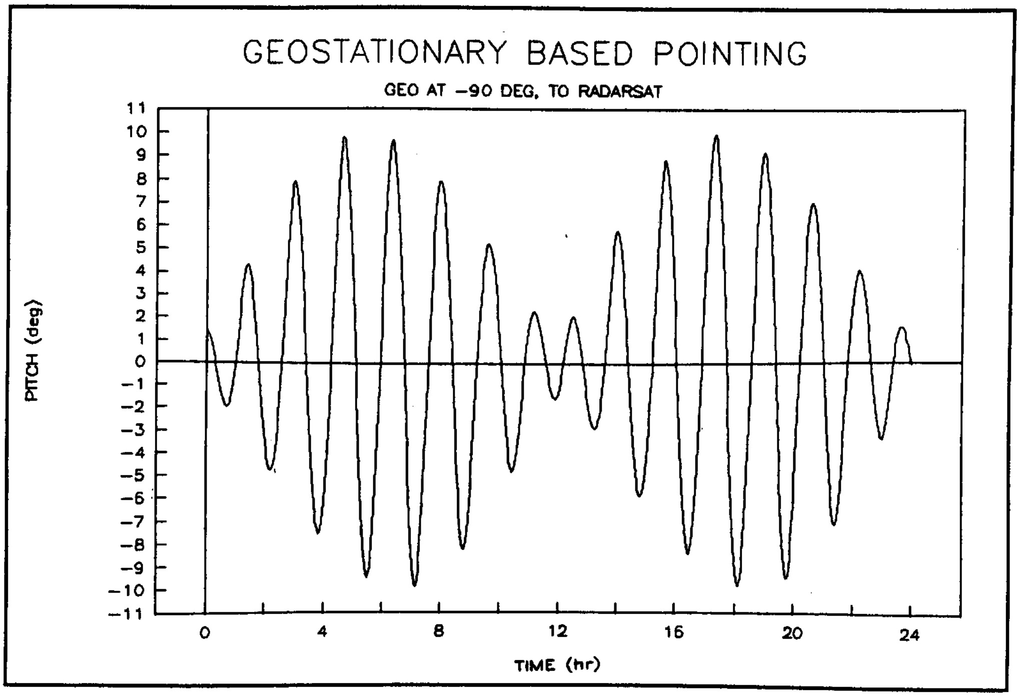


Figure A.3.1-4b *Pitch Angle on the Geostationary Satellite at -90 Degrees Longitude Required to Point at Radarsat*

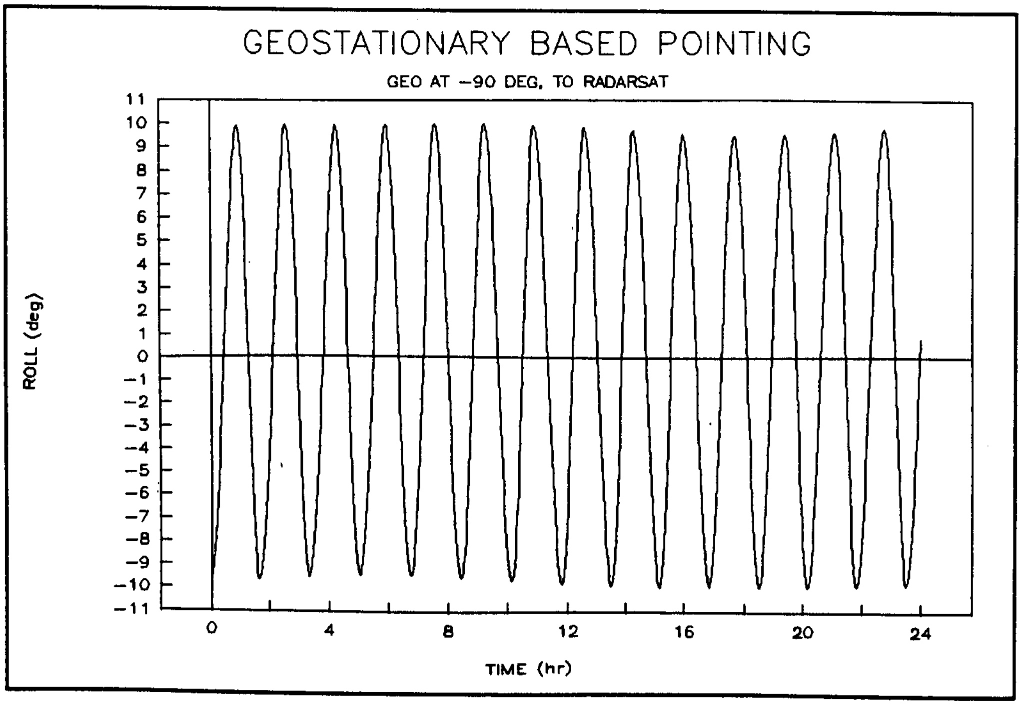


Figure A.3.1-4c *Roll Angle on the Geostationary Satellite at -90 Degrees Longitude Required to Look at Radarsat*

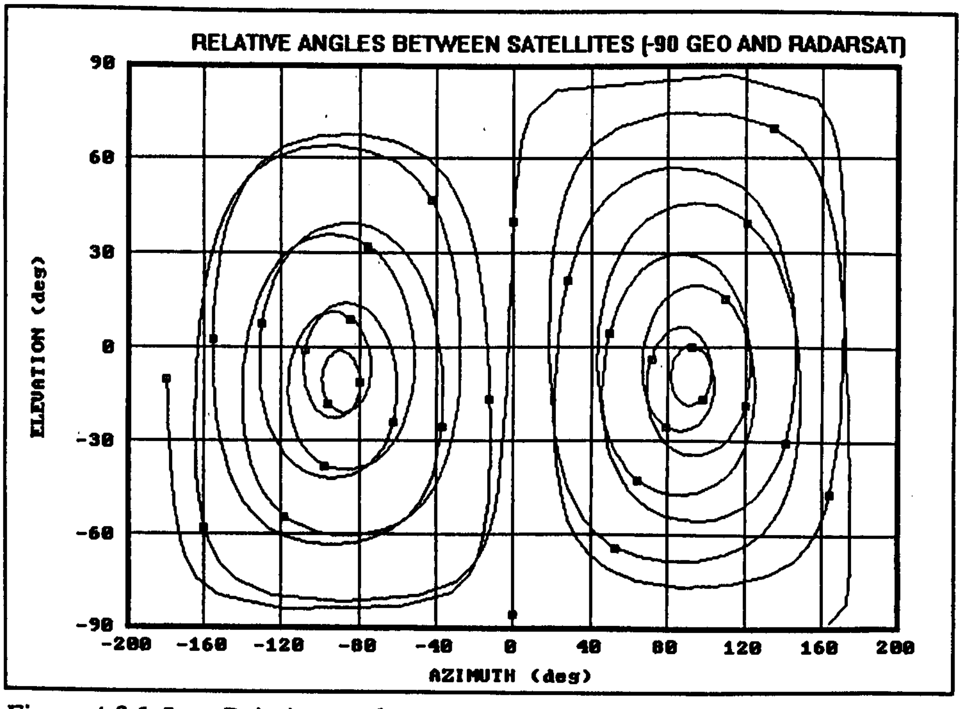


Figure A.3.1-5a *Pointing Angle over a 24 Hour Period of the Terminal on Radarsat Required to Point at a Geostationary Satellite at -90° Longitude*

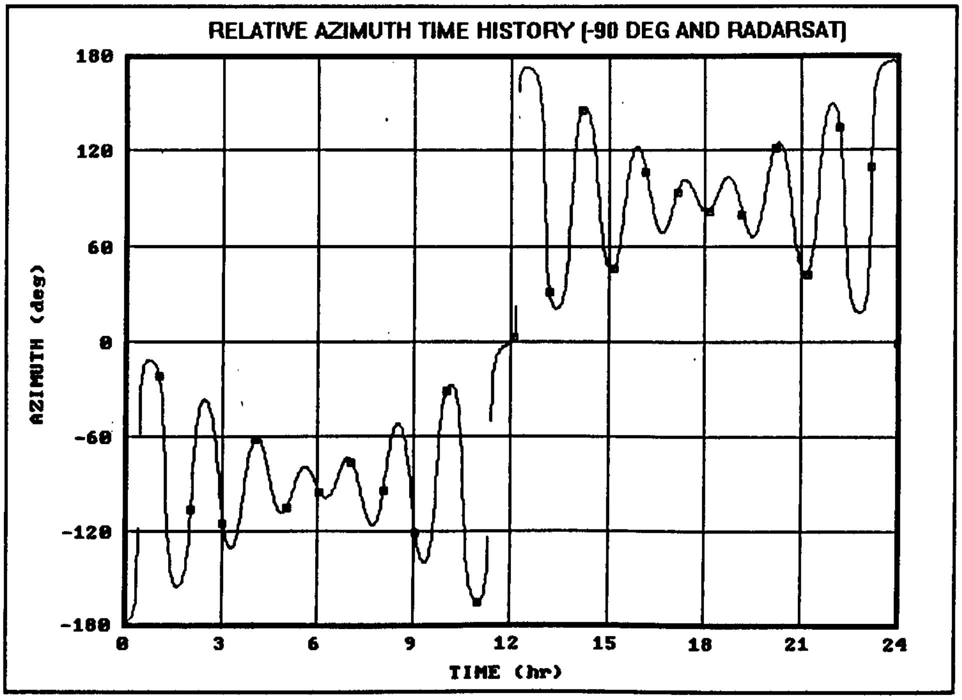


Figure A.3.1-5b *Azimuth Angle on Radarsat, Measured from the Velocity Vector, Required to Point to a Geostationary Satellite at -90° Longitude*

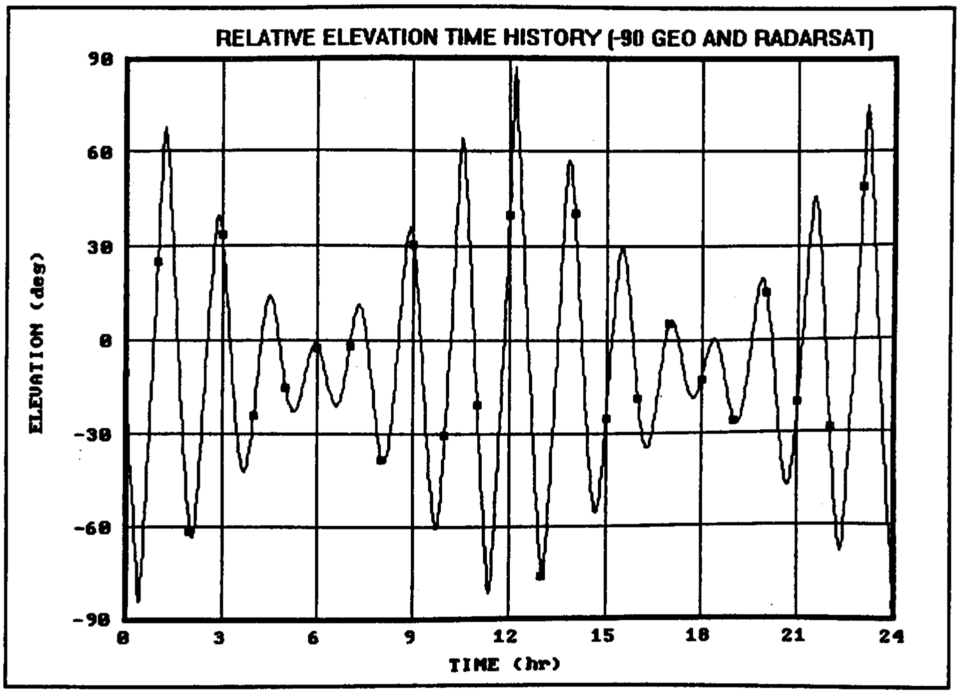


Figure A.3.1-5c *Elevation Angle on Radarsat Required to Point to a Geostationary Satellite at -90° Longitude*

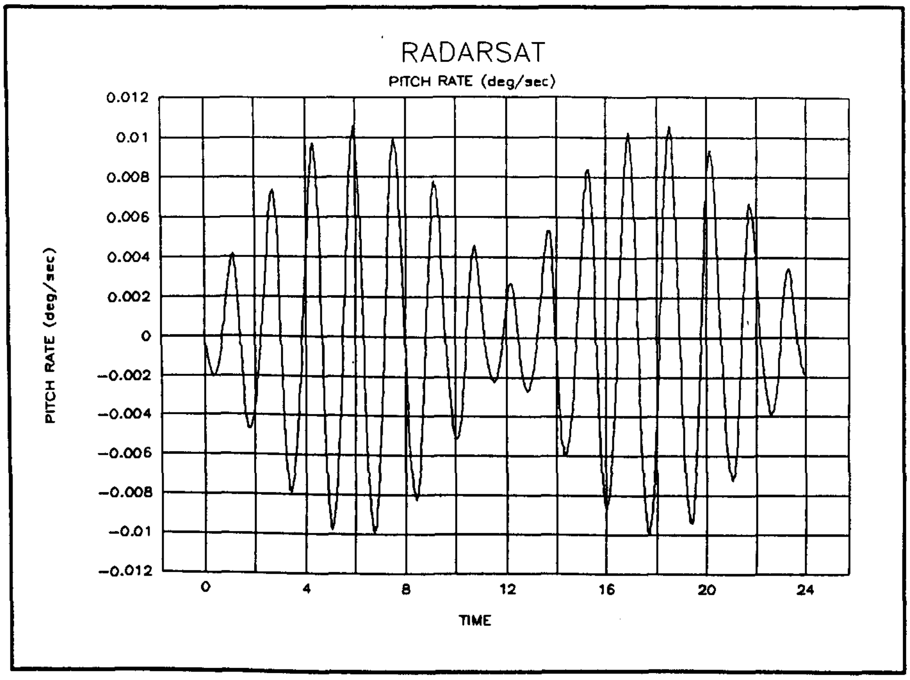


Figure A.3.1-6a *Rate of Change of Pitch for the Terminal on the Geostationary Satellite at -90° Longitude when Pointing at Radarsat*

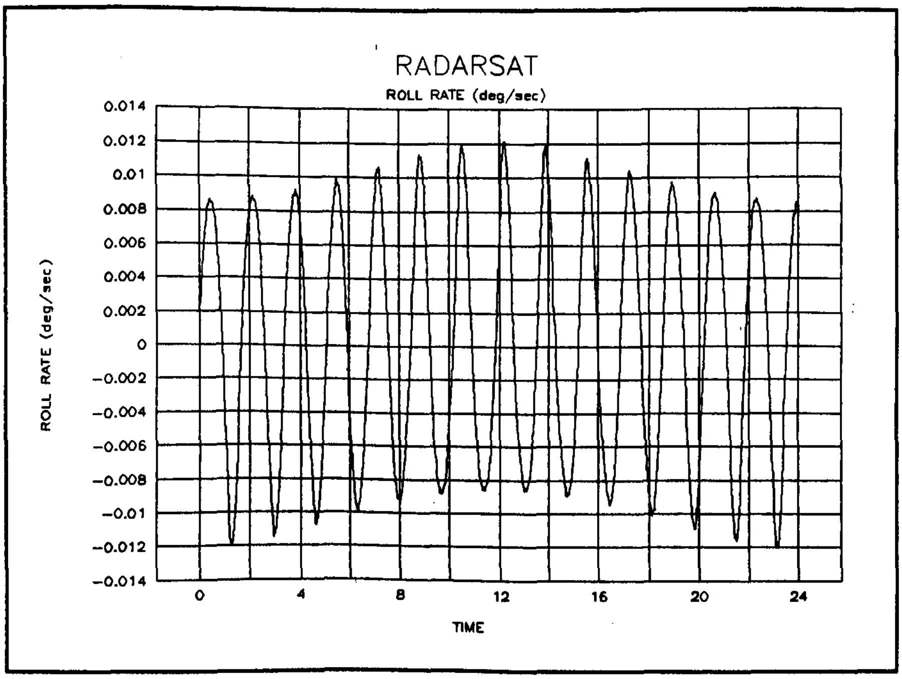


Figure A.3.1-6b *Rate of Change of Roll for the Terminal on the Geostationary Satellite at -90 Degrees Longitude when Pointing at Radarsat*

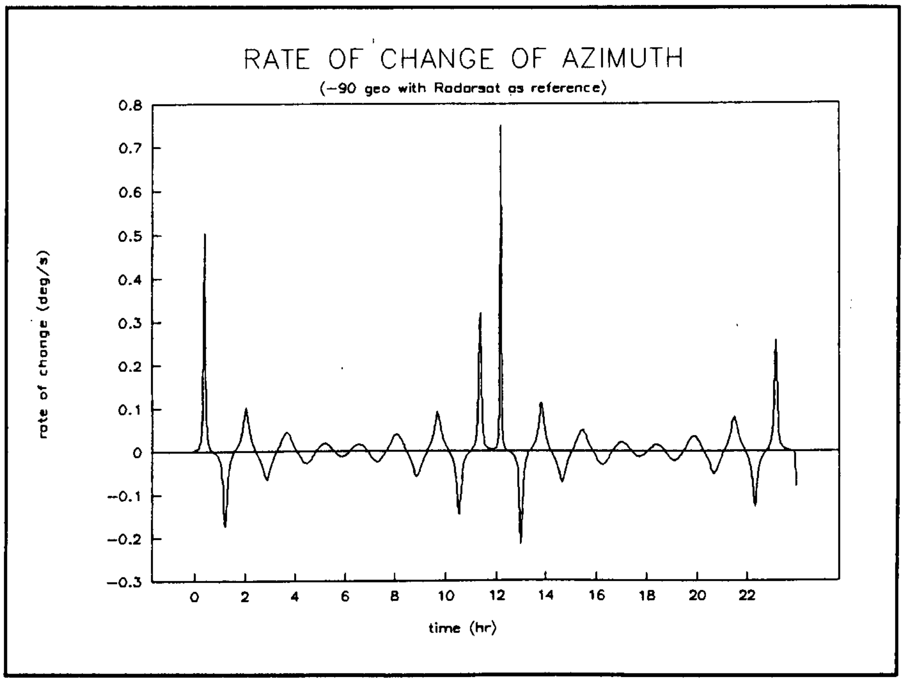


Figure A.3.1-7a *Rate of Change of Azimuth of the Terminal on Radarsat when Pointing at the Geostationary Satellite at -90° Longitude*

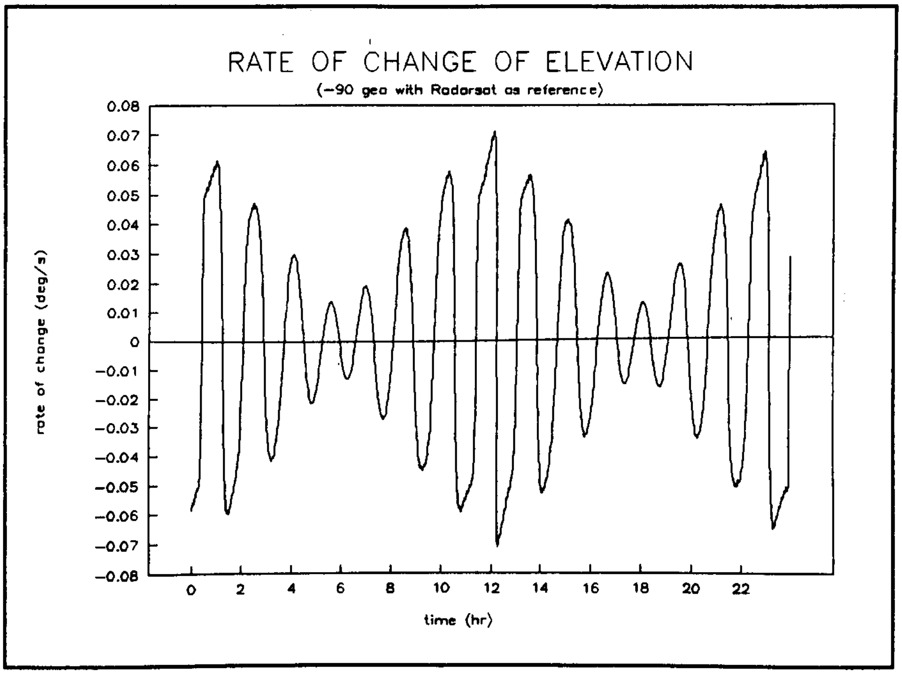


Figure A.3.1-7b *Rate of Change of Elevation of the Terminal on Radarsat when Pointing of a Geostationary Satellite at -90° Longitude*

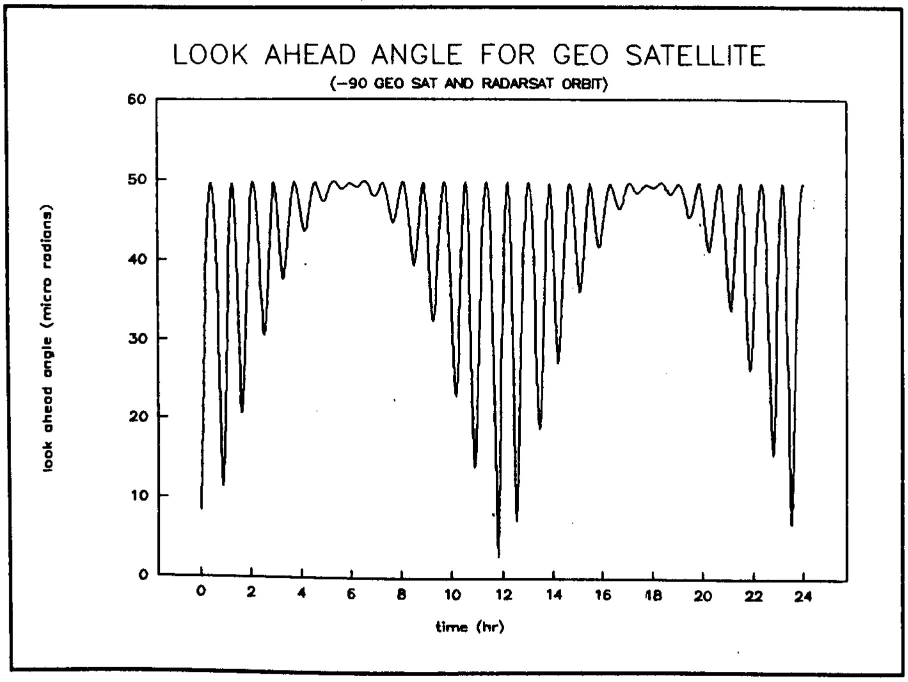


Figure A.3.1-8 ***Look Ahead Angle over a 24 Hour Period for the Terminal on the Geostationary Satellite at -90° Longitude when Pointing at Radarsat***

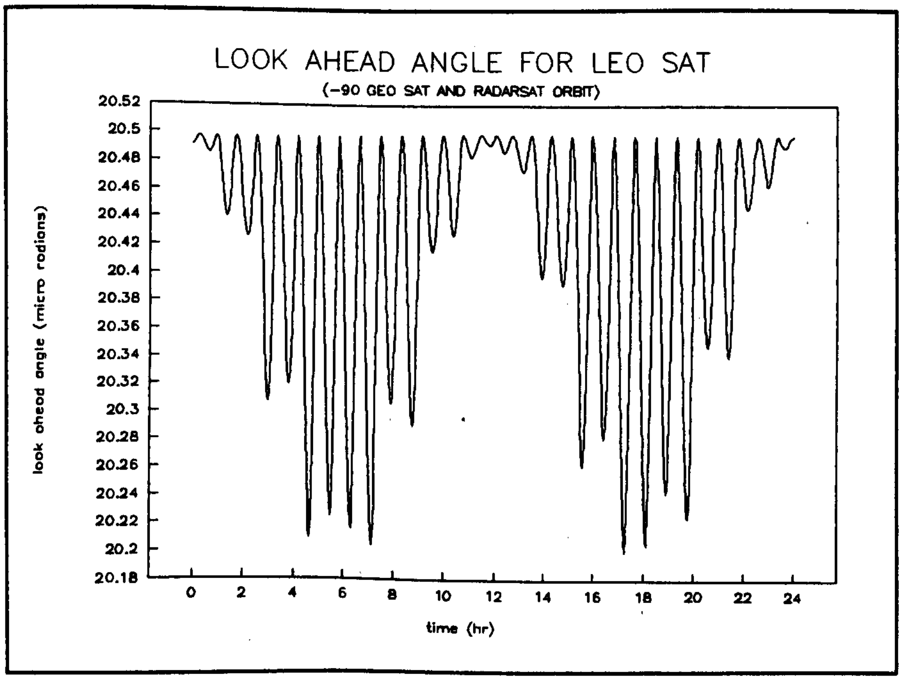


Figure A.3.1-9 ***Look Ahead Angle over a 24 Hour Period for the Terminal on Radarsat when Pointing at the Geostationary Satellite at -90° Longitude***

A.3.2 Space Station Freedom Orbit

The planned orbit for Space Station Freedom has been taken as representative of a near equatorial orbit. The parameters of the orbit are given in Table 2.0-1.

Figures A.3.2-1 gives the ground trace of the orbit. Figures A.3.2-2 to A.3.2-9 give the link parameters of range, range rate, pointing angles and angular rates as well as the look ahead angles when the cooperating terminal is on a geostationary satellite at -90° longitude.

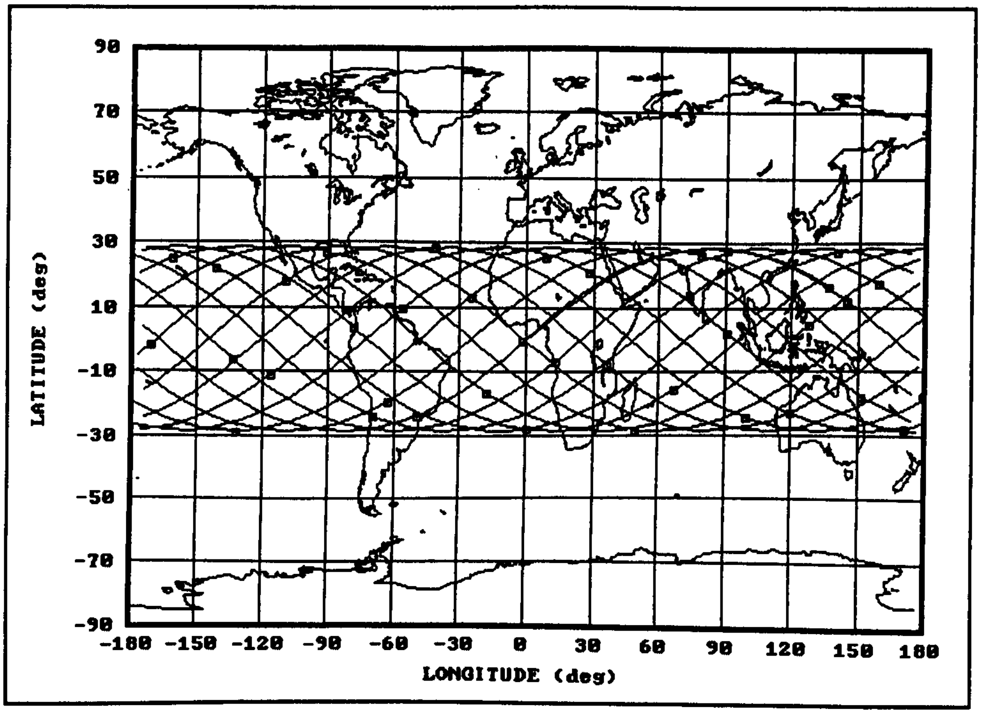


Figure A.3.2-1 The Ground Trace of Space Station Freedom over a Period of 24 Hours

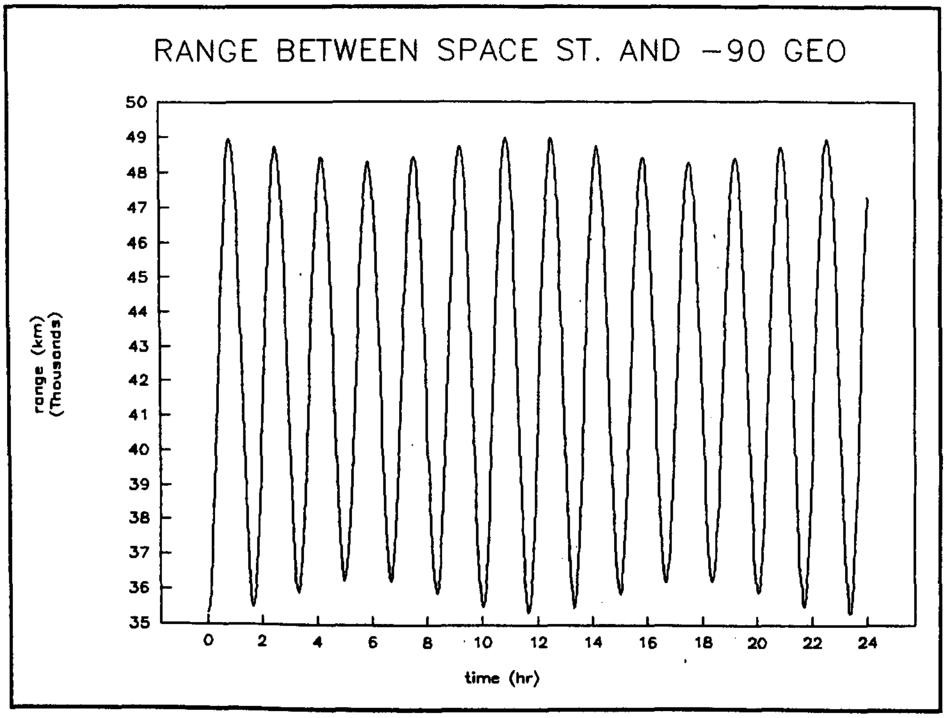


Figure A.3.2-2 ***Range Between Space Station Freedom and a Geostationary Satellite at -90° Longitude***

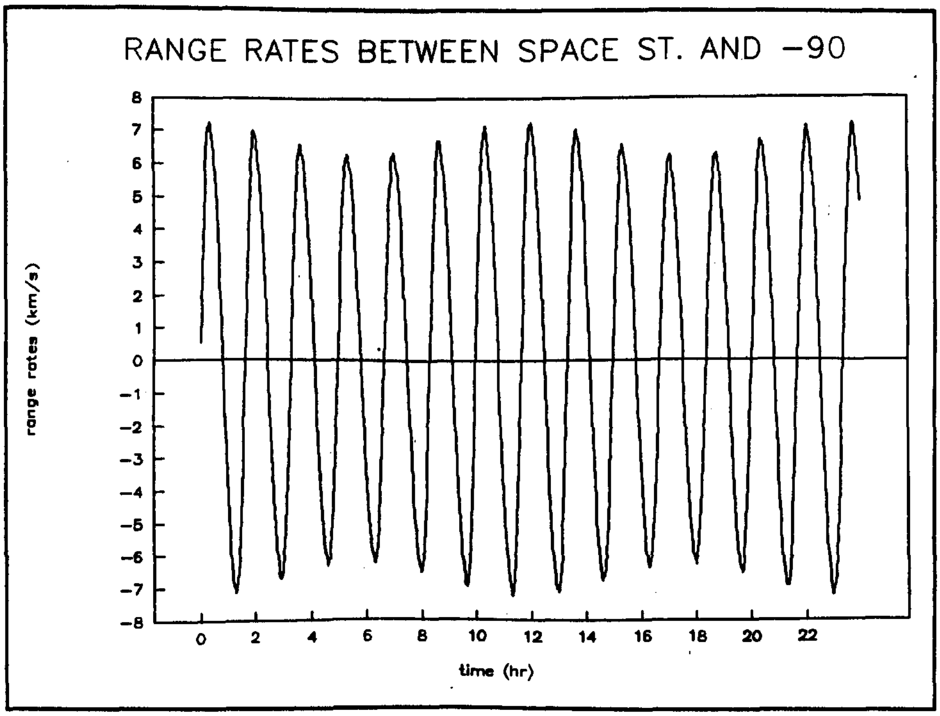


Figure A.3.2-3 ***Range Rate Between Space Station Freedom and a Geostationary Satellite at -90° Longitude***

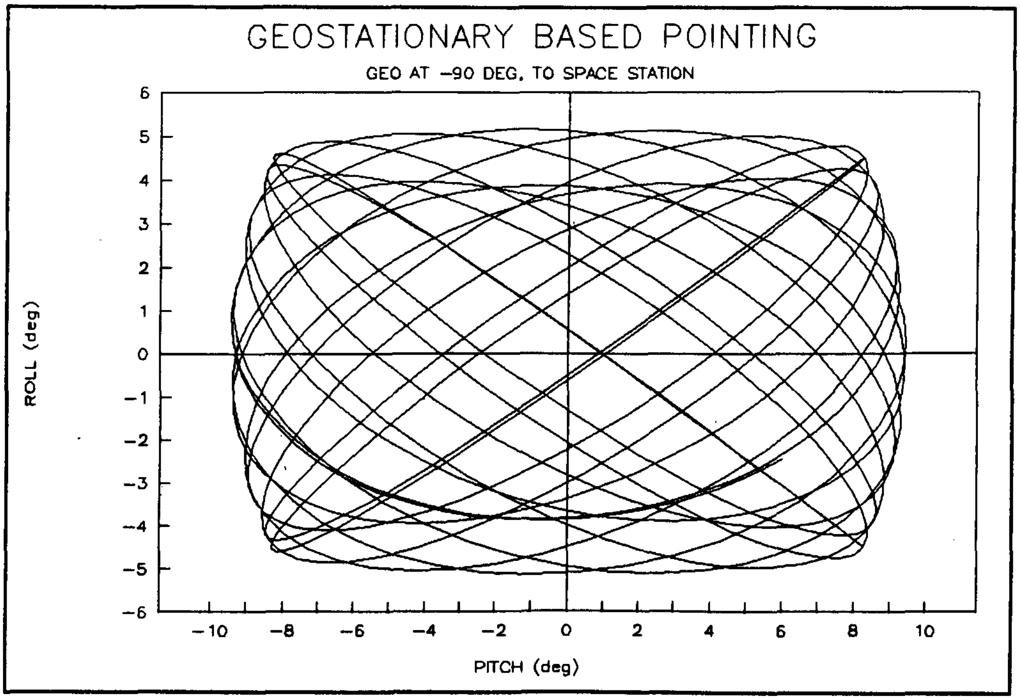


Figure A.3.2-4a Pointing Angles over a 24 Hour Period of the Terminal on the Geostationary Satellite at -90° Longitude Required to Point at Space Station Freedom

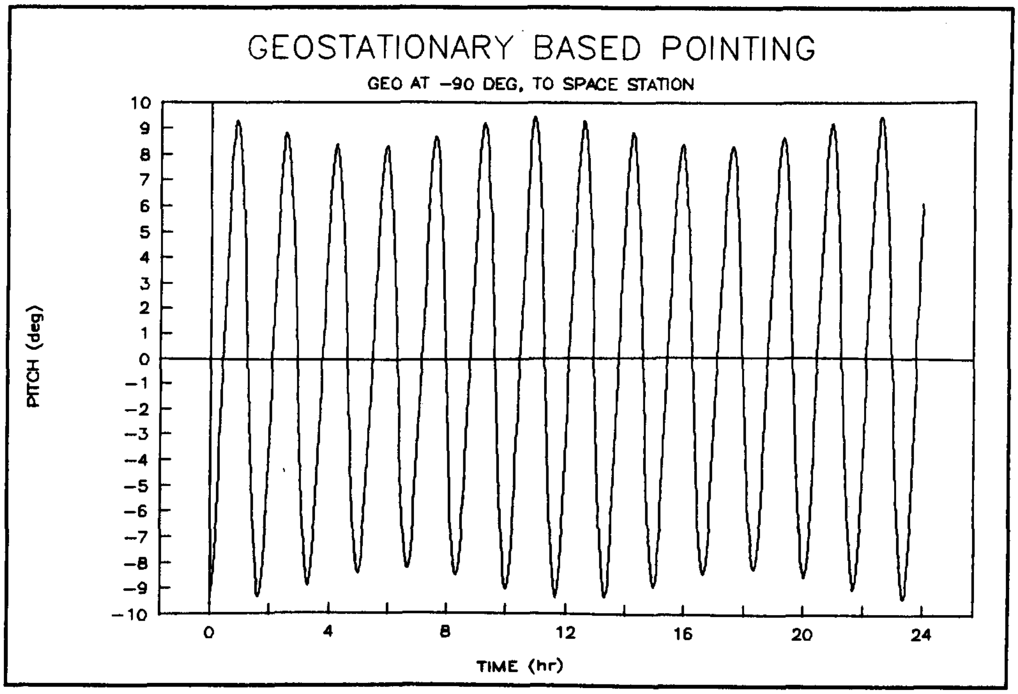


Figure A.3.2-4b Pitch Angle on the Geostationary Satellite at -90 Degrees Longitude Required to Point at Space Station Freedom

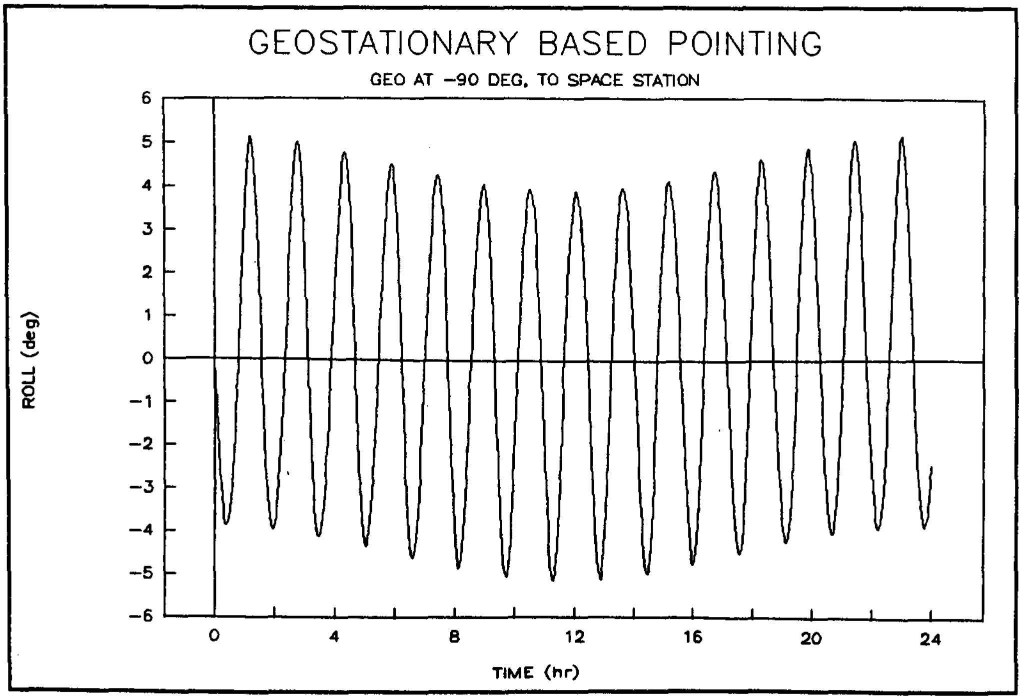


Figure A.3.2-4c ***Roll Angle on the Geostationary Satellite at -90 Degrees Longitude Required to Point at Space Station Freedom***

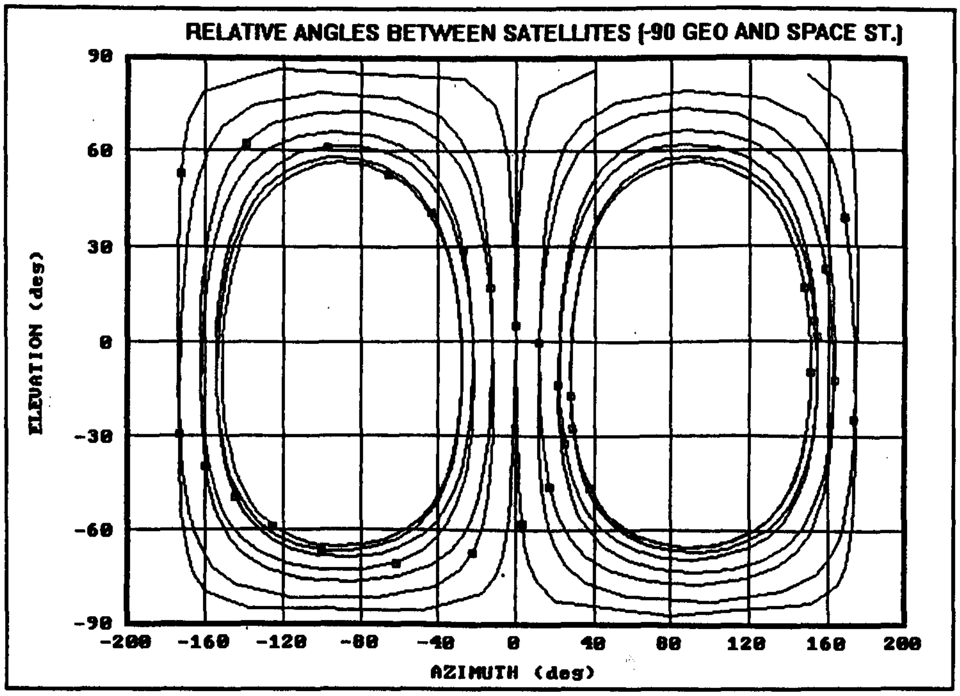


Figure A.3.2-5a ***Pointing Angle over a 24 Hour Period of the Terminal on the Space Station Freedom Required to Point at a Geostationary Satellite at -90° Longitude***

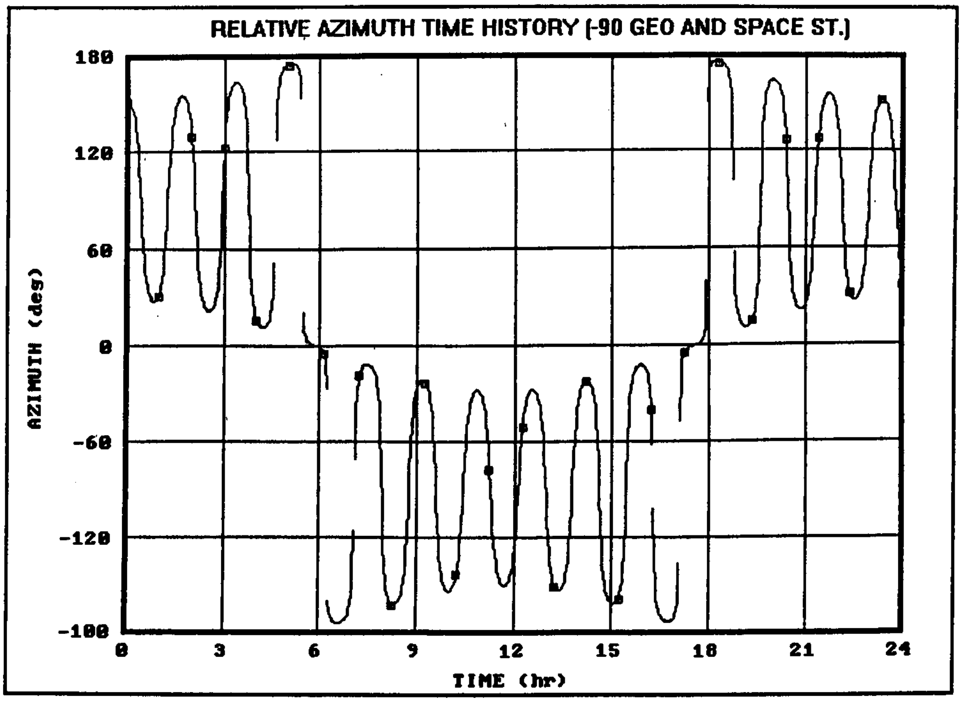


Figure A.3.2-5b Azimuth Angle on Space Station Freedom, Measure from the Velocity Vector, Required to Point at a Geostationary Satellite at -90° Longitude

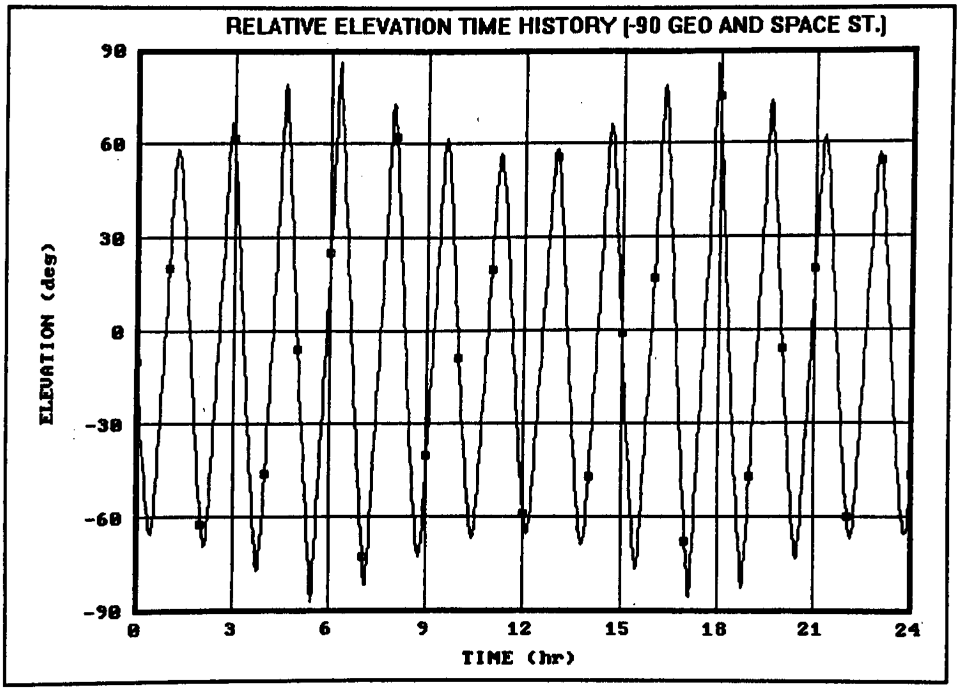


Figure A.3.2-5c Elevation Angle on Space Station Freedom Required to Point at a Geostationary Satellite at -90° Longitude

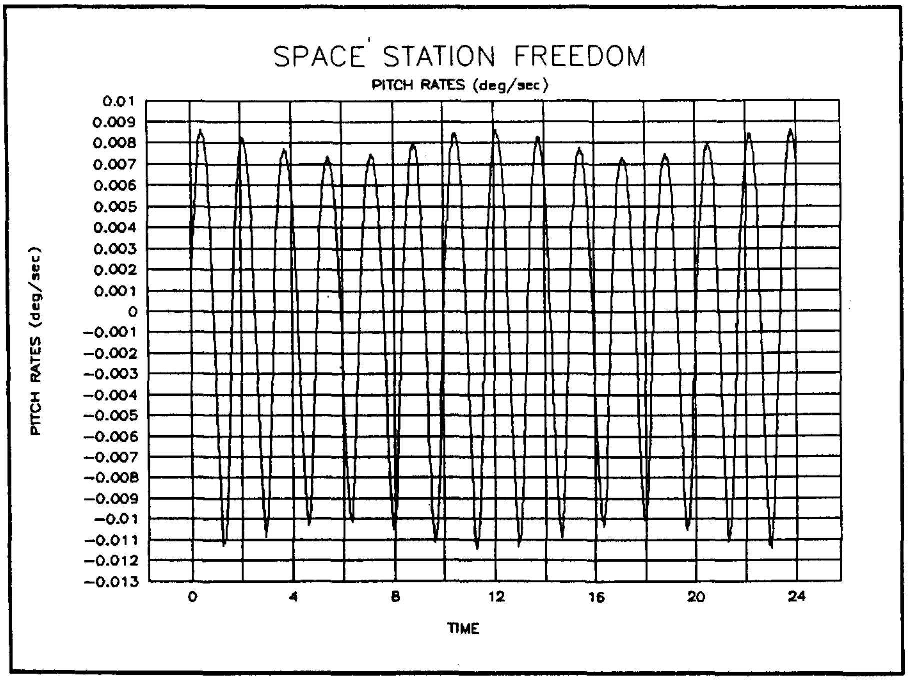


Figure A.3.2-6a ***Rate of Change of Pitch for the Terminal on the Geostationary Satellite at -90° Longitude when Pointing at Space Station Freedom***

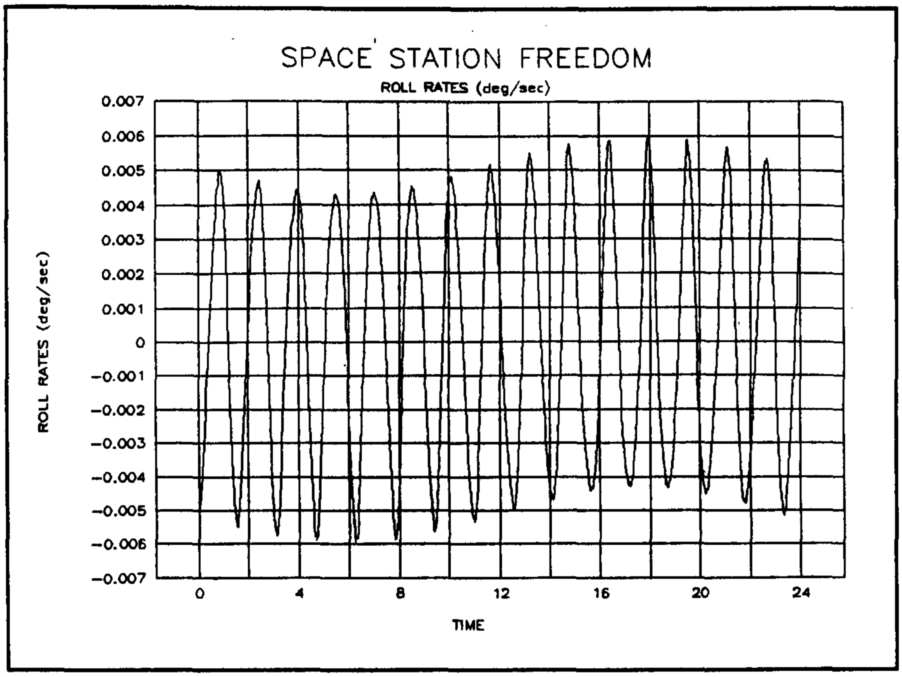


Figure A.3.2-6b ***Rate of Change of Roll for the Terminal on a Geostationary Satellite at -90 Degrees Longitude when Pointing at Space Station Freedom***

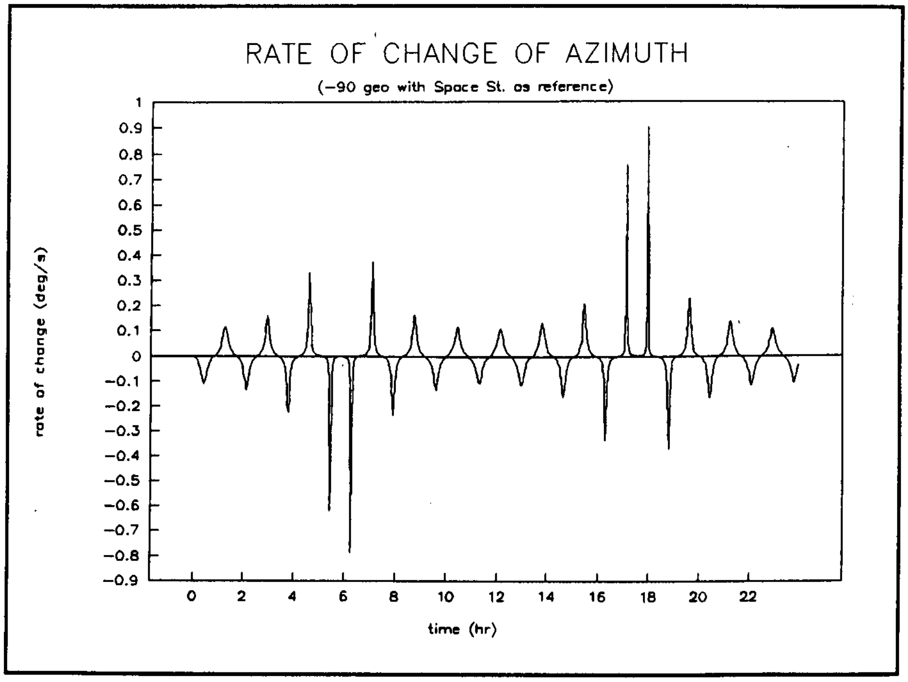


Figure A.3.2-7a ***Rate of Change of Azimuth of the Terminal on Space Station Freedom when Pointing at the Geostationary Satellite at -90° Longitude***

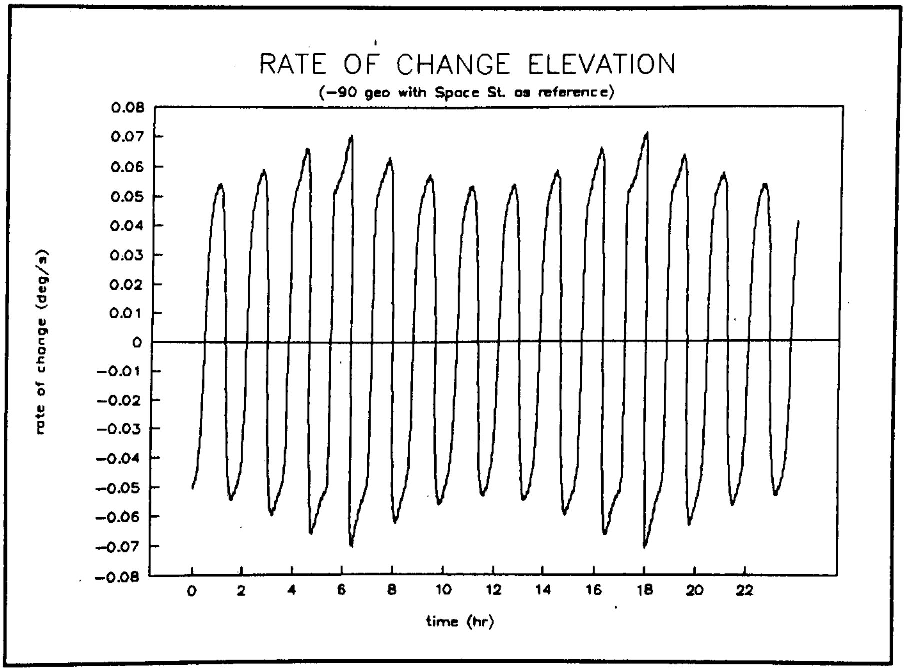


Figure A.3.2-7b ***Rate of Change of Elevation of the Terminal on Space Station Freedom when Pointing of a Geostationary Satellite at -90° Longitude***

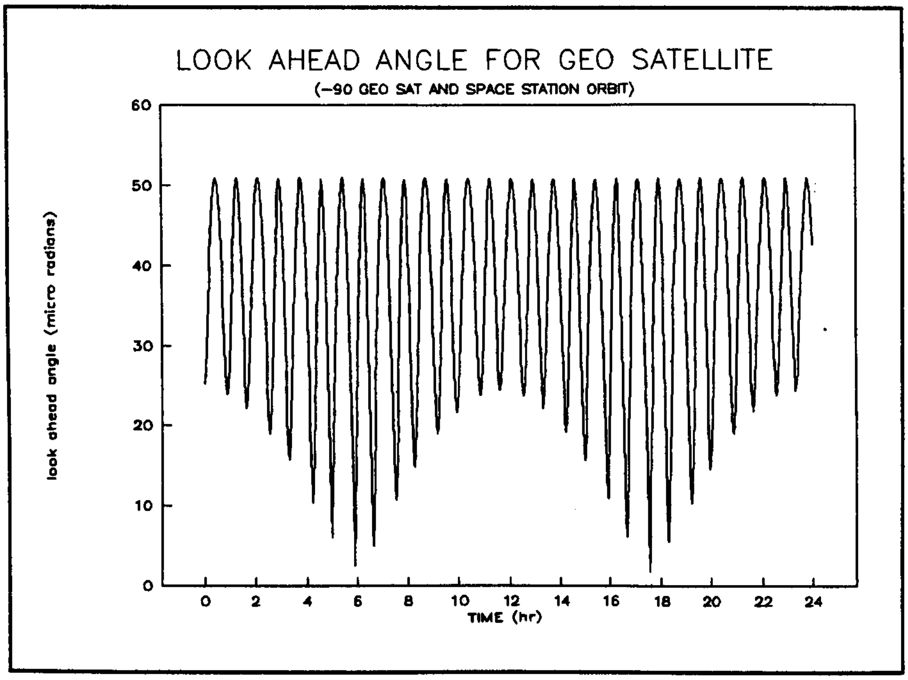


Figure A.3.2-8 *Look Ahead Angle over a 24 Hour Period for the Terminal on the Geostationary Satellite at -90° Longitude when Pointing at Space Station Freedom*

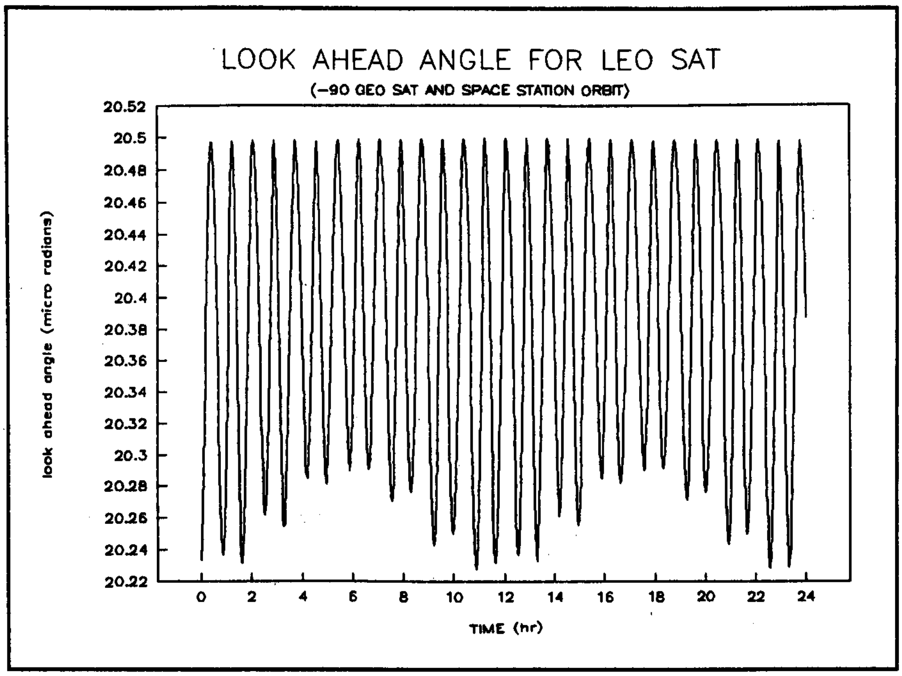


Figure A.3.2-9 *Look Ahead Angle over a 24 Hour Period for the Terminal on Space Station Freedom when Pointing at the Geostationary Satellite at -90° Longitude*

APPENDIX B

DETAILED LINK BUDGETS FOR COMPARISON OF HETERODYNE AND DIRECT DETECTION SYSTEMS

List of Tables

Table B-1 Comparison Between Heterodyne and Direct Detection for a CO_2 Laser at 1 Gbps

LASER ISL GEO-GEO	Heterodyne	File A:GG1GC.wk1	Direct detection	
Laser Type	CO2		CO2	
Wavelength (nm)	10600		10600	
Bit Rate (Mbps)	1000		1000	
Modulator type	External		External	
Modulation type	FSK		FSK	
Detection type	Heterodyne		Direct	
Path Length (km)	73000		73000	
TRANSMIT TELESCOPE GAIN (dB)		95.8		95.8
Aperture Diameter (cm)	30.0		30.0	
Aperture Gain	99.0		99.0	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.3		0.3	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.1		0.1	
N.E.A. (micro rad.)	1.5		1.5	
NET TRANSMITTER POWER (dBW)		6.5		10.2
Average Laser Power (dBW	7.2		10.7	
(Watts)	5.25		11.75	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.5		0.5	
Polarizer Loss	0.2		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Det. Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-278.7		-278.7
RECEIVER TELESCOPE GAIN (dB)		97.6		97.6
Aperture Diameter (cm)	30.0		30.0	
Aperture Gain	99.0		99.0	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.3		0.3	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-2.8		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.14		0.14	
Comms Det. Coupler	0.1		0.1	
Polarizer loss	0.2		0.0	
L. O. Coupler loss	0.3		0.0	
Wavefront mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVE SENSITIVITY		-85.4		-79.4
Photon Energy (J)	1.87E-20		1.87E-20	
Av. Ph./Bit at BER=10^-6	150.0		600.0	
Rcv. Sens. (dBW)	-85.5		-79.5	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.1		0.0	
Background Illumination	0.0		0.07	
SYSTEM MARGIN		3.0		3.0

Table B-2 Comparison Between Heterodyne and Direct Detection for an InGaAsP Laser at 1 Gbps

LASER ISL GEO-GEO — File A:GG1GI.WK3

	Heterodyne		Direct detection	
Laser Type	InGaAsP		InGaAsP	
Wavelength (nm)	1550		1550	
Bit Rate (Mbps)	1000		1000	
Modulator type	Bias		Bias	
Modulation type	FSK		ASK	
Detection type	Heterodyne		Direct	
Path Length (km)	73000		73000	
TRANSMIT TELESCOPE GAIN (dB)		111.9		111.9
Aperture Diameter (cm)	30.0		30.0	
Aperture Gain	115.7		115.7	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.5		0.5	
N.E.A. (micro rad.)	0.45		0.45	
TRANSMITTER POWER (dBW)		-5.4		-0.2
Average Laser Power (dBW	-5.1		-0.2	
(Watts)	0.31		0.95	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.3		0.0	
TRANSMIT OPTICS PATH LOSS(dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-295.4		-295.4
RECEIVER OPTICS GAIN (dB)		114.1		114.1
Aperture Diameter (cm)	30.0		30.0	
Aperture Gain	115.7		115.7	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-2.8		-0.5
Fine Poiting Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.14		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.3		0.0	
L. O. Coupler loss	0.2		0.0	
Wavefront mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVER SENSITIVITY (dBW)		-81.4		-73.9
Photon Energy (J)	1.28E-19		1.28E-19	
Av. Ph./Bit at BER=10^-6	55.0		310.0	
Rcv. Sens. (dBW)	-81.5		-74.0	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.1		0.0	
Background Illumination	0.0		0.07	
SYSTEM MARGIN		3.0		3.0

Table B-3 Comparison Between Heterodyne and Direct Detection for a Nd:Yag Laser at 1 Gbps

LASER ISL GEO-GEO — File A:GG1GN.wk1

	Heterodyne		Direct detection	
Laser Type	Nd:Yag		Nd:Yag	
Wavelength (nm)	1060		1060	
Bit Rate (Mbps)	1000		1000	
Modulator type	External		External	
Modulation type	FSK		FSK	
Detection type	Heterodyne		Direct	
Path Length (km)	73000		73000	
TRANSMIT TELESCOPE GAIN (dB)		113.7		113.7
Aperture Diameter (cm)	25.0		25.0	
Aperture Gain	117.4		117.4	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.4		0.4	
N.E.A. (micro rad.)	0.35		0.35	
TRANSMITTER POWER (dBW)		-3.9		-0.7
Average Laser Power(dBW)	-3.5		-0.6	
(Watts)	0.45		0.87	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.1		0.1	
Polarizer Loss	0.3		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-298.7		-298.7
RECEIVE TELESCOPE GAIN (dB)		115.8		115.8
Aperture Diameter (cm)	25.0		25.0	
Aperture Gain	117.4		117.4	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-2.8		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.14		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.3		0.0	
L. O. Coupler loss	0.2		0.0	
Wavefront Mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVER SENSITIVITY (dBW)		-79.8		-74.2
Photon Energy (J)	1.87E-19		1.87E-19	
Av. Ph./Bit at BER=10^-6	55.0		200.0	
Rcv. Sens. (dBW)	-79.9		-74.3	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.1		0.0	
Background Illumination	0.0		0.07	
SYSTEM MARGIN		3.0		3.0

Table B-4 Comparison Between Heterodyne and Direct Detection for an AlGaAs Laser at 1 Gbps

LASER ISL GEO-GEO	File A:GG1GA.wk1			
	Heterodyne		Direct detection	
Laser Type	AlGaAs		AlGaAs	
Wavelength (nm)	850		850	
Bit Rate (Mbps)	1000		1000	
Modulator type	Bias		Bias	
Modulator type	FSK		ASK	
Detection type	Heterodyne		Direct	
Path Length (km)	73000		73000	
TRANSMIT TELESCOPE GAIN (dB)		116.9		116.9
Aperture Diameter (cm)	30.0		30.0	
Aperture Gain	120.9		120.9	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.7		0.7	
N.E.A. (micro rad.)	0.3		0.3	
TRANSMITTER POWER (dBW)		-7.8		-7.1
Average Laser Power (dBW	-7.5		-7.1	
(Watts)	0.18		0.19	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.3		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-300.7		-300.7
RECEIVE TELESCOPE GAIN (dB)		119.3		119.3
Aperture Diameter (cm)	30.0		30.0	
Aperture Gain	120.9		120.9	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-2.8		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.14		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.3		0.0	
L. O. coupler loss	0.2		0.0	
Wavefront mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVER SENSITIVITY (dBW)		-78.8		-75.8
Photon Energy (J)	2.34E-19		2.34E-19	
Av. Ph./Bit at BER=10^-6	55.0		110.0	
Rcv. Sens. (dBW)	-78.9		-75.9	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.1		0.0	
Background Illumination	0.0		0.07	
SYSTEM MARGIN		3.0		3.0

Table B-5 Comparison Between Heterodyne and Direct Detection for a CO_2 Laser at 100 Mbps

LASER ISL GEO-GEO	File A:GG100MC.wk1			
	Heterodyne		Direct detection	
Laser Type	CO2		CO2	
Wavelength (nm)	10600		10600	
Bit Rate (Mbps)	100		100	
Modulator type	External		External	
Modulation type	FSK		FSK	
Detection type	Heterodyne		Direct	
Path Length (km)	73000		73000	
TRANSMIT TELESCOPE GAIN (dB)		90.9		90.9
Aperture Diameter (cm)	17.0		17.0	
Aperture Gain	94.0		94.0	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.3		0.3	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.05		0.05	
N.E.A. (micro rad.)	1.7		1.7	
NET TRANSMITTER POWER (dBW)		6.3		10.5
Average Laser Power (dBW	7.0		11.0	
(Watts)	5.01		12.59	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.5		0.5	
Polarizer Loss	0.2		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Det. Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-278.7		-278.7
RECEIVER TELESCOPE GAIN (dB)		92.6		92.6
Aperture Diameter (cm)	17.0		17.0	
Aperture Gain	94.0		94.0	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.3		0.3	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-2.8		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.14		0.14	
Comms Det. Coupler	0.1		0.1	
Polarizer loss	0.2		0.0	
L. O. Coupler loss	0.3		0.0	
Wayefront mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVE SENSITIVITY		-95.4		-89.0
Photon Energy (J)	1.87E-20		1.87E-20	
Av. Ph./Bit at BER=10^-6	150.0		600.0	
Rcv. Sens. (dBW)	-95.5		-89.5	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.1		0.0	
Background Illumination	0.0		0.5	
SYSTEM MARGIN		3.0		3.0

Table B-6 Comparison Between Heterodyne and Direct Detection for an InGaAsP Laser at 100 Mbps

LASER ISL GEO-GEO File A:GG100MI.WK3

	Heterodyne		Direct detection	
Laser Type	InGaAsP		InGaAsP	
Wavelength (nm)	1550		1550	
Bit Rate (Mbps)	100		100	
Modulator type	Bias		Bias	
Modulation type	FSK		ASK	
Detection type	Heterodyne		Direct	
Path Length (km)	73000		73000	
TRANSMIT TELESCOPE GAIN (dB)		111.5		111.5
Aperture Diameter (cm)	29.0		29.0	
Aperture Gain	115.4		115.4	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.6		0.6	
N.E.A. (micro rad.)	0.5		0.5	
TRANSMITTER POWER (dBW)		-16.1		-11.0
Average Laser Power (dBW	-15.8		-11.0	
(Watts)	0.026		0.08	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.3		0.0	
TRANSMIT OPTICS PATH LOSS(dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-295.4		-295.4
RECEIVER OPTICS GAIN (dB)		113.8		113.8
Aperture Diameter (cm)	29.0		29.0	
Aperture Gain	115.4		115.4	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-2.8		-0.5
Fine Poiting Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.14		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.3		0.0	
L. O. Coupler loss	0.2		0.0	
Wavefront mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVER SENSITIVITY (dBW)		-92.8		-85.4
Photon Energy (J)	1.28E-19		1.28E-19	
Av. Ph./Bit at BER=10^-6	40.0		200.0	
Rcv. Sens. (dBW)	-92.9		-85.9	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.1		0.0	
Background Illumination	0.0		0.5	
SYSTEM MARGIN		3.0		3.0

Table B-7 Comparison Between Heterodyne and Direct Detection for a Nd:Yag Laser at 100 Mpbs

LASER ISL GEO-GEO	File A:GG100MN.wk1			
	Heterodyne		Direct detection	
Laser Type	Nd:Yag		Nd:Yag	
Wavelength (nm)	1060		1060	
Bit Rate (Mbps)	100		100	
Modulator type	External		External	
Modulation type	FSK		FSK	
Detection type	Heterodyne		Direct	
Path Length (km)	73000		73000	
TRANSMIT TELESCOPE GAIN (dB)		106.8		106.8
Aperture Diameter (cm)	11.0		11.0	
Aperture Gain	110.3		110.3	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.2		0.2	
N.E.A. (micro rad.)	0.5		0.5	
TRANSMITTER POWER (dBW)		-1.3		-0.5
Average Laser Power (dBW)	-0.9		-0.4	
(Watts)	0.81		0.91	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.1		0.1	
Polarizer Loss	0.3		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-298.7		-298.7
RECEIVE TELESCOPE GAIN (dB)		108.7		108.7
Aperture Diameter (cm)	11.0		11.0	
Aperture Gain	110.3		110.3	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-2.8		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.14		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.3		0.0	
L. O. Coupler loss	0.2		0.0	
Wavefront Mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVER SENSITIVITY (dBW)		-91.2		-88.0
Photon Energy (J)	1.87E-19		1.87E-19	
Av. Ph./Bit at BER=10^-6	40.0		75.0	
Rcv. Sens. (dBW)	-91.3		-88.5	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.1		0.0	
Background Illumination	0.0		0.5	
SYSTEM MARGIN		3.0		3.0

Table B-8 Comparison Between Heterodyne and Direct Detection for an AlGaAs Laser at 100 Mbps

LASER ISL GEO-GEO	File A:GG100MA.wk1			
	Heterodyne		Direct detection	
Laser Type	AlGaAs		AlGaAs	
Wavelength (nm)	850		850	
Bit Rate (Mbps)	100		100	
Modulator type	Bias		Bias	
Modulator type	FSK		ASK	
Detection type	Heterodyne		Direct	
Path Length (km)	73000		73000	
TRANSMIT TELESCOPE GAIN (dB)		113.4		113.4
Aperture Diameter (cm)	20.0		20.0	
Aperture Gain	117.4		117.4	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.7		0.7	
N.E.A. (micro rad.)	0.45		0.45	
TRANSMITTER POWER (dBW)		-12.1		-13.5
Average Laser Power (dBW	-11.8		-13.5	
(Watts)	0.066		0.04	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.3		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-300.7		-300.7
RECEIVE TELESCOPE GAIN (dB)		115.8		115.8
Aperture Diameter (cm)	20.0		20.0	
Aperture Gain	117.4		117.4	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-2.8		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.14		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.3		0.0	
L. O. coupler loss	0.2		0.0	
Wavefront mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVER SENSITIVITY (dBW)		-90.2		-89.3
Photon Energy (J)	2.34E-19		2.34E-19	
Av. Ph./Bit at BER=10^-6	40.0		45.0	
Rcv. Sens. (dBW)	-90.3		-89.8	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.1		0.0	
Background Illumination	0.0		0.5	
SYSTEM MARGIN		3.0		3.0

Table B-9 Comparison Between Heterodyne and Direct Detection for a CO_2 Laser at 1 Mbps

LASER ISL GEO-GEO   File A:GG1MC.wk1

	Heterodyne		Direct detection	
Laser Type	CO2		CO2	
Wavelength (nm)	10600		10600	
Bit Rate (Mbps)	1		1	
Modulator type	External		External	
Modulation type	FSK		FSK	
Detection type	Heterodyne		Direct	
Path Length (km)	73000		73000	
TRANSMIT TELESCOPE GAIN (dB)		82.1		82.1
Aperture Diameter (cm)	6.8		6.8	
Aperture Gain	86.1		86.1	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.3		0.3	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.9		0.9	
N.E.A. (micro rad.)	18		18	
NET TRANSMITTER POWER (dBW)		5.4		9.5
Average Laser Power (dBW	6.1		10.0	
(Watts)	4.07		10.00	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.5		0.5	
Polarizer Loss	0.2		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Det. Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-278.7		-278.7
RECEIVER TELESCOPE GAIN (dB)		82.7		84.7
Aperture Diameter (cm)	5.4		6.8	
Aperture Gain	84.1		86.1	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.3		0.3	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-3.2		-0.9
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.46		0.46	
Comms Det. Coupler	0.1		0.1	
Polarizer loss	0.2		0.0	
L. O. Coupler loss	0.3		0.0	
Wavefront mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVE SENSITIVITY		-115.4		-107.0
Photon Energy (J)	1.87E-20		1.87E-20	
Av. Ph./Bit at BER=10^-6	150.0		600.0	
Rcv. Sens. (dBW)	-115.5		-109.5	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.1		0.0	
Background Illumination	0.0		2.5	
SYSTEM MARGIN		3.0		3.0

Table B-10 Comparison Between Heterodyne and Direct Detection for an InGaAs Laser at 1 Mbps

LASER ISL GEO-GEO	File A:GG1MI.WK3			
	Heterodyne		Direct detection	
Laser Type	InGaAsP		InGaAsP	
Wavelength (nm)	1550		1550	
Bit Rate (Mbps)	1		1	
Modulator type	Bias		Bias	
Modulation type	FSK		ASK	
Detection type	Heterodyne		Direct	
Path Length (km)	73000		73000	
TRANSMIT TELESCOPE GAIN (dB)		102.5		102.5
Aperture Diameter (cm)	10.0		10.0	
Aperture Gain	106.1		106.1	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.3		0.3	
N.E.A. (micro rad.)	1.1		1.1	
TRANSMITTER POWER (dBW)		-17.3		-10.2
Average Laser Power (dBW	-17.0		-10.2	
(Watts)	0.020		0.10	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.3		0.0	
TRANSMIT OPTICS PATH LOSS(dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-295.4		-295.4
RECEIVER OPTICS GAIN (dB)		104.5		104.5
Aperture Diameter (cm)	10.0		10.0	
Aperture Gain	106.1		106.1	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-3.5		-1.2
Fine Poiting Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.76		0.76	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.3		0.0	
L. O. Coupler loss	0.2		0.0	
Wavefront mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVER SENSITIVITY (dBW)		-112.8		-103.4
Photon Energy (J)	1.28E-19		1.28E-19	
Av. Ph./Bit at BER=10^-6	40.0		200.0	
Rcv. Sens. (dBW)	-112.9		-105.9	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.1		0.0	
Background Illumination	0.0		2.5	
SYSTEM MARGIN		3.0		3.0

Table B-11 Comparison Between Heterodyne and Direct Detection for a Nd:Yag Laser at 1 Mbps

LASER ISL GEO-GEO	File A:GG1MN.wk1			
	Heterodyne		Direct detection	
Laser Type	Nd:Yag		Nd:Yag	
Wavelength (nm)	1060		1060	
Bit Rate (Mbps)	1		1	
Modulator type	External		External	
Modulation type	FSK		FSK	
Detection type	Heterodyne		Direct	
Path Length (km)	73000		73000	
TRANSMIT TELESCOPE GAIN (dB)		97.9		97.9
Aperture Diameter (cm)	4.0		4.0	
Aperture Gain	101.5		101.5	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.3		0.3	
N.E.A.	1.7		1.7	
TRANSMITTER POWER (dBW)		-3.0		-0.3
Average Laser Power (dBW)	-2.6		-0.2	
(Watts)	0.55		0.95	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.1		0.1	
Polarizer Loss	0.3		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-298.7		-298.7
RECEIVE TELESCOPE GAIN (dB)		99.9		99.9
Aperture Diameter (cm)	4.0		4.0	
Aperture Gain	101.5		101.5	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-3.4		-1.1
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.68		0.68	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.3		0.0	
L. O. Coupler loss	0.2		0.0	
Wavefront Mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVER SENSITIVITY (dBW)		-111.1		-106.0
Photon Energy (J)	1.87E-19		1.87E-19	
Av. Ph./Bit at BER=10^-6	40.0		75.0	
Rcv. Sens. (dBW)	-111.3		-108.5	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.2		0.0	
Background Illumination	0.0		2.5	
SYSTEM MARGIN		3.0		3.0

Table B-12 Comparison Between Heterodyne and Direct Detection for an AlGaAs Laser at 1 Mbps

LASER ISL GEO-GEO	File A:GG1MA.wk1			
	Heterodyne		Direct detection	
Laser Type	AlGaAs		AlGaAs	
Wavelength (nm)	850		850	
Bit Rate (Mbps)	1		1	
Modulator type	Bias		Bias	
Modulator type	FSK		ASK	
Detection type	Heterodyne		Direct	
Path Length (km)	73000		73000	
TRANSMIT TELESCOPE GAIN (dB)		102.9		102.9
Aperture Diameter (cm)	6.0		6.0	
Aperture Gain	106.9		106.9	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.7		0.7	
N.E.A. (micro rad.)	1.5		1.5	
TRANSMITTER POWER (dBW)		-10.9		-10.4
Average Laser Power (dBW	-10.6		-10.4	
(Watts)	0.087		0.09	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.3		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-300.7		-300.7
RECEIVE TELESCOPE GAIN (dB)		105.3		105.3
Aperture Diameter (cm)	6.0		6.0	
Aperture Gain	106.9		106.9	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-3.1		-0.8
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.38		0.38	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.3		0.0	
L. O. coupler loss	0.2		0.0	
Wavefront mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVER SENSITIVITY (dBW)		-110.1		-107.3
Photon Energy (J)	2.34E-19		2.34E-19	
Av. Ph./Bit at BER=10^-6	40.0		45.0	
Rcv. Sens. (dBW)	-110.3		-109.8	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.2		0.0	
Background Illumination	0.0		2.5	
SYSTEM MARGIN		3.0		3.0

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APPENDIX C

DETAILED LINK BUDGETS OF OPERATIONAL SYSTEMS

List of Tables

Table C-1 Two Way 100 Mbps Link Between Geostatinary and Inclined Orbit Satellites Using a CO_2 Laser and Heterodyne or Direct Detection

LASER ISL GEO-INC		File A:GI100MC.wk1		
	Forward		Return	
Laser Type	CO2		CO2	
Wavelength (nm)	10600		10600	
Bit Rate (Mbps)	100		100	
Modulator type	External		External	
Modulation type	FSK		FSK	
Detection type	Heterodyne		Direct	
Path Length (km)	77000		77000	
TRANSMIT TELESCOPE GAIN (dB)		91.6		91.6
Aperture Diameter (cm)	18.5		18.5	
Aperture Gain	94.8		94.8	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.3		0.3	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.0		0.0	
N.E.A. (micro rad.)	1.6		1.6	
NET TRANSMITTER POWER (dBW)		5.3		9.4
Average Laser Power (dBW	6.0		9.9	
(Watts)	3.98		9.77	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.5		0.5	
Polarizer Loss	0.2		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Det. Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-279.2		-279.2
RECEIVER TELESCOPE GAIN (dB)		93.4		93.4
Aperture Diameter (cm)	18.5		18.5	
Aperture Gain	94.8		94.8	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.3		0.3	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-2.8		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.14		0.14	
Comms Det. Coupler	0.1		0.1	
Polarizer loss	0.2		0.0	
L. O. Coupler loss	0.3		0.0	
Wavefront mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVE SENSITIVITY		-95.4		-89.0
Photon Energy (J)	1.87E-20		1.87E-20	
Av. Ph./Bit at BER=10^-6	150.0		600.0	
Rcv. Sens. (dBW)	-95.5		-89.5	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.1		0.0	
Background Illumination	0.0		0.5	
SYSTEM MARGIN		3.0		3.0

Table C-2 Two Way 100 Mbps Link Between Geostationary and Inclined Orbit Satellites Using an InGaAsP Laser and Heterodyne or Direct Detection

LASER ISL GEO-INC		File A:GI100MI.WK3		
	Forward		Return	
Laser Type	InGaAsP		InGaAsP	
Wavelength (nm)	1550		1550	
Bit Rate (Mbps)	100		100	
Modulator type	Bias		Bias	
Modulation type	FSK		ASK	
Detection type	Heterodyne		Direct	
Path Length (km)	77000		77000	
TRANSMIT TELESCOPE GAIN (dB)		111.4		111.4
Aperture Diameter (cm)	28.5		28.5	
Aperture Gain	115.2		115.2	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.5		0.5	
N.E.A. (micro rad.)	0.5		0.5	
TRANSMITTER POWER (dBW)		-15.4		-10.3
Average Laser Power (dBW	-15.1		-10.3	
(Watts)	0.031		0.09	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.3		0.0	
TRANSMIT OPTICS PATH LOSS(dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-295.9		-295.9
RECEIVER OPTICS GAIN (dB)		113.6		113.6
Aperture Diameter (cm)	28.5		28.5	
Aperture Gain	115.2		115.2	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-2.8		-0.5
Fine Poiting Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.14		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.3		0.0	
L. O. Coupler loss	0.2		0.0	
Wavefront mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVER SENSITIVITY (dBW)		-92.8		-85.4
Photon Energy (J)	1.28E-19		1.28E-19	
Av. Ph./Bit at BER=10^-6	40.0		200.0	
Rcv. Sens. (dBW)	-92.9		-85.9	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.1		0.0	
Background Illumination	0.0		0.5	
SYSTEM MARGIN		3.0		3.0

Table C-3 Two Way 100 Mbps Link Between Geostationary and Inclined Orbit Satellites Using a Nd:Yag Laser and Heterodyne or Direct Detection

LASER ISL GEO-INC		File A:GI100MN.wk1		
	Forward		Return	
Laser Type	Nd:Yag		Nd:Yag	
Wavelength (nm)	1060		1060	
Bit Rate (Mbps)	100		100	
Modulator type	External		External	
Modulation type	FSK		FSK	
Detection type	Heterodyne		Direct	
Path Length (km)	77000		77000	
TRANSMIT TELESCOPE GAIN (dB)		107.5		107.5
Aperture Diameter (cm)	12.0		12.0	
Aperture Gain	111.0		111.0	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.2		0.2	
N.E.A. (micro rad.)	0.5		0.5	
TRANSMITTER POWER (dBW)		-2.3		-1.5
Average Laser Power (dBW)	-1.9		-1.4	
(Watts)	0.65		0.72	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.1		0.1	
Polarizer Loss	0.3		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-299.2		-299.2
RECEIVE TELESCOPE GAIN (dB)		109.4		109.4
Aperture Diameter (cm)	12.0		12.0	
Aperture Gain	111.0		111.0	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-2.8		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track Det. Coupler	0.14		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.3		0.0	
L. O. Coupler loss	0.2		0.0	
Wavefront Mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVER SENSITIVITY (dBW)		-91.2		-88.0
Photon Energy (J)	1.87E-19		1.87E-19	
Av. Ph./Bit at BER=10^-6	40.0		75.0	
Rcv. Sens. (dBW)	-91.3		-88.5	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.1		0.0	
Background Illumination	0.0		0.5	
SYSTEM MARGIN		3.0		3.0

Table C-4 Two Way 100 Mbps Link Between Geostationary and Inclined Orbit Satellites Using an InGaAs Laser and Heterodyne or Direct Detection

LASER ISL GEO-INC			File A:GI100MA.wk1	
	Forward		Return	
Laser Type	AlGaAs		AlGaAs	
Wavelength (nm)	850		850	
Bit Rate (Mbps)	100		100	
Modulator type	Bias		Bias	
Modulator type	FSK		ASK	
Detection type	Heterodyne		Direct	
Path Length (km)	77000		77000	
TRANSMIT TELESCOPE GAIN (dB)		113.2		113.2
Aperture Diameter (cm)	20.0		20.0	
Aperture Gain	117.4		117.4	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.9		0.9	
N.E.A. (micro rad.)	0.5		0.5	
TRANSMITTER POWER (dBW)		-11.5		-12.9
Average Laser Power (dBW	-11.1		-12.9	
(Watts)	0.078		0.051	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.1		0.0	
Polarizer Loss	0.3		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-301.1		-301.1
RECEIVE TELESCOPE GAIN (dB)		115.8		115.8
Aperture Diameter (cm)	20.0		20.0	
Aperture Gain	117.4		117.4	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-2.8		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.14		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.3		0.0	
L. O. coupler loss	0.2		0.0	
Wavefront mismatch	0.3		0.0	
Alignment mismatch	1.5		0.0	
RECEIVER SENSITIVITY (dBW)		-90.2		-89.3
Photon Energy (J)	2.34E-19		2.34E-19	
Av. Ph./Bit at BER=10^-6	40.0		45.0	
Rcv. Sens. (dBW)	-90.3		-89.8	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.1		0.0	
Background Illumination	0.0		0.5	
SYSTEM MARGIN		3.0		3.0

Table C-5 Two Way Geostationary to Inclined Orbit Link with 1 Mbps AlGaAs Forward and 100 Mbps CO_2 Return

LASER ISL GEO-INC			File A:G100I1C.wk1	
	Forward		Return	
Laser Type	AlGaAs		CO2	
Wavelength (nm)	850		10600	
Bit Rate (Mbps)	1		100	
Modulator type	Bias		External	
Modulation type	ASK		FSK	
Detection type	Direct		Direct	
Path Length (km)	77000		77000	
TRANSMIT TELESCOPE GAIN (dB)		113.2		91.3
Aperture Diameter (cm)	20.0		20.0	
Aperture Gain	117.4		95.5	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.9		0.9	
N.E.A. (micro rad.)	0.5		0.5	
TRANSMITTER POWER (dBW)		-30.6		9.3
Average Laser Power (dBW)	-30.6		9.8	
(Watts)	0.0009		9.55	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.1	
Polarizer Loss	0.0		0.4	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-301.1		-279.2
RECEIVE TELESCOPE GAIN (dB)		115.8		93.9
Aperture Diameter (cm)	20.0		20.0	
Aperture Gain	117.4		95.5	
Aperture Eff./blockage	0.3		0.3	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-0.9		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.46		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.0		0.0	
L. O. coupler loss	0.0		0.0	
Wavefront mismatch	0.0		0.0	
Alignment mismatch	0.0		0.0	
RECEIVER SENSITIVITY (dBW)		-107.3		-89.0
Photon Energy (J)	2.34E-19		1.87E-20	
Av. Ph./Bit at BER=10^-6	45.0		600.0	
Rcv. Sens. (dBW)	-109.8		-89.5	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.0		0.0	
Background Noise	2.5		0.5	
SYSTEM MARGIN		3.0		3.0

Table C-6 Two Way Geostationary to Inclined Orbit Link with 1 Mbps Forward and 100 Mbps Return using InGaAsP Lasers

LASER ISL GEO-INC — File A:G100I1I.wk1

	Forward		Return	
Laser Type	InGaAsP		InGaAsP	
Wavelength (nm)	1550		1550	
Bit Rate (Mbps)	1		100	
Modulator type	Bias		Bias	
Modulation type	ASK		ASK	
Detection type	Direct		Direct	
Path Length (km)	77000		77000	
TRANSMIT TELESCOPE GAIN (dB)		111.2		111.8
Aperture Diameter (cm)	30.0		30.0	
Aperture Gain	115.7		115.7	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	1.2		0.6	
N.E.A. (micro rad.)	0.7		0.5	
TRANSMITTER POWER (dBW)		-28.2		-11.1
Average Laser Power (dBW)	-28.2		-11.1	
(Watts)	0.00151		0.078	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.0		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-295.9		-295.9
RECEIVE TELESCOPE GAIN (dB)		114.1		114.1
Aperture Diameter (cm)	30.0		30.0	
Aperture Gain	115.7		115.7	
Aperture Eff./blockage	0.3		0.3	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-0.9		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.46		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.0		0.0	
L. O. coupler loss	0.0		0.0	
Wavefront mismatch	0.0		0.0	
Alignment mismatch	0.0		0.0	
RECEIVER SENSITIVITY (dBW)		-103.4		-85.4
Photon Energy (J)	1.28E-19		1.28E-19	
Av. Ph./Bit at BER=10^-6	200.0		200.0	
Rcv. Sens. (dBW)	-105.9		-85.9	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.0		0.0	
Background Noise	2.5		0.5	
SYSTEM MARGIN		3.0		3.0

Table C-7 Two Way Geostationary to Inclined Orbit Link with 1 Mbps AlGaAs Forward and 100 Mbps Nd:Yag Return

LASER ISL GEO-INC File A:G100I1N.wk1

	Forward		Return	
Laser Type	AlGaAs		Nd:Yag	
Wavelength (nm)	850		1060	
Bit Rate (Mbps)	1		100	
Modulator type	Bias		External	
Modulation type	ASK		FSK	
Detection type	Direct		Direct	
Path Length (km)	77000		77000	
TRANSMIT TELESCOPE GAIN (dB)		107.8		106.0
Aperture Diameter (cm)	10.0		10.0	
Aperture Gain	111.4		109.4	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.2		0.1	
N.E.A. (micro rad.)	0.5		0.5	
TRANSMITTER POWER (dBW)		-19.0		-0.6
Average Laser Power (dBW)	-19.0		-0.5	
(Watts)	0.0126		0.891	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.1	
Polarizer Loss	0.0		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-301.1		-299.2
RECEIVE TELESCOPE GAIN (dB)		109.8		107.8
Aperture Diameter (cm)	10.0		10.0	
Aperture Gain	111.4		109.4	
Aperture Eff./blockage	0.3		0.3	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-1.1		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.68		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.0		0.0	
L. O. coupler loss	0.0		0.0	
Wavefront mismatch	0.0		0.0	
Alignment mismatch	0.0		0.0	
RECEIVER SENSITIVITY (dBW)		-107.3		-90.2
Photon Energy (J)	2.34E-19		1.87E-19	
Av. Ph./Bit at BER=10^-6	45.0		45.0	
Rcv. Sens. (dBW)	-109.8		-90.7	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.0		0.0	
Background Noise	2.5		0.5	
SYSTEM MARGIN		3.0		3.0

Table C-8 Two Way Geostationary to Inclined Orbit Link with 1 Mbps Forward and 100 Mbps Return using AlGaAs Lasers

LASER ISL GEO-INC	Forward		Return	File A:G100I1A.wk1
Laser Type	AlGaAs		AlGaAs	
Wavelength (nm)	850		850	
Bit Rate (Mbps)	1		100	
Modulator type	Bias		Bias	
Modulation type	ASK		ASK	
Detection type	Direct		Direct	
Path Length (km)	77000		77000	
TRANSMIT TELESCOPE GAIN (dB)		112.0		112.0
Aperture Diameter (cm)	17.0		17.0	
Aperture Gain	116.0		116.0	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.6		0.6	
N.E.A. (micro rad.)	0.5		0.3	
TRANSMITTER POWER (dBW)		-28.0		-10.3
Average Laser Power (dBW)	-28.0		-10.3	
(Watts)	0.0016		0.093	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.0		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-301.1		-301.1
RECEIVE TELESCOPE GAIN (dB)		114.4		114.4
Aperture Diameter (cm)	17.0		17.0	
Aperture Gain	116.0		116.0	
Aperture Eff./blockage	0.3		0.3	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-0.8		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.42		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.0		0.0	
L. O. coupler loss	0.0		0.0	
Wavefront mismatch	0.0		0.0	
Alignment mismatch	0.0		0.0	
RECEIVER SENSITIVITY (dBW)		-107.3		-89.3
Photon Energy (J)	2.34E-19		2.34E-19	
Av. Ph./Bit at BER=10^-6	45.0		45.0	
Rcv. Sens. (dBW)	-109.8		-89.8	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.0		0.0	
Background Noise	2.5		0.5	
SYSTEM MARGIN		3.0		3.0

Table C-9 Two Way Geosationary to LEO Link with 19.2 Kbps Both Directions using InGaAsP Lasers

LASER ISL GEO-LEO File A:G19L19I.wk1

	Forward		Return	
Laser Type	InGaAsP		InGaAsP	
Wavelength (nm)	1550		1550	
Bit Rate (Mbps)	0.0192		0.0192	
Moduator type	Bias		Bias	
Moduation type	ASK		ASK	
Detection type	Direct		Direct	
Path Length (km)	47000		47000	
TRANSMIT TELESCOPE GAIN (dB)		101.4		101.4
Aperture Diameter (cm)	10.5		10.5	
Aperture Gain	106.6		106.6	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	1.8		1.8	
N.E.A. (micro rad.)	2.5		2.5	
TRANSMITTER POWER (dBW)		-11.2		-11.2
Averaage Laser Power(dBW	-11.2		-11.2	
(Watts)	0.076		0.076	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.0		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-291.6		-291.6
RECEIVE TELESCOPE GAIN (dB)		105.0		105.0
Aperture Diameter (cm)	10.5		10.5	
Aperture Gain	106.6		106.6	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-15.4864		-15.4864
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	15.09		15.09	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.0		0.0	
L. O. coupler loss	0.0		0.0	
Wavefront mismatch	0.0		0.0	
Alignment mismatch	0.0		0.0	
RECEIVER SENSITIVITY (dBW)		-115.6		-115.6
Photon Energy (J)	1.28E-19		1.28E-19	
Photons/Bit at BER=10^-6	200.0		200.0	
Rcv. Sens. (dBW)	-123.1		-123.1	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.0		0.0	
Background Noise	7.5		7.5	
SYSTEM MARGIN		3.0		3.0

Table C-10 Two Way Geostationary to LEO Link with 19.2 Kbps Both Directions using AlGaAs Lasers

LASER ISL GEO-LEO		File A:G19L19A.wk1		
	Forward		Return	
Laser Type	AlGaAs		AlGaAs	
Wavelength (nm)	850		850	
Bit Rate (Mbps)	0.0192		0.0192	
Moduator type	Bias		Bias	
Moduation type	ASK		ASK	
Detection type	Direct		Direct	
Path Length (km)	47000		47000	
TRANSMIT TELESCOPE GAIN (dB)		98.3		98.3
Aperture Diameter (cm)	3.5		3.5	
Aperture Gain	102.2		102.2	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.7		0.7	
N.E.A. (micro rad.)	2.5		2.5	
TRANSMITTER POWER (dBW)		-10.4		-10.4
Averaage Laser Power(dBW	-10.4		-10.4	
(Watts)	0.091		0.091	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.0		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-296.8		-296.8
RECEIVE TELESCOPE GAIN (dB)		100.6		100.6
Aperture Diameter (cm)	3.5		3.5	
Aperture Gain	102.2		102.2	
Aperture Eff./blockage	0.3		0.3	
Suppor Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-7.4		-7.4
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	6.97		6.97	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.0		0.0	
L. O. coupler loss	0.0		0.0	
Wavefront mismatch	0.0		0.0	
Alignment mismatch	0.0		0.0	
RECEIVER SENSITIVITY (dBW)		-119.4		-119.4
Photon Energy (J)	2.34E-19		2.34E-19	
Photons/Bit at BER=10^-6	45.0		45.0	
Rcv. Sens. (dBW)	-126.9		-126.9	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.0		0.0	
Background Noise	7.5		7.5	
SYSTEM MARGIN		3.0		3.0

Table C-11 Two Way Geostationary to LEO Link with 19.2 Kbps AlGaAs Forward and 1 Mbps CO_2 Return

LASER ISL GEO-LEO		File A:G19L1MC.wk1		
	Forward		Return	
Laser Type	AlGaAs		CO2	
Wavelength (nm)	850		10600	
Bit Rate (Mbps)	0.0192		1.00	
Modulator type	Bias		External	
Modulation type	ASK		FSK	
Detection type	Direct		Direct	
Path Length (km)	47000		47000	
TRANSMIT TELESCOPE GAIN (dB)		102.6		80.8
Aperture Diameter (cm)	5.5		5.5	
Aperture Gain	106.2		84.2	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.3		0.2	
N.E.A. (micro rad.)	1		10	
TRANSMITTER POWER (dBW)		-15.9		9.6
Average Laser Power(dBW)	-15.9		9.7	
(Watts)	0.0257		9.333	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.1	
Polarizer Loss	0.0		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-296.8		-274.9
RECEIVE TELESCOPE GAIN (dB)		104.6		82.6
Aperture Diameter (cm)	5.5		5.5	
Aperture Gain	106.2		84.2	
Aperture Eff./blockage	0.3		0.3	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-10.1		-1.4
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	9.74		0.99	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.0		0.0	
L. O. Mixer loss	0.0		0.0	
Wavefront Errors	0.0		0.0	
Spatial Mixing	0.0		0.0	
RECEIVER SENSITIVITY (dBW)		-119.4		-107.0
Photon Energy (J)	2.34E-19		1.87E-20	
Rcv. Sens. (Photons/Bit)	45.0		600.0	
Rcv. Sens. (dBW)	-126.9		-109.5	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.0		0.0	
Background Noise	7.5		2.5	
SYSTEM MARGIN		3.0		3.0

Table C-12 Two Way Geostationary to LEO Link with 19.2 Kbps Forward and 1 Mbps Return using InGaAsP Lasers

LASER ISL GEO-LEO			File A:G19L1MI.wk1	
	Forward		Return	
Laser Type	InGaAsP		InGaAsP	
Wavelength (nm)	1550		1550	
Bit Rate (Mbps)	0.0192		1.00	
Modulator type	Bias		Bias	
Modulation type	ASK		ASK	
Detection type	Direct		Direct	
Path Length (km)	47000		47000	
TRANSMIT TELESCOPE GAIN (dB)		100.2		100.2
Aperture Diameter (cm)	8.0		8.0	
Aperture Gain	104.2		104.2	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.7		0.7	
N.E.A. (micro rad.)	2		2	
TRANSMITTER POWER (dBW)		-15.7		-10.1
Average Laser Power(dBW)	-15.7		-10.1	
(Watts)	0.0269		0.098	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.0		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-291.6		-291.6
RECEIVE TELESCOPE GAIN (dB)		102.6		102.6
Aperture Diameter (cm)	8.0		8.0	
Aperture Gain	104.2		104.2	
Aperture Eff./blockage	0.3		0.3	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-7.4		-0.8
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	6.97		0.42	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.0		0.0	
L. O. Mixer loss	0.0		0.0	
Wavefront Errors	0.0		0.0	
Spatial Mixing	0.0		0.0	
RECEIVER SENSITIVITY (dBW)		-115.6		-103.4
Photon Energy (J)	1.28E-19		1.28E-19	
Rcv. Sens. (Photons/Bit)	200.0		200.0	
Rcv. Sens. (dBW)	-123.1		-105.9	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.0		0.0	
Background Noise	7.5		2.5	
SYSTEM MARGIN		3.0		3.0

Table C-13 Two Way Geostationary to LEO Link with 19.2 Kbps AlGaAs Forward and 1 Mbps Nd:Yag Return

LASER ISL GEO-LEO			File A:G19L1MN.wk1	
	Forward		Return	
Laser Type	AlGaAs		Nd:Yag	
Wavelength (nm)	850		1060	
Bit Rate (Mbps)	0.0192		1.00	
Modulator type	Bias		External	
Modulation type	ASK		FSK	
Detection type	Direct		Direct	
Path Length (km)	47000		47000	
TRANSMIT TELESCOPE GAIN (dB)		97.9		96.0
Aperture Diameter (cm)	3.3		3.3	
Aperture Gain	101.7		99.8	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.5		0.5	
N.E.A. (micro rad.)	2.3		2.8	
TRANSMITTER POWER (dBW)		-8.2		-0.7
Average Laser Power(dBW)	-8.2		-0.6	
(Watts)	0.151		0.871	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.1	
Polarizer Loss	0.0		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-296.8		-294.9
RECEIVE TELESCOPE GAIN (dB)		100.1		98.2
Aperture Diameter (cm)	3.3		3.3	
Aperture Gain	101.7		99.8	
Aperture Eff./blockage	0.3		0.3	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-8.8		-1.0
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	8.37		0.56	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.0		0.0	
L. O. Mixer loss	0.0		0.0	
Wavefront Errors	0.0		0.0	
Spatial Mixing	0.0		0.0	
RECEIVER SENSITIVITY (dBW)		-119.4		-106.0
Photon Energy (J)	2.34E-19		1.87E-19	
Rcv. Sens. (Photons/Bit)	45.0		75.0	
Rcv. Sens. (dBW)	-126.9		-108.5	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.0		0.0	
Background Noise	7.5		2.5	
SYSTEM MARGIN		3.0		3.0

Table C-14 Two Way Geostationary to LEO Link with 19.2 Kbps Forward and 1 Mbps Return using AlGaAs Lasers

LASER ISL GEO-LEO		File A:G19L1MA.wk1		
	Forward		Return	
Laser Type	AlGaAs		AlGaAs	
Wavelength (nm)	850		850	
Bit Rate (Mbps)	0.0192		1.00	
Modulator type	Bias		Bias	
Modulation type	ASK		ASK	
Detection type	Direct		Direct	
Path Length (km)	47000		47000	
TRANSMIT TELESCOPE GAIN (dB)		100.7		100.7
Aperture Diameter (cm)	4.8		4.8	
Aperture Gain	105.0		105.0	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	1.0		1.0	
N.E.A. (micro rad.)	2.2		2.2	
TRANSMITTER POWER (dBW)		-16.6		-10.1
Average Laser Power(dBW)	-16.6		-10.1	
(Watts)	0.0219		0.098	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.0		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-296.8		-296.8
RECEIVE TELESCOPE GAIN (dB)		103.4		103.4
Aperture Diameter (cm)	4.8		4.8	
Aperture Gain	105.0		105.0	
Aperture Eff./blockage	0.3		0.3	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-6.4		-0.8
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	5.97		0.35	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.0		0.0	
L. O. Mixer loss	0.0		0.0	
Wavefront Errors	0.0		0.0	
Spatial Mixing	0.0		0.0	
RECEIVER SENSITIVITY (dBW)		-119.4		-107.3
Photon Energy (J)	2.34E-19		2.34E-19	
Rcv. Sens. (Photons/Bit)	45.0		45.0	
Rcv. Sens. (dBW)	-126.9		-109.8	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.0		0.0	
Background Noise	7.5		2.5	
SYSTEM MARGIN		3.0		3.0

Table C-15 Two Way Geostationary to LEO Link with 19.2 Kbps AlGaAs Forward and 100 Mbps CO_2 Return

LASER ISL GEO-LEO		File A:G19L100C.wk1		
	Forward		Return	
Laser Type	AlGaAs		CO2	
Wavelength (nm)	850		10600	
Bit Rate (Mbps)	0.0192		100	
Modulator type	Bias		External	
Modulation type	ASK		FSK	
Detection type	Direct		Direct	
Path Length (km)	47000		47000	
TRANSMIT TELESCOPE GAIN (dB)		110.7		89.2
Aperture Diameter (cm)	15.0		15.0	
Aperture Gain	114.9		93.0	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.9		0.5	
N.E.A. (micro rad.)	8.5		6	
TRANSMITTER POWER (dBW)		-25.9		9.6
Average Laser Power(dBW)	-25.9		9.7	
(Watts)	0.0026		9.333	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.1	
Polarizer Loss	0.0		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-296.8		-274.9
RECEIVE TELESCOPE GAIN (dB)		113.3		91.4
Aperture Diameter (cm)	15.0		15.0	
Aperture Gain	114.9		93.0	
Aperture Eff./blockage	0.3		0.3	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-16.9		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	16.5		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.0		0.0	
L. O. coupler loss	0.0		0.0	
Wavefront mismatch	0.0		0.0	
Alignment mismatch	0.0		0.0	
RECEIVER SENSITIVITY (dBW)		-119.4		-89.0
Photon Energy (J)	2.34E-19		1.87E-20	
Av. Ph./Bit at BER=10^-6	45.0		600.0	
Rcv. Sens. (dBW)	-126.9		-89.5	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.0		0.0	
Background Noise	7.5		0.5	
SYSTEM MARGIN		3.0		3.0

Table C-16 Two Way Geostationary to LEO Link with 19.2 Kbps Forward and 100 Mbps Return using InGaAsP Lasers

LASER ISL GEO-LEO File A:G19L100I.wk1

	Forward		Return	
Laser Type	InGaAsP		InGaAsP	
Wavelength (nm)	1550		1550	
Bit Rate (Mbps)	0.0192		100	
Modulator type	Bias		Bias	
Modulation type	ASK		ASK	
Detection type	Direct		Direct	
Path Length (km)	47000		47000	
TRANSMIT TELESCOPE GAIN (dB)		108.9		109.2
Aperture Diameter (cm)	22.0		22.0	
Aperture Gain	113.0		113.0	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.8		0.5	
N.E.A. (micro rad.)	0.8		0.6	
TRANSMITTER POWER (dBW)		-25.3		-10.2
Average Laser Power(dBW)	-25.3		-10.2	
(Watts)	0.00295		0.095	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.0		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-291.6		-291.6
RECEIVE TELESCOPE GAIN (dB)		111.4		111.4
Aperture Diameter (cm)	22.0		22.0	
Aperture Gain	113.0		113.0	
Aperture Eff./blockage	0.3		0.3	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-15.2		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	14.79		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.0		0.0	
L. O. coupler loss	0.0		0.0	
Wavefront mismatch	0.0		0.0	
Alignment mismatch	0.0		0.0	
RECEIVER SENSITIVITY (dBW)		-115.6		-85.4
Photon Energy (J)	1.28E-19		1.28E-19	
Av. Ph./Bit at BER=10^-6	200.0		200.0	
Rcv. Sens. (dBW)	-123.1		-85.9	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.0		0.0	
Background Noise	7.5		0.5	
SYSTEM MARGIN		3.0		3.0

Table C-17 Two Way Geostationary to LEO Link with 19.2 Kbps AlGaAs Forward and 100 Mbps Nd:Yag Return

LASER ISL GEO-LEO		File A:G19L100N.wk1		
	Forward		Return	
Laser Type	AlGaAs		Nd:Yag	
Wavelength (nm)	850		1060	
Bit Rate (Mbps)	0.0192		100	
Modulator type	Bias		External	
Modulation type	ASK		FSK	
Detection type	Direct		Direct	
Path Length (km)	47000		47000	
TRANSMIT TELESCOPE GAIN (dB)		105.3		103.8
Aperture Diameter (cm)	8.0		8.0	
Aperture Gain	109.4		107.5	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.8		0.4	
N.E.A. (micro rad.)	1.2		1.1	
TRANSMITTER POWER (dBW)		-16.8		-0.7
Average Laser Power(dBW)	-16.8		-0.6	
(Watts)	0.020893		0.871	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.1	
Polarizer Loss	0.0		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-296.8		-294.9
RECEIVE TELESCOPE GAIN (dB)		107.8		105.9
Aperture Diameter (cm)	8.0		8.0	
Aperture Gain	109.4		107.5	
Aperture Eff./blockage	0.3		0.3	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-15.2		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	14.79		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.0		0.0	
L. O. coupler loss	0.0		0.0	
Wavefront mismatch	0.0		0.0	
Alignment mismatch	0.0		0.0	
RECEIVER SENSITIVITY (dBW)		-119.4		-90.2
Photon Energy (J)	2.34E-19		1.87E-19	
Av. Ph./Bit at BER=10^-6	45.0		45.0	
Rcv. Sens. (dBW)	-126.9		-90.7	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.0		0.0	
Background Noise	7.5		0.5	
SYSTEM MARGIN		3.0		3.0

Table C-18 Two Way Geostationary to LEO Link with 19.2 Kbps Forward and 100 Mbps Return using AlGaAs Lasers

LASER ISL GEO-LEO			File A:G19L100A.wk1	
	Forward		Return	
Laser Type	AlGaAs		AlGaAs	
Wavelength (nm)	850		850	
Bit Rate (Mbps)	0.0192		100	
Modulator type	Bias		Bias	
Modulation type	ASK		ASK	
Detection type	Direct		Direct	
Path Length (km)	47000		47000	
TRANSMIT TELESCOPE GAIN (dB)		110.1		110.3
Aperture Diameter (cm)	13.6		13.6	
Aperture Gain	114.0		114.0	
Aperture Eff./blockage	1.8		1.8	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Defocusing	0.2		0.2	
Transmission Loss	0.8		0.8	
Pointing Loss	0.6		0.4	
N.E.A. (micro rad.)	0.62		0.5	
TRANSMITTER POWER (dBW)		-34.1		-10.9
Average Laser Power(dBW)	-34.1		-10.9	
(Watts)	0.000389		0.081	
Modulator Efficiency	0.0		0.0	
Modulator Transmission	0.0		0.0	
Polarizer Loss	0.0		0.0	
TRANSMIT OPTICS PATH LOSS (dB)		-0.7		-0.7
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	0.1		0.1	
Comms. Det. Coupler	0.1		0.1	
Look-ahead Coupler	0.1		0.1	
Look-ahead Mirrors	0.1		0.1	
SPACE LOSS (dB)		-296.8		-296.8
RECEIVE TELESCOPE GAIN (dB)		112.4		112.4
Aperture Diameter (cm)	13.6		13.6	
Aperture Gain	114.0		114.0	
Aperture Eff./blockage	0.3		0.3	
Support Member Blockage	0.0		0.0	
Surface Errors	0.5		0.5	
Transmission Loss	0.8		0.8	
RECEIVE OPTICS PATH LOSS (dB)		-7.4		-0.5
Fine Pointing Mirrors	0.1		0.1	
Beacon Laser Coupler	0.1		0.1	
Beacon Detector Coupler	0.1		0.1	
Fine Track. Det. Coupler	6.97		0.14	
Comms. Det. Coupler	0.1		0.1	
Polarizer loss	0.0		0.0	
L. O. coupler loss	0.0		0.0	
Wavefront mismatch	0.0		0.0	
Alignment mismatch	0.0		0.0	
RECEIVER SENSITIVITY (dBW)		-119.4		-89.3
Photon Energy (J)	2.34E-19		2.34E-19	
Av. Ph./Bit at BER=10^-6	45.0		45.0	
Rcv. Sens. (dBW)	-126.9		-89.8	
Extinction ratio assumed	0.05		0.05	
Laser Linewidth	0.0		0.0	
Background Noise	7.5		0.5	
SYSTEM MARGIN		3.0		3.0

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APPENDIX D

CORPORATE PROFILES

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PROFILE OF CORPORATE CAPABILITIES

Key Personnel: Include names of the top two executives within the company. Please identify one executive as the key contact person.

Nature of Business: Please identify your company's mission/markets.

Major Achievements: Please elaborate on scientific/technical breakthroughs, successful commercialized/marketed products, and other events that you feel are significant to your company's development.

Company Profile: Please provide the following information:

- The year your company was established;
- Total number of employees;
- Identify how many are in Sales & Marketing and R&D functions;
- Annual Revenues by Product/Service for most current fiscal year (exact data or growth percentage figures are accepted);
- R&D Expenditures - as a % of overall revenues;
- Stock listing - is your company publicly traded or privately held; and
- Total number of Customers.

Company Background: A brief description of the company including historical development and general direction.

Business Description: Current Products: Identify and briefly describe each of your products and their applications.
Future Product Directions: Identify and describe current methods of product distributions both direct and indirect (i.e. Direct Sales, Distributors, Manufacturer Agents).

Principal Clients: Firms with which that you repeatly conduct business.

Collaborative Agreements: Identify current collaborative business arrangements (i.e. business partners, agreements with Universities, etc ...).

Partnering Interests: Identify and describe the type of business opportunities your company is seeking (i.e. investment, distribution of your product/service, representing other groups in Canada/ the Unites States, commercial collaboration (e.g. OEMs), and joint research).

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D.2 EG&G

Key Personnel

Ron Swarbrick,
General Manager

Dr. Andrew MacGregor,
Manager, New Business Development
(for ISL projects)

Nature of Business

Since January 1991, EG&G Optoelectronics has been an operating division of EG&G Canada Ltd., which is part of EG&G Inc., headquartered in Wellesley, Massachusetts.

In 1991, Optoelectronics has a staff of 160, approximately one-third of whom are qualified scientists and engineers.

The division's products are Semiconductor Light Detectors and Light Emitters and their associated electronic circuits. All business functions, including Research and Development, Production, Testing, packing, and Marketing are performed on site. Seventy-five percent of sales are to the U.S.; the balance of sales is mainly to Europe, less than two percent being with Canada. Sixty-five percent of sales are directly to the defence industry for applications such as laser rangefinders and intersatellite optical communications, the balance of sales is mainly to the instrumentation and fibre optic markets.

Twenty percent of sales are catalogue items. Eighty percent of sales are either development contracts, completely custom device, or are major or minor variants on catalogue items.

Major semiconductor products areas are:

Detectors:

- Silicon PIN's (Standard Photodiodes)
- Silicon APD's (Avalanche Photodiodes)
- InGaAs PIN's
- InGaAs APD's

Emitters

- A1GaAs LED's (Light Emitting Diodes)
- A1GaAs LD's (laser Diodes)
- InGaAsP LED's
- InGaAsP LD's

Modules and Subassemblies

- Hybrid, PCB and surface mount assemblies based on all of the above.

Electro Optics holds about 50% of the U.S. military silicon PIN market. It has a unique capability in silicon APD's in terms of low noise, high speed and long wavelength response, and has over fifty percent of the world market for Si APD's. In emitters, it specializes in pulse lasers, laser pump sources and specialized LED's. Within EG&G, Optoelectronics at Vaudreuil is the sole producer of these products.

Major R&D Achievements - Last Decade

In detectors:

- 1977 "Low-k" APD's
- 1978 - APD's with enhanced 1060 nm response for laser rangefinders

- 1979 - Prototype quadrant APD's
- 1982 - Prototype InGaAs PIN photodiodes
- 1983 - Large area APD's for use with scintillators
- 1984 - 25-element linear APD arrays
- 1985 - Commercial APD's for photon counting
- 1985 - Gamma ray detecting APD modules
- 1986 - Planar passivate InGaAs photodiodes
- 1987 - APD arrays with reduced dead-space
- 1988 - InGaAs APD's
- 1989 - APD-based photon counting module
- 1990 - 2-dimensional silicon APD arrays

In emitters prior to 1987, research was performed in Princeton by DSRC as part of RCA Corp.

- 1978 - Constricted double-heterostructure (CDH demonstrated)
- 1978 - 1.06 m diode lasers
- 1980 - CDH Large Optical Cavity (LOC) single mode lasers
- 1981 - Vapour grown lasers made commercially available
- 1982 - High power lasers developed (for optical recording)
- 1984 - Edge emitting laser diode arrays
- 1984 - Metal Organic VPE III-V research commenced
- 1985 - High power superluminescent LED's
- 1986 - Surface emitting laser diode arrays
- 1987 - Non-lasing angle striped LED
- 1989 - High power quantum-well MOCVD lasers
- 1990 - High power quantum-well, strained layer InGaAs, MOCVD laser

Company Profile

- Commercial operations began in approximately 1970 as an outgrowth of RCA Research Laboratory.
- Approximately 160 employees, of which:
  - approximately 12 Sales and Marketing plus use of Group Sales Organization, and
  - approximately 12 R&D, approximately 25 if a more generous "development" definition us used.
- Revenues of approximately $20M per annum.
- R&D expenditure is approximately 10% of sales.
- Stock is wholly owned by EG&G which is a publicly traded company.

Business Description

Refer to "Nature of Business" section. Future product directions emphasizw added value products with integral electronics.

Market Activities

Direct sales organization in North America, Paris office, distributors elsewhere.

Principal Clients:

Confidential information. Encompass major defence, instrumentation and telecommunications companies.

Collaborative Agreements

Various, including SSOC (Solid State Optical Consortium) in Ottawa.

D.3 MPB TECHNOLOGIES INC.

Company Description

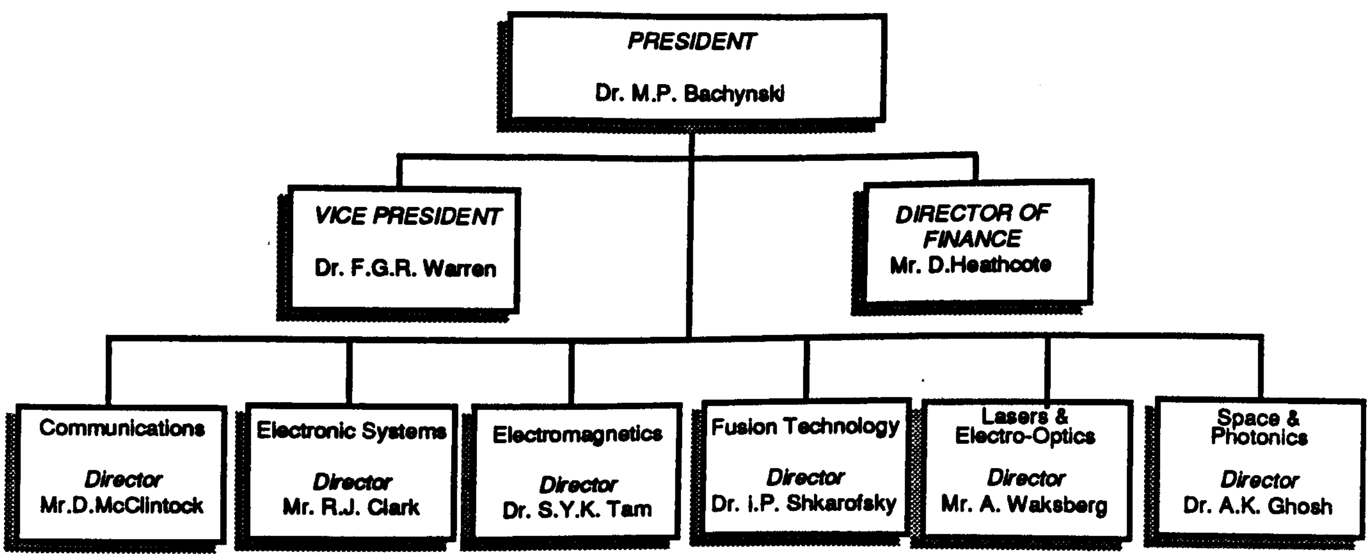
Federally incorporated in late 1976, MPB Technologies Inc. commenced operation at the beginning of 1977. Starting from an initial staff of 8, the Company has grown to a strength of over 200 full time employees. The personnel of MPB Technologies Inc. consists of a unique combination of physicists, electronic and mechanical engineers and technical staff, backed by experienced, efficient project management. Many of the key staff members are widely recognized for their contributions to various disciplines. Of the order of 30% of the professional staff members possesses the Ph.D degree.

Among the Company achievements are:

- Winning a major international contract to develop the world's first undersea branching multiplexers. These are to be put into operation in 1991 in the optical fibre Trans Atlantic Telecommunications System.
- Designing and developing the control system, feedback system, data acquisition and various measuring systems for Canada's only major facility to research in fusion energy located at the Centre canadien de fusion magn)tique in Varennes, Quebec.
- Developing long-life sealed lasers for scientific and industrial applications.
- Developments related to space experiments and intersatellite communications

R&D capability encompasses the areas denoted in the Company Profile, together with telerobotics, acousto-optic devices, non-linear optics, optical techniques, radar detection, scattering, clutter, target discrimination and simulation, radar cross sections and doppler measurements, plasma and high power r-f theory, impurity kinetics and transport properties.

The on-going activities of MPB Technologies Inc. rank the company amongst the top 10 industrial R&D performers in all of Quebec.



MPB Technologies Inc. specializes in high technology products and systems, research and development, and measurement services. The Company activities encompass:

Communications

Telecommunications, multiplexing, high speed terminals, timing and supervisory systems, optical fibre communications.

Electromagnetics

Development of millimeter wave radiometers, radars, scatterometers, and specialized instrumentation in the 5 to 140 GHz frequency range.

Electronic Systems

Design and manufacture of microprocessor based systems (both hardware and software) for television broadcast, sport events, data acquisition and control.

Fusion

Engineering design, instrumentation, physics and measurements including data acquisition and control systems, magnetic, electromagnetic and optical instrumentation.

Lasers and Electro-Optics

Lasers and devices in the optical to far infrared, systems for radar, ranging, communications, nondestructive testing and industrial material processing.

Space Technology

Space shuttle type experiments including control electronics software, "quick look" ground readout facilities, materials processing under microgravity conditions, intersatellite laser systems, and low noise radiometric systems.

Facilities Include:

Clean Rooms

- Modern clean rooms rated at class 100,000
- Individual laminar flow units within the clean room are used when greater cleanliness is required.

Reliability Test Lab

- Life testing of integrated circuits conducted in multimillion dollar clean rooms
- Specialized systems include four liquid burn-in tanks, a burn-in oven, an automated tester for life testing, and ASIC & MMIC functional testing.

ASIC Design Facility

- Mentor Graphics computer-aided design systems used for Application Specific Integrated Circuit and Monolithic Microwave Integrated Circuit design.
- Liaison with international semi conductor foundries and process test facilities.

Multi-layer Printed Circuit Board Facility

- Drafting, PC Board Design and Prototype Facility
- Includes a CAD design centre based on Mentor Graphics and CADSTAR, mechanical design, machine shop, and an in-house multilayer PCB circuit board facility.

Optical Fibre Facility

- Equipped with a high bit rate laser diodes, fast oscilloscope, spectrum analyzers, BER measurement, fibre optics, wide beam detectors and optical calibration equipment such as lamp sources, spectrometers and beam analyzers.

- Fibre splicing routinely performed.

Laser Materials Processing Lab

- Provides quick, accurate feasibility studies for industrial applications
- Facilities include pulsed CO_2 lasers, beam delivery systems, beam diagnostic equipment, computer controlled X-Y tables and analytical equipment.

Laser Production

- Production facility for sealed-off CO_2 lasers and cleaning bath, bake out oven for glass laser tubes, vacuum furnace with controlled atmosphere for metallizing and annealing of ceramic materials, gas filling facility.

Scientific Glass Centre

- Custom professional glass service for both pyrex and quartz

Electromagnetics Measurement Facility

- Automated antenna instrumentation covering 20 MHz to 18 GHz.
- Electromagnetic compatibility (TEM test cell) and electromagnetic field (anechoic chamber) and electromagnetic pulse (EMP) test cell.
- Investigations of industrial and medical application of microwave energy-power sources to 30 kw at 2450 MHz and 915 MHz.

Products

Products developed, manufactured and marketed by the Company include:

- Lasers, laser systems, devices and accessories for scientific and industrial applications;
- Laser communication systems, optical fibre communication systems, optical fibre devices;
- High speed (600 Mbts) communication terminals, timing and supervisor systems;
- Undersea branching multiplexers and associated special terminal equipment for undersea optical fibre telecommunication systems.
- Graphic systems and character generators for TV broadcast and sporting events;
- Instrumentation for space shuttle experiments - materials processing under microgravity conditions and wideband width intersatellite optical communications;
- Special antennas, transponders, "hot" loads, dichroic plates;
- Millimeter wave radars, radiometers and scatterometers for ground, airborne and space applications.

The product of MPB Technologies Inc. are sold world wide including Japan, the United States, Europe (United Kingdom, Germany, Switzerland, France, Norway, Italy, etc.), Israel and Australia. More than 70% of the Company business originates from outside of Canada and more than 90% from outside Quebec.

Awards Won by MPB Technologies Inc.

1977	Canadian Enterprise Canadian Enterprise Corporation, Financial Post, La Presse
1984	Most Dynamic West Island Small Business Government of Quebec
1987	Accolades '87: Job Creation - Large Business West Island Chamber of Commerce
1988	Prix de la PME: Deuxieme Carriere Royal Bank, Hydro Quebec, PME Magazine - Quebec
1989	Mercuriades '89: Research & Development - Finalist Quebec Chamber of Commerce
	Mercuriades '89: Export - Winner Quebec Chamber of Commerce

Mercuriades '89: Business of the Year: Runner up
Quebec Chamber of Commerce

Canada Awards for Business Excellence - Entrepreneurship
Industry, Science and Technology Canada

1990 Canada Export Award - Winner
External Affairs and International Trade, Canada

Prix MICA 1990 - Export
Le Conseil de l'Industrie Electronique du Quebec

Prix MICA 1990 - Business of the Year
Le Conseil de l'Industrie Electronique de Quebec

Canada Awards for Business Excellence - Entrepreneurship
Industry, Science and Technology Canada

Canada Awards for Business Excellence - Innovation
Industry, Science and Technology Canada

Company Capability

MPBT Expertise

The personnel of MPBT has been involved in Laser Communication both theoretical and experimental work, for more than 20 years. This includes a major involvement with NASA on a feasibility study on a complete CO_2 laser communication system between satellites and satellites to earth. A variety of Laser Communication Systems have been designed and developed by the Company. A list of them with some of their characteristics is given in the Table below.

Along with its work on laser communication, MPBT has developed contacts with other Groups and Space Agencies working in the same field, such as NASA, ESA, MATRA, Lincoln Laboratory. Publications and Conferences have also been part of MPBT activity in this area.

A large number of laser communication systems have been built and investigated by MPBT personnel. Table 1 summarizes some of them.

Table 1 Laser Communication Systems

Laser	Detection	Format	Sub-Carrier Frequency	Baseband Bandwidth
HeNe	Direct	IM-FM	70 MHz	5 MHz Video
HeNe	Direct	PCM 8 bit/word	80 Mbit (1nsec pulse width)	5 MHz Video
CO_2	Direct	IM-FM	40 MHz	5 MHz Video
CO_2	Heterodyne	FM	--	5 MHz Video
CO_2	Direct	OOK	--	5 Mbit/sec
CO_2	Heterodyne	ASK	--	5 Mbit/sec
GaA1As	Direct	IM-FM	70 MHz	5 MHz Video
GaA1As	Direct	OOK	--	140 Mbit/sec
GaA1As	Heterodyne	FSD CP-FSK	--	1 Gbit/s 1 Gbit/s
GaA1As	Direct	OOK	--	1 Gbit/s

Relevant Projects in Laser Communication

A short description of relevant projects accomplished by MPBT in Laser communication and other related technologies is given here.

Development of a Laser Diode Wideband Communication System for ISL

MPB Technologies Inc. has amply demonstrated its R&D capabilities in the field of intersatellite laser communication links (ISL) with several studies performed for the Canadian government. Feasibility studies, both experimental and theoretical, have been carried out in laser/detector noise reduction techniques, receiver optimization at data transmission rates up to 1 Gbit/s, comparison f direct versus heterodyne detection and the effect of laser excess noise on system performance. MPBT is presently seeking new participation with space agencies such as the European Space Agency, NASA and the Canadian Space Agency in the development of future ISL systems.

MPBT has just completed designing and testing an FSK heterodyne laser diode system (operating at 0.84 μm) for 1 Gbit/s data rates. The breadboard system includes two GaA1As laser diodes mounted individually in temperature controlled chambers with their collimating optics. Both beams pass through optical isolators and are combined on a fast silicon avalanche photodiode. A delay line discriminator is used to frequency stabilize the IF signal. Extensive component characterization such as measurement of laser IM and FM noises, FM and IM response, detector preamplifier bandwidth, heterodyne signal stability versus temperature, automatic frequency control loop performance, and laser driver response is performed before integration into the system. Measurements are being carried out to determine system sensitivity for direct, heterodyne and dual balanced receiver detection modes.

CO_2 Laser Communication Feasibility Study for NASA

An in-depth feasibility study of a CO_2 laser communication system was performed for NASA. The system investigated was a CO_2 laser link between earth and a synchronous satellite, and another link between two satellites. Both theoretical and experimental work were involved in this study. As a result, a long life laser was developed, heterodyne detection was studied, and AM and FM noise sources were evaluated; signature measurements of the laser, automatic acquisition techniques, modulation, packaging, etc. were all studied during the course of this program. An automatic frequency control effective to 3 parts in 10^9 was developed and marketed.

Atmospheric Laser Communication System

Using the experience gained with an FM-AM HeNe system built previously, MPBT has developed a communication system for point-to-point terrestrial links which is now on the market. The system is capable of video, multi-voice channels or high rate data transmission. The link incorporates a GaA1As laser diode at a wavelength of .83 micrometers. The collimated laser output permits communication in noisy environments or where a high degree of security is required. Quick installation and optical battery operation allows for temporary links or links in areas of difficult access. The range is up to 2 km depending on the application.

Laser Diode, 16 km, Digital Link

A 140 Mbit/s link, based on laser diode at 0.83 m, has been built and delivered to CRC. The system was designed to operate for distances up to 16 km.

FM-AM Helium-Neon Communication System

In order to orbit experience in laser communication systems, a complete HeNe laser communication system was developed a number of years ago.

This was a shorthaul system that was useful in applications where a video link had to be established spanning up to 5 km. As it was a "visible" laser, communication could be established between two inside locations such as offices, studios, etc., the beam passing through ordinary windows without any problems.

Evaluation of the HeNe communication system in a downtown environment has shown that very good transmission can be obtained most of the time on a 3.6 km link through pollution, haze, rain and light fog.

CO_2 Laser Communication System

A complete CO_2 laser communication system was designed and built for "Communication Research Centre" in Ottawa. This system is versatile and can operate in the envelope or heterodyne detection mode. It was built to operate on a 16 km link using diffraction limited optics. An off-axis parabola was used for the transmitting telescope.

CO_2 Coherent Laser Radar System

MPBT has designed, built and delivered to the Canadian Government a coherent (heterodyne) laser radar system for remote vibration measurements to work in the atmosphere.

Heterodyne Laser Receivers

A CO_2 waveguide laser local oscillator operating at 10.6 μm has been developed for Defence Research Establishment Valcartier (DREV) as part of a radar laser receiver. The design characteristics included a wideband tuning capability of ± 150 MHz, long life and low noise. AM and FM noise measurements were performed and heterodyne techniques used for the latter. Ceramic waveguide lasers with bandwidth of up to 1 GHz were developed for DREV also for radar receivers.

CO_2 Laser Radar System

A feasibility study of a CO_2 laser side looking radar for active IR imaging was performed for the Department of Energy, Mines and Resources. It comprised both theoretical studies as well as experimental work to verify critical laser subsystems definitions. Q-switch lasers were built and heterodyne measurements were done to study Doppler effect. Analytical work demonstrated the effect of FM laser noise in a laser Doppler radar.

FM CO_2 Laser Communication Systems

A program was completed to investigate various CO_2 laser communication systems. A detailed theoretical study was carried out to determine the relative advantages of a wide variety of modulation schemes when applied to particular communication applications. A lab model based on one of those, namely FM-AM modulation, was constructed and it was shown that very good TV transmission can be obtained from such a system. Theoretical models also suggest that good transmission over substantial ranges is possible under a variety of weather conditions. Liberal use of the computer was made for both programs, especially to obtain optimization conditions.

Laser Propagation Experiment

A laser propagation experiment was completed a number of years ago. It includes the collection of statistics on atmospheric attenuation of laser radiation at 10.6 μm and .6328 μm over a link of about 2 km (round trip). The two lasers were transmitting essentially over the same link and thus attenuation correlation was possible. many problems involved in over-the-air transmission and reception of the laser beam, stability of the system and calibration had to be resolved.

Pulse Code Modulation Communication system

A complete laser PCM communication system to transmit a video signal was built. An 8 bit-per-word format was used and with a clock rate of 80 Mbit/s a high quality TV picture could be obtained. To produce the train of pulses, an HeNe laser was forced into mode locking producing pulses less than 1 ns wide at an 80 Mbit rate. Much experience was thus acquired with short laser pulse modulation and detection. Also fast electronics were designed and built for serial-to-parallel and parallel-to-serial converters. Phase jitter measurements of narrow pulses going through the atmosphere were also performed.

Stark Cell Stabilization System

MPB Technologies Inc. has developed a complete Stark Cell stabilization subsystem together with the electronic control module for regular and waveguide CO_2 lasers. This work has resulted in a long life Stark Cell which is now on the market.

Thomson Scattering Receiver

During the last 5 years, MPB Technologies Inc. has developed a complete receiver system for a Thomson Scattering plasma diagnostic experiment. The system is presently operating successfully on the Canadian Tokamak installed at Varennes, Quebec. The receiver measures the spectrum of the light of a 1 Joule 20 ns pulse Nd:YAG laser (1.06 μm) as scattered by the electrons of the plasma. It includes a grating spectrometer which has 6 spectral channels from which radiation is collected using Si avalanche photodiodes. The detector output pulses are, after amplification, integrated by a fast 9-bit A to D convertor. Considering the Thomson scattering cross-section and the amount of background light, the system operates with a signal-to-noise ratios close to 1. The minimum number of detectable photons is about 100 during the brief gate opening (few nanoseconds) and corresponds to the dark current noise of the photodiodes. Each laser pulse gives a single scattered light spectrum from which the electron temperature and density of the plasma is calculated. Calibration, both absolute and relative between spectral channels, is very important in terms of determining the plasma parameters and extensive set of testing measurements have been defined and applied to the system.

MPBT Laser Communication Product

The MPBT expertise in laser communication has resulted in the development of an Atmospheric Laser Communicator which is on the market. The system is based on a laser diode optical link and allows transmission of video, audio and/or data with possibility of channels multiplexing.

Space Related Projects

MPBT has been and is presently involved with the designing and developing hardware and systems for space applications.

Laser Material Processing in Space (LAMPS) Program

Including: the design and development of a modular, multi-users facility for variable gravity research that was flown aboard the NASA KC-135 aircraft. The system provides a convenient support for mounting special purpose equipment such as interferometers, CCD cameras or growth cells, and at the same time is supplemented by generic peripherals such as control and data acquisition electronics, high power laser, beam delivery and monitoring optics, linear translation stages. This concept is currently being developed for the Canadian Space Agency to fulfil the needs of the scientific community for research in variable gravity environment.

Microgravity Experimental (GET AWAY SPECIAL) Program

Including: Design, Development and Construction of a Flight Qualified Configurable Hardware for Multidisciplinary Projects in Space (CHAMPS); Experiments on Liquid Phase Electro Epitaxial (LPEE) for semiconductors (e.g.

GaA1As); configurable for Crystal Growth, Ceramics Processing, Protein Crystal, Metal Alloy Mixing, Marangoni effect, etc.

Waves in Space Plasmas (WISP) - a Space Shuttle Experiment

MPBT involvement included: Definition Phase Study, Systems Design for this Multipurpose Computer Controlled Experiment, Total Control Electronics Software, Ground Support Equipment for Receiving, Storing and "Quick Look" analysis of the 3 Mb/s Data Stream from the Experiment during the Flight. Also used as System Test Equipment during Design, Fabrication, and Integration with other Equipment.

Optical Techniques for Space Based Radar

The program includes: design of laser optical links to meet radar signal distribution requirements; RF generation by means of optical techniques such as direct modulation of laser diode, heterodyning, non-linear signal generation; design of fibre optic networks for Phased Array Radar Application; study of effects of space environment on the proposed configurations.

Acquisition - Tracking Related Projects

Electronic Processor for IR-Seeker Using FM-Reticle

MPB Technologies Inc. completed a project in designing an electronic processor for an IR-seeker using FM-reticle. The processor was designed and built by state-of-the-art electronics. The optical head is mounted on a spinning precessible gimbal. IR source from a target is focused to a detector through a rotating reticle with spokes. The IR beam is chopped by the reticule and carrier frequency is produced in the detector output signal. When the target is away from the optical line of sight, frequency modulation is produced on the carrier signal. The detector signal is first AGC amplified, bandpass filtered and then FM demodulated to produce the error signal. This error signal is proportional to the difference between the target and the optical line of sight. With a phase reference signals from the seeker head, correct amounts of current are sent to drive the gimbal which then tracks the target. The error signal is also sent to the missile control system to correct the missile axis to the optical axis.

Laser Seeker Simulator

MPB Technologies Inc. completed program in developing a Laser Seeker Simulator for EW application. A system which was designed and built by state-of-the-art electronics was delivered to DREV. Laser pulse is sent out and reflected by the target. The reflected beam is collected by the optical had and illuminates a quadrant detector of the laser seeker. The output pulses from the quadrant detectors are amplified and detected by high speed peak detectors. The peak detected outputs which represented the target position are than analog-to-digital converted and sent to a digital processor. The target position is computed by microprocessor and corresponding control signals drive the platform which then tracks the target. The laser pulses are specially coded for ECCM purposes.

MPBT International Involvement in Communication

Development of Fibre Optics Submarine Cable Traffic Splitter/Combiner

The TAT-9 Submarine Cable System, being installed in 1991, will link five countries: The United States, Canada, France, Spain and the United Kingdom. It will be the second trans Atlantic cable to utilize fibre optic technology.

MPB Technologies Inc. has been contracted by the TAT-9 owners to research, develop, engineer, manufacture and qualify the Undersea Branching Multiplexer (UBM) and the associated Special

Terminal Equipment (STE) for the TAT-9 Cable System.

The TAT-9 system, will operate at an unprecedented line rate of 591.2 mbit/s (twice the TAT-8 data rate). The UBM is designed to interchange traffic groups of 140 Mbit/s and 45 Mbit/s among the five TAT-9 terminals. The UBM also has the capability to allow synchronization and supervisory signals to be exchanged with TAT-9 to ensure proper operation of the total system. The STE ensures the proper functioning of the UBMs by multiplexing and demultiplexing signals at the landing point terminals and providing monitoring and control.

The UBM requires high performance, high speed, compact multiplexing circuitry. The UBM data exchanger Application Specific Integrated Circuit (ASIC) is a Large Scale Integration (LSI) device, unique in its ability to operate at ≈600 Mbit/s under worst case conditions while at the same time satisfying the ultra-high reliability specifications required for submarine operation. The TAT-9 system has a design life of 25 years. The data exchanger ASIC (as well as all other components) must therefore meet very strict qualification and certification standards. The rigorous performance testing of such a complex LSI device at rates as high as 600 Mbit/s made it necessary for MPBT team members to develop innovative test procedures and equipment. The design, development and testing of this ASIC was one of the most critical steps in making the UBM feasible.

MPBT Reliability Lab

MPBT has established the Technology Development group for the purpose of evaluating, qualifying and certifying electronic components prior to installation in ultra high reliability electronic systems. At present, the group is involved in component supply for the next generation trans Atlantic fibre optic telecommunications cable system (TAT-9).

A typical high reliability component procurement program consists of prequalification, qualification, certification and device selection stages. Prequalification is defined as a series of small sample stress tests with components from a number of different technology types and manufacturers. These tests may be electrical, thermal or mechanical stresses as applicable to the specific component. following successful completion of prequalification testing, vendors are selected and specific vendor requirements prior to device acceptance established. MPBT personnel perform all vendor audits and program monitoring (precap visual inspections, etc.) during the procurement exercise. Typically, devices are procured to the highest reliability level available from the vendor and upgraded at the MPBT site to meet the most stringent reliability requirements. MPBT activities include lifetesting to establish baseline failure rates, low stress level, long term certification testing to aid in specific device selection and specialized stress testing to characterize individual failure mechanisms (for example, electro migration testing). Device failure analysis and destructive physical analysis are also performed in conjunction with QRF Analysis (Ottawa, Ontario, Canada). Programs presently in progress at MPBT include such components as high speed ECL Gate Arrays, linear integrated circuits, Schottky barrier diodes, power MOSFETs, capacitors, resistors and transformers.

MPBT provides to facilities for Technology Development Group activities: a reliability laboratory and 2200 square foot clean room. the clean room area is humidity, temperature and particle controlled and is used primarily for lifetesting integrated circuits and the certification testing of candidate components for final system use. The clean room is presently classified as a Class 100,000 facility with plans to upgrade to 10,000 in the near future. All power to the room is backed up by a standby generator and data logging equipment is protected by an uninterruptable power supply. All work areas are protected to prevent electrostatic discharge damage to electrical components.

Equipment on site includes:

i) Four Flourinert liquid burn-in baths for lifetesting and burn-in on high power density components,

ii) Numerous ovens, temperature cycling chambers and humidity chambers,

iii) IMS XL60 ASIC Verification System for high speed characterization of complex ASIC devices,

iv) Six Anritsu ME522 Transmitter/Receiver Sets for Very High Frequency characterization of integrated circuits.

v) Tektronix 371 High Power Curve Tracer for Discrete Component Stress and Characterization,

vi) Numerous dataloggers and computers.

MPBT Quality Assurance Activity Plan

MPBT has recently established a QA Group.

D.4 SED Systems

Key Personnel

Dugald Buchanan,	General Manager
Ray Basler,	Director of Finance

SED's Mission Statement

SED's markets may be identified in a general way as follows:

- Canadian government communication and space programs via the CSA, DND, DOC, and Transport Canada. Many of SED's contracts are via prime contractors such as Spar Aerospace, Paramax, Oerlikon Aerospace, Raytheon, etc.
- Domestic satellite operators and users
- International satellite carriers and operators such as Inmarsat, Intelsat, etc.

Major Recent Achievements

- Successful manufacture and launch of Superthermal Mass Spectrometer instrument on Japanese satellite. Fully functional after 1 1/2 years.
- Contract award from British Telecom to supply the world's first Inmarsat B/M dual ocean region Access Control and Signalling Equipment (ACSE) system.
- Contract award from Intelsat to supply Intelsat's world-wide Satellite In-Orbit System.

Company Overview

SED Systems Inc. is a leading Canadian advanced technology company specializing in space and communications systems engineering. Since its inception, SED has acquired extensive expertise in space, communications, satellite test and control, and defence systems engineering and in custom electronic system manufacturing. With proven professional capabilities, a strong renewing technological base, and an international reputation for excellence, SED is well positioned for growth in Canadian and international markets.

SED has been a successful national and international systems team member on numerous large projects since 1965 and has established associations with numerous commercial and government ventures. As a result of this experience, SED has the project management skills, systems engineering capability, integrated logistics support, and product assurance procedures in place to meet the highest project standards.

Finally, SED is a Prairie region advanced space and communications system technology leader and is already providing guidance and leadership in the provision of Industrial Benefits to the region through its association with Spar Aerospace, Paramax Electronics, and Raytheon Company. Contacts and associations with advanced technology companies in the region complement SED's capabilities in systems engineering, software development, and custom manufacturing.

SED is headquartered in Saskatoon, Saskatchewan and is located in a research and development park near the University of Saskatchewan. As a member company of the CALIAN Group, SED has access to different but complementary technologies, to broader markets, and a strong financial base. The relationship significantly enhances SED's ability to pursue and achieve its business objectives. SED's fiscal year

1989/90 sales volume was approximately $25 million with a backlog of projects of similar value. SED also has access to the expertise of the many other advanced technology companies located in Saskatoon.

SED currently employs about 275 personnel of whom about one-third are technical professionals. Most personnel are cleared to SECRET level and personnel security is enhanced by regular security briefings and seminars.

Evolution

SED began in 1965 as the Space Engineering Division of the University of Saskatchewan with a mandate to design and build rocket instrumentation for upper atmospheric studies. To date, 65 launches have been completed as a result of this initiative.

After five years of working exclusively in the design and construction of such scientific payloads, SED diversified. Work began on the design and development of space systems technology related to the satellite communications industry. Work on the CTS/Hermes project in 1970 helped focus the company on systems engineering, which is now its dominant business thrust.

The expertise developed during this period also led to a contract for the systems' design and conversion of the Prince Albert Radar laboratory to Canada's LANDSAT Satellite Tracking and Receiving Station (PASS) in 1972. SED operated PASS for over 15 years, acquiring extensive remote sensing and operations expertise.

SED became a privately incorporated company in 1972 and has evolved in step with space and communications technology. The company's first commercial satellite earth station was produced in 1973. Since then, numerous stations and systems have been designed and installed around the world, many of them employing proprietary SED designs.

Since its beginning, SED has been involved in hundreds of successful space and communications projects which have ranged in size up to $30 million and have included Satellite Telemetry and Tracking Command Stations, Satellite System Test Sets, command and Control Centres, Communications Systems, Meterological Systems, Radar Displays, and various SED proprietary Communications Products and Systems.

Now in its 26th year, SED has further evolved and diversified its original Space business into four Business Sectors; Space Programs Satellite Ground Systems, Defence and Government Systems, and Custom Manufacturing.

Corporate Objectives

SED's objectives are stable, controlled, profitable growth, increased sales in commercial, government, and international markets; development of its technological base; and enhancement of staff and facilities to meet new challenges.

Customers

A cornerstone of SED's strategy has been to develop and maintain long-term relationships and strategic associations with major, high quality customers and associates. SED's many Canadian and international clients include Transport Canada, the Department of National Defence, Spar Aerospace, the National Research Council of Canada, Oerlikon Aerospace, Department of Communications, Raytheon Canada, Raytheon U.S., Paramax Electronics, Telesat Canada, Teleglobe Canada, Inmarsat, Societe Europeenne des Satellites, British Satellite Broadcasting, British Telecom PLC and Intelsat, many of whom SED has dealt with for over ten years. SED's quality customer base provides a strong foundation to pursue new contracts with confidence.

Facilities

In February of 1987, SED integrated its operations under one roof in its new 11,600 square metre (125,000 square foot) custom-built facility in Saskatoon. The company, with its significant strength in systems engineering, reorganized along functional lines and placed a clear focus on the systems aspects of its business.

The facility includes 4,000 square metres (43,000 square feet) of manufacturing and integration space, a Class 10000 clean room, and a thermal vacuum chamber. The building is fully secure. Automatic data processing facilities are available for administration, design, engineering, project management and Computer Aided Drafting (CAD).

Regional Coordinator

SED, as a leading advanced technology company on the Canadian Prairies, is in an excellent position to coordinate the activities of smaller Prairie companies that can provide complementary technology. In such a leadership role, SED provides for increased regional collaboration through distribution of Industrial Benefits to qualified firms. The result is greatly expanded opportunities and overall capability of both SED and its regional partners.

Throughout its history, SED has developed numerous products and commercial applications o technologies derived from government and commercial contracts. Success in these areas has resulted ina large number of spin-off companies that trace their roots to SED. The evolution from a minor scientific research division of the University of Saskatchewan to an internationally recognized aerospace systems contractor has helped SED create an environment where it can readily assist other Canadian companies to grow and prosper.

This role was strengthened when SED became the Industrial Associate of Spar Aerospace for the Prairie region. This has assured SED of continuing participation in Canada's Space Programs such as Space Station, Radarsat, and MSAT, and increasing responsibility for coordinating Prairie involvement in these regionally distributed programs. SED also provides regional leadership through its work on programs for Paramax Electronics and the Raytheon Company.

Business Sectors

SED has established a strong core of engineering expertise. Consequently, the company employs one of Western Canada's strongest systems engineering teams and has diversified its original space business into four business sectors: space, satellite ground systems, defence and government systems, and custom manufacturing. The common hardware and software technology base of these sectors, combined with a common customer base, makes them natural divisions of SED's business. At the same time, they allow for diversification without straining the company's capabilities in providing complete systems design, engineering and installation.

Space Programs

Space science is SED's original business area with 65 scientific rocket-borne payloads designed and launched to date. GEODE, Canada's first microgravity, rocket-based payload, was launched in 19876 and successfully demonstrated a unique microgravity infrared sensor manufacturing system. Under a new contract, SED is making further developments to this infrared sensor manufacturing system for the future launch of GEODE II.

SED has been the prime contractor for two spaceborne instruments: one to measure upper atmospheric winds (Wide Angle Michelson Doppler Imaging Interferometer - WAMDII); a second to measure solar emissions (Suprathermal and Energetic Ion Mass Spectrometer - SMS). The SMS was launched on the orbiting Japanese AKEBONO satellite in February 1989, and is the first foreign scientific instrument ever to fly on a Japanese satellite. SED is one of the few Canadian companies with the engineering, scientific, and manufacturing capability to lead projects of this type, and the company has gained a solid international reputation as a leader in Space Sciences.

SED is one of the five lead Canadian companies developing the Mobile Service Centre to be provided by Canada for the Space Station. SED is responsible for the ground Segment including the ground-based test and control systems. The company is committed to developing applications to be flown on the Space Station itself, such as the GEODE previously described. as regional coordinator, SED is managing the entire Prairie component of the program.

SED is also applying its expertise to environmental issues by working with a team of western aerospace companies to define a new space-based earth environment monitoring system. The Earth Environment Space Initiative (EESI) program is aimed at developing the technology necessary to comprehensively monitor the Canadian environment from space, including air, land and water. One aspect of the program is the development of satellite sensors especially suited to conditions in the Canadian atmosphere. SED will lend its particular expertise to the EESI program in the areas of spaceflight instruments and satellite test and control systems.

As a member of the Canadian Network for Space Research, SED's strong technological base and reputation for excellence will continue to be applied in expanded Canadian and international space programs.

Satellite Ground Systems

In-Orbit Test and Control Systems

SED has been a leader in Test and Control since the early 1970's, beginning with the design and operation of the ground control station for the communications Technology Satellite (CTS/hermes) program. SED also provided telemetry, tracking, and ground control equipment for the entire Anik series, SBS, and Intelsat V satellites. In association with Spar Aerospace, SED completed the design, manufacture and installation of the complete Brazilian Telecommunications Satellite System Ground Segment.

SED's Brazilian experience led directly to another major contract to design and provide complete real-time In-Orbit Test Systems and Communications Monitoring systems to Inmarsat, and to contracts for similar systems for Luxembourg's Direct Broadcast Satellite (SES) and for British Satellite Broadcasting (BSB). The first Inmarsat system was installed in Fucino, Italy, in 1988; a second was installed in Beijing, China, in 1989; and a third system is being installed in Southbury, Connecticut. SED just recently won another contract to design and provide two In-orbit Test Systems for Intelsat. SED will install the systems in Beijing, China, and Clarksburg, Maryland, in 1992. The contract includes an option for two additional systems.

These contracts, based on proprietary SED real-time monitoring and control software, were won in direct international competition against major European aerospace companies, and SED continues to pursue other markets for this unique system.

SED has secured a place in the Mobile Coast Earth Station market by winning the first international contract to be awarded for development of equipment to support the new Inmarsat B and M services. Under the two-year contract signed with British Telecommunications PLC of the United Kingdom, SED is developing an Access Control and Signalling Equipment (ACSE) system that will allow British Telecom to provide the new digital mobile communications services. The system will be installed by SED engineers at British Telecom's satellite station in Goonhilly Downs, England, in November of 1992.

SED is very involved in the Radarsat program, participating in three major areas. First, SED is providing the synthetic Aperture Radar (SAR) Subsystem Checkout Equipment (SCOE), a system for measuring and testing the Radarsat payload during spacecraft manufacture. Second, SED will perform the integration and test of the Radar Data Downlink Transmitter Subsystem (DDTS), the satellite-borne unit which transmits the payload data to the ground receiving stations. Third, SED will participate in the design, manufacture, integration, test and operation of the backup Mission Control System (MCS) and the Telemetry, Tracking and Command (TT&C) stations for the satellite.

Communications Systems

Voice and data networks are primarily based on the Skyswitch™ satellite communications system technology. To augment Skyswitch™, SED has developed an even more cost-effective, two-way VSAT for voice and data. As well, SED has full capability in the design of radio and microwave communications links for frequencies in the HF through EHF bands.

Skyswitch™ systems have been installed in several countries including Canada. One Canadian example was the design and installation of a major system (CANOPUS) for the National Research Council which included 15 two-way voice and data stations to provide continuous, real-time data from remote Arctic sites. SED has also installed systems for Transport Canada, the Department of National Defence, and the Coast Guard for use in Northern Canada. A similar opportunity is being pursued with SaskTel to provide telecommunications to northern regions of the province complementing a seven-station system already installed for SaskPower.

SED is currently providing the engineering, manufacturing, installation and testing of the Ground Communications Equipment and monitor, Alarm and Control Subsystem for Teleglobe Canada's Laurentides Intelsat "A" station.

SED will continue to emphasize the systems approach utilizing its proprietary systems, products and technology. continued access to Skyswitch™ technology will provide an ongoing base on which to apply SED's continually developing technologies and enhance its proven expertise as a custom, large system supplier, the result of the many hundreds of Satellite Ground Terminals installed to date.

Defence and Government Systems

SED has intensified its penetration of the defence market. It has provided a northern satellite communications system, manufactured digital switches for the American and Canadian Air Defence System, and is deeply involved with the Search and Rescue Satellite (SARSAT) and the Canadian Patrol Frigate (CPF) programs.

Involvement with SARSAT has been in two phases. Under the Engineering Phase, SED provided the initial control and monitoring capability for the entire Canadian SARSAT system by designing and installing the Canadian Mission Control Centre at Trenton. This initial phase was very successful and was followed by SED upgrading the system to full operational capability. New contracts are ongoing to support and enhance this system further.

SED's largest project to date is the system design, integration, and testing of the Exterior and Miscellaneous Interior Communications System and the shipboard Meterological System for the Canadian Patrol Frigates. This program has involved the design, development and manufacture of naval qualified hardware and software systems to strict quality assurance guidelines. SED was recently awarded a major follow-on contract to CPF to supply the integrated exterior communications systems for the second group of six vessels in the 12 ship Canadian Patrol Frigate program. The six systems will be identical to those designed and built by SED for the first six ships.

SED is providing the design and manufacture of specialized test sets to AQAP-1 standards for the LLAD project on behalf of Oerlikon Aerospace.

The experience gained in managing these major defence projects has positioned SED to pursue opportunities in many major new programs planned by Transport Canada, the Department of National Defence, and other government agencies. Future defence work for SED includes a Communications System (TCCCS) Program. As a member of the Computing Device team that won the contract, SED will provide major elements of the satellite-based Very Long Range Communications System as well as other systems engineering and high-quality manufacturing work.

Custom Manufacturing

To penetrate new markets and acquire technologies, SED has established a comprehensive custom manufacturing capability for specialized electronic systems for major customers. Currently underway is the manufacture of 178 Radar Displays for Raytheon as part of Transport Canada's Radar Modernization Program (RAMP). Under a separate contract with Raytehon, SED also manufactured Radar Display for Trinidad.

SED also manufactures digital switches for Hughes Aircraft and many of its own proprietary systems including Skyswitch™, LCES, and satellite video receivers. Additionally, SED manufactures Static Frequency Converters for the NATO Seasparrow Program under contract to Raytheon U.S.

SED manufactures to full space, defence, or commercial (NASA, AQAP-1, or AQAP-4) standards as required. SED achieved formal AQAP-1 recognition in October 1990.

Capabilities

SED has the proven capability to successfully manage and complete all requirements of projects in its chosen business sectors. The Operations Division is the focal point for these capabilities. As well, full product Assurance capability is provided through a separate, independent Quality Assurance Department.

Project Management

A Business Manager is responsible for each of SED's business sectors.

- Satellite Ground Systems
- Defence Systems
- Space Programs
- Custom Manufacturing

The Business Managers report to the General Manager, and are responsible for project management of signed contracts and for business development in their sector. They are accountable for project performance and profitability, from proposal preparation through to contract wrap-up. A matrix management system is used to provide engineering services.

A Program Control Section provides centralized services to Business Managers in the areas of:

- contract administration
- cost estimating
- scheduling
- cost control
- project cost accounting
- control centre management
- administrative support

SED has over 25 years of project management experience gained in hundreds of Canadian and international projects. As a result, the company has well established and proven staff, facilities, and procedures in place. A key element of SED's project management philosophy is a strong, experienced project manager who has full responsibility, accountability, and authority for all aspects of a project. The Project Manager is supported by project management systems which provide for full monitoring and control of all project activities through computer-aided scheduling, planning, and cost control systems such as PRIMAVERA. All departments are keyed to this project management system and report into it.

Engineering

Engineering

SED has developed a highly capable team of professional engineers and scientists with specialties in systems, software, electronic, and mechanical engineering. This team has the skills to fully address the requirements of all SED market sectors.

Systems Engineering

Systems Engineering is responsible for the establishment of design baselines which translate customer requirements (commercial and government) into high quality systems at an economical cost. Capabilities have been developed in the areas of voice and data networks; telemetry, tracking and command and control systems; satellite test equipment; in-orbit communications measurement and test systems; and specialized microwave applications. Computer-aided design and engineering (CAD/CAE) tools are utilized to assist this group in full satellite and radio link analysis, and system design.

Software Engineering

SED's Software Engineering Department is responsible for the specification, design and production of all software/firmware, and the specification of off-the-shelf software required to support all project work. The emphasis is on real-time applications such as satellite in-orbit test,g round support systems, communications monitor and control, and automated test systems.

SED's software development methodology, based on DOD-STD-2167A, is used to fulfill the requirements of commercial and government projects. An object-oriented approach to requirements analysis and design is used. Computer-aided software engineering (CASE) tools are used to design SED's software more effectively and efficiently.

SED's software development facility is centred on a collection of DEC processors, running VMS, configured in a local area network. SED has a broad base of experience with a variety of target processors (DEC, HP, Sperry, Intel), operating systems (VMS, UNIX,RTE-A, SDX), and programming languages (C, FORTRAN, Modula 2, CMS-2, Assembler). an extensive capability development program has prepared SED's software engineers to utilize Ada, both as a program Design Language (PDL) and for implementation purposes. Additional steps are being taken to augment SED's software engineering capabilities and resources to facilitate the development of knowledge based systems.

Design Engineering

Design Engineering is responsible for developing detailed electrical and mechanical designs of all subsystems and units. SED's hardware engineering capability includes design of instrument control and data handling microprocessors, detectors, power supplies, circuit cards, RF assemblies, and optical and ion optical instruments. Mechanical Engineering develops structural, thermal and packaging designs. Electrical and mechanical designs and the development of devices, components, assemblies and units meet the requirements of AQAP-1, para. 207.

Technical Services

This department provides documentation and drafting services to all projects. The drafting section provides quality mechanical and electrical design and drafting services. Documentation and drafting are based on MIL-STD-100 and D-01-400-001/SG00. Both AUTOCAD and PCAD systems are utilized.

Manufacturing

Manufacturing Engineering

SED is organized to provide the full configuration management materials management, production control, purchasing, manufacturing change control, and manufacturing engineering per AQAP requirements.

Production

Production capability includes component stuffing of bought-in-double-sided and multilayer circuit cards; microwave stripline boards; cable and wire harnesses; and final assembly, integration and test.

Facilities

SED has allocated a total of 43,000 square feet of manufacturing space dedicated to shipping/receiving, stores, production, integration and test. An ESD damage prevention program is in place per DOD-STD-1686.

Workmanship

Workmanship is based on MIL-STD-454, WS6536, Martin-Marietta procedures and IPC. There is an in-house high reliability soldering program based on USN Weapons standards. Assembly is controlled through detailed manufacturing instructions and quality control is based on AQAP-1 requirements.

Production Planning

SED's Manufacturing Department uses a Manufacturing Resources Planning System (MRP II) for production scheduling, materials ordering, and labour resource planning.

Integrated Logistics Support

ILS is provided including planning and management, Logistics Support analysis, Configuration Management for both hardware and software, customer training (either in-plant or on-site), technical data support, PHST, and appropriate support equipment. Procedures are based on AQAP requirements.

Configuration and Data Management

SED has developed a Configuration Management System modelled after DOD-STD-480 and MIL-STD-483, and can support small-scale design and production projects or large-scale systems deliveries for defence projects. The SED Configuration Management System provides effective support in the planning, identification and change control of a product. It also allows for accountability that SED designs meet the stated performance specified in the contract.

SED has also established a Data Management organization which helps to identify and monitor all data contractually required for each project. This support enables effective data cost estimating, delivery schedules and approval status.

Quality Assurance

SED's Quality Assurance department reports independently and works to AQAP-1, AQAP-4, AQAP-13, DND 1015/1016, MIL-Q-9858A, and MIL-I-45208A standards.

Business Sector Highlights

Space Programs

1965 - 65 - Rocket Payloads for NRC and others

1978 - 1980 - Firewheel sub-satellite for NRC

1981-1990 - WAMDII for NRC

1985 - GEODE for CSA

1985 - 1989 - SMS for NRC

1985 - Space Station for Spar

1990 - Radarsat for Spar

Satellite Ground Systems

Telemetry Tracking and Command

1970 - 1976 - CTS Mission Planning and Support Centre

1972 - Anik-A TT&C for Telesat Canada

1972 - 1987 - Landsat/GEOS Tracking Station for CCRS

1978 - 1982 - Anik C&D, SBS, Intelsat V Ground Segment for Hughes

1982 - Anik C/D TT&C for Hughes Aircraft

1982 - 1985 - Brazilsat ground segment for Spar

1986 - In-Orbit test systems for Inmarsat

1987 - 1989 - In-Orbit Test System for Luxembourg

1988 - 1989 - In-Orbit Test System for BSB

1989 - 1991 - Radarsat SAR SCOE for Spar

1990 - 1992 - In-Orbit Test System for Intelsat

Communications Systems

1973 - Hundreds of satellite ground terminals installed

1981 - 1983 - Two-way satellite ground system for Telesat

1985 - 1990 - Fifteen-station Skyswitch system for NRC

1985 - 1986 - Six-station Skyswitch system for SaskPower

1985 - Two-station Skyswitch system for Transport Canada

1986 - Skyswitch system for Coast Guard

1988 - Skyswitch systems for Newfoundland Telephone

1989 - 1990 - Ground Communications Equipment for Teleglobe Canada

1990 - 1991 - Skyswitch system for SaskPower Points North Network

1990 - 1992 - Access Control and Signalling Equipment for British Telecom

Defence and Government Systems

1981 - 1983 - Two-way system for Telesat

1981 - 1983 - SARSAT Mission Control Centre - Engineering Phase for DND

1983 - 1993 - Canadian Patrol Frigate Exterior Communications for Paramax

1985 - 1988 - SARSAT Mission Control Centre - Operational Phase for DND

1988 - NVTS for Oerlikon Aerospace

1988 - SARSAT Enhancements

1990 - LCRU or oerlikon Aerospace

Custom Manufacturing

1979 - 1987 - NORAD Digital Switches for Hughes Aircraft

1985 - 1993 - Radar Displays for Radar Modernization Program for Raytheon Canada

1987 - Static Frequency Converters for Raytheon U.S.

Ongoing - Broadcast quality TVROs

Principal Clients

- Spar Aerospace
- Paramax
- Raytheon
- Canadian Space Agency
- Intelsat
- General Motors Diesel Division
- Department of National Defence
- Oerlikon Aerospace
- National Research Council
- Inmarsat
- British Telecom plc

Collaborative Agreements

- Spar Aerospace
- Canada Network Space Research
- Alberta Research Council
- Sask. Research Council
- Computing Devices of Canada
- Hughes Network Systems
- (many others)

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D.5 SPAR AEROSPACE LIMITED

ATSG and Electro-Optical Systems Division

Relevant Capabilities

Introduction

The Electro-Optical Systems Division's organization chart is provided as Figure 1. EOSD is responsible for all electro-optical systems and device development within Spar's space, defence and commercial market sectors.

EOSD is a world leader in military passive infrared surveillance and has been engaged in the development of active and passive electro-optical systems for Canadian and U.S. defence agencies for more than two decades.

The Electro-Optical Systems Division has extensive capabilities in a broad range of technical and managerial areas including all phases of engineering support to the Canadian and U.S. Armed Forces.

In the programs and facilities described below, Spar has demonstrated the managerial and technical expertise needed to successfully design, manufacture of test advanced electro-optical systems. The ongoing development and production programs at Spar, such as the AN/SAR-8 infrared search and track program, IR&D on advanced focal plane arrays and machine vision camera design for the Manned Space Station Program, ensures a broad technology base for the development of advanced optical systems.

Optical Engineering Capabilities

The Optical group, within the EOSD organization, has substantial experience in the design, manufacture and test of complex optical systems. Figure 2 illustrates Spar's 30 years involvement in IR technology. In addition to designing the Infrared Optical Telescope for the AN/SAR-8 program, the Optics group has provided support as a resource group to a variety of Spar divisions.

Ongoing projects include participation in the Intersatellite Laser Link study for the Satellite and Communications Division, the design of a dual inspection and diagnostic vision system concept for the Compact Ignition Tokomak and the analysis and design of a camera and lighting system for use on the Manned Space Station (MSS) Special Purpose Dextrous Manipulator (SPDM).

Optical Design

To support our in-house Optical Engineering Staff, a variety of optical software tools have been purchased. Ongoing staff training and regular software updates ensure that Spar is well equipped to solve even the most complex optical problems.

The Optical Industry's premier optical design program, Code V is maintained in-house, at Spar. Software updates purchased every six months, ensure that the software remains state-of-the-art. Using Code V, Spar Engineers have designed and analyzed a variety of IR lenses for surveillance and thermal imaging. Recently advanced features have been employed to examine the design of exotic refractive (binary optic) lenses for a variety of infrared applications. For less complex problems, the PC based optical design program from Kidger Optics is also available at Spar.

Since high sensitivity optical systems are susceptible to stray radiation, Spar EOSD has allocated funds in 1991 to procure the PC based Guerap III and SOAR 2.0. SOAR is a first order stray light analysis program while Guerap III is a recognized Monte-Carlo ray trace optical scattering analysis program.

Most optical ISL's employ reflective telescopes to ensure that the lightweight, high performance requirements can be achieved. Since the mid 1960's, EOSD has designed a variety of telescopes, based upon the Schmidt design, using both aluminum and beryllium. Extensive field and environmental testing has enhanced Spar's understanding of telescope behaviour when subject to adverse environments. Recently, EOSD has undertaken an R&D program to design high-performance 3-mirror asymmetrical telescope systems. The primary advantage of these systems over conventional Schmidt Cassegrain or Maksutov-Cassegrain telescopes is the elimination of the central obscuration. By eliminating the obscuration, the Gaussian beam performance is enhanced while the overall telescope aperture size can be reduced without a loss of performance. Combining EOSD's Telescope design expertise with ATSG's experience with space-qualified optical Black coatings (Martin Black, etc), EOSD is well positioned to support S&CSD in a Canadian-based ISL initiative.

Optical Systems Engineering

The EOSD systems group also has a variety of software modelling and simulation tools which could be applied to a variety of optical design problems.

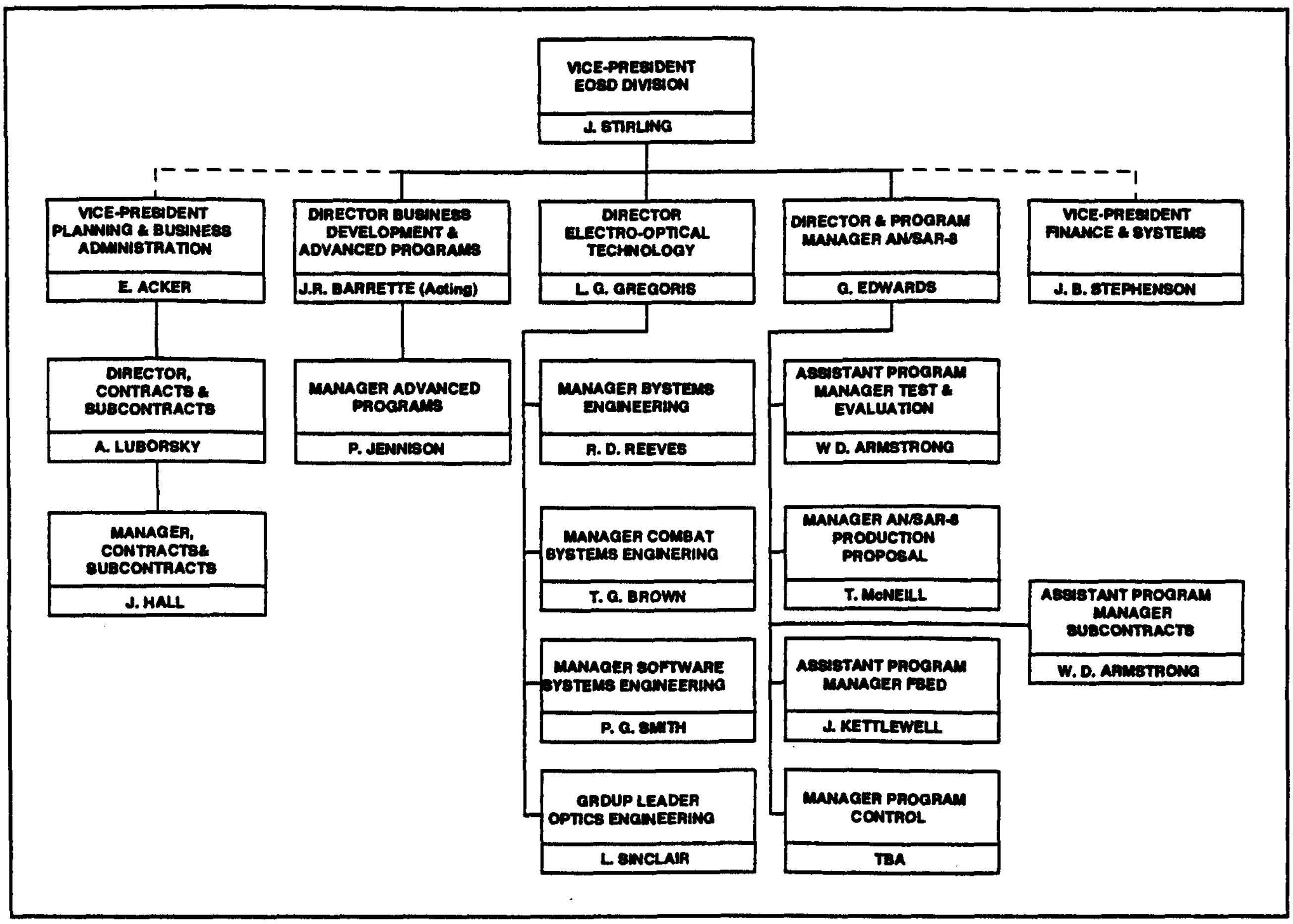

Figure 1 EOSD Organization

The Evolution of Spar Infrared Search and Track Systems

Date	Program Name & Sponsor		Trials Location
1962	Mauler U.S., Army/DND		Malton, Ontario
1964	Mauler U.S., Army/DND		Cold Lake, Alberta
1965	Mauler U.S., Army/DND		Eglin AFB, Florida
1966	Mauler U.S., Army/DND		Uplands, Ontario
1966	Mauler Extension U.S., Army/DND		China Lake, CA
1966	Mauler Extension U.S., Army/DND		Ft. Bliss, El Paso
1967	Mauler Extension U.S., Army/DND		Osborne Head, N.S.
1967	Mauler Extension U.S., Army/DND		Eglin AFB, Florida
1968-69	IREWS, U.S. Navy		Washington, D.C.
1969-70	IREWS, U.S. Navy		Key West, FLA
1969-74	DIR-Research Model, (IRSS), DIR/DND		Toronto, Ontario
1971-72	DREV Aircraft Imaging System, DND		Osborne Head, N.S.
1972-73	Hip Pocket I, U.S. Navy		USS Lawrence: Atlantic, Pacific, S.E. Asia
1972	DREV Aircraft Imaging System, DND		DDH 265, Osborne Head, N.S.
1974	Hip Pocket III, U.S. Navy		USS Buchanan, Pacific
1974-75	SPSDS, Can. Navy/DND		HMCS Algonquin
1976-79	ADM - IRST, U.S. Navy/DND		HMCS Algonquin, USS KINKAID
1984-Present	EDM - AN/SAR-8, U.S. Navy/DND	(EDM#1)	SWEF Port Hueneme, CA
		(EDM#2)	USS KINKAID

Legend:

IREWS:	Infrared Electronic Warfare System
DIR:	Defence Industrial Research (Grant)
ADM:	Advanced Development Model
EDM:	Engineering Development Model

Figure 2 Spar - Over 30 Years of Experience in IR Technology

For modelling, the TACOM and FLIR-90 programs are Minimum Resolvable Temperature (MRT) performance models designed to predict the performance of a variety of IR imaging systems.

IR Detector and Sensor Design

In the Infrared, a variety of detector technologies are available including InSb, HgCdTe and PtSi. Spar has several ongoing research programs designed to examine the operation of a variety of advanced detector concepts in which processing electronics are incorporated with the detector to generate a Focal Plane Array (FPA).

In these projects InSb, PtSi and GaAs detector arrays are all employed to further understand the performance and limitations of these devices for a variety of infrared applications.

During the past thirty years of IR surveillance system design, Spar has acquired extensive experience with both InSb and HgCdTe detectors. In addition, a close working relationship with Cincinnati Electronics (one of premier suppliers of space qualified InSb detectors and FPA) has been established. This experience and understanding of the industry quality Spar EOSD on the most experienced Canadian Company for conducting infrared detector design and procurement.

Once an infrared detector is selected, a variety of issues must be addressed to ensure that the device is adequately packaged. Again, Spar's extensive experience with cryogenic materials, thermal analysis, vacuum dewar design, cold shield, optical chopper design and optical filter specification will ensure the successful design of the entire IR sensor package.

Cryogenic Engineering

Most Infrared Detectors require some form of cryogenic cooling. A variety of technologies are available including cryostats, thermal electric and mechanical cryocoolers. For over thirty years, Spar EOSD has operated a variety of cryogenic cooling systems and amassed substantial practical experience in the operation of these devices. Cryogenic systems based upon the Gifford McMahon and Stirling cycles have both been employed.

Extensive industry contacts have also been established with companies such as CTI Cryogenics, Hughes Aircraft, Lockheed and Magnavox. Regular contact within the industry allows EOSD to monitor the operating performance and lifetime improvements which are occurring in the development of space and military qualified cryocoolers.

To support the An/SAR-8 program, Spar EOSD designed a cryogenic test bed. Using this test set-up, a variety of innovative demountable cryocooler-to-detector interfaces were designed. This test bed was also instrumental in obtaining valuable cryocooler performance data to support the detailed cryogenic design effort.

In support of all cryogenic engineering efforts EOSD has accumulated extensive materials data at cryogenic temperatures. This data is invaluable in ensuring that all performance requirements are met after subjecting the sensor to the low temperature operational environment.

Optical Stabilization and Control Systems Engineering

Spar EOSD has obtained over 20 years optical stabilization experience in conjunction with the development of tactical infrared surveillance systems.

Optical Integration and Test

Optical Testing

In support of a variety of infrared programs, Spar has established an Optical Laboratory. The laboratory, illustrated in Figure 3 contains a variety of mirrors, lasers, backbody sources, optical choppers as well as several large off-axis collimators and an interferometer. This test equipment can be employed in conjunction with the optical design program Code V to ensure

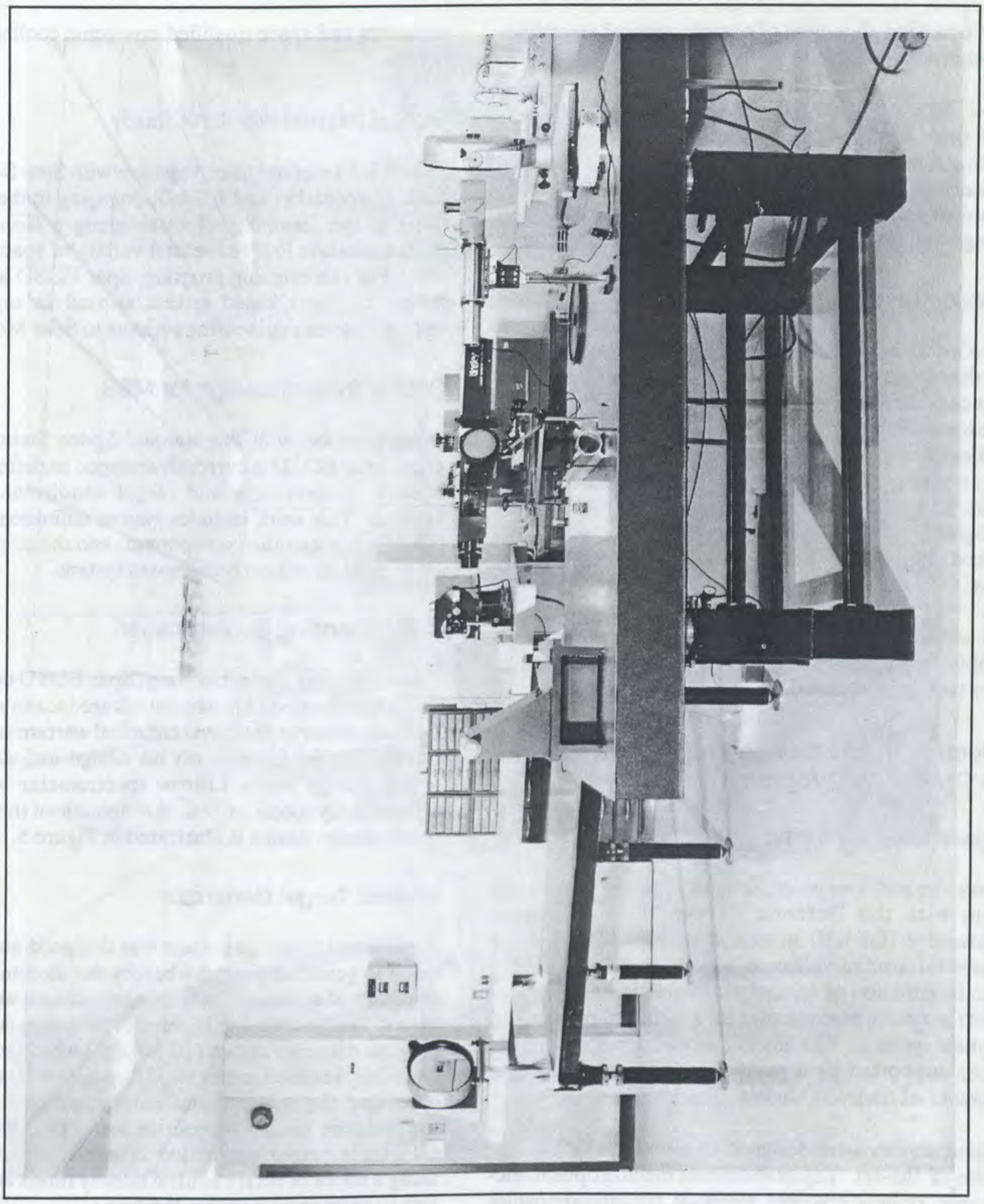

Figure 3 Optical Laboratory

that precision alignment of complex optical assemblies is achieved.

Since Spar's Optical Design Engineers integrate and test their own designs, continuity and cost-effective testing is ensured. Also, the Integration and Test Engineering Department employs a skilled Opto-Mechanical Engineer, who is available to assist in the design and fabrication of test fixtures and test set-ups.

Sensor Testing

Spar's dedication to Infrared Optical Systems design is further emphasized by its capital investment a detector test console (DTC). Illustrated in Figure 4, this versatile test facility contains two blackbody sources, several optical choppers, a monochromator, two radiometers and a variety of power supplies, cryogenic coolers and infrared test detectors. Designed for the AN/SAR-8 program, this facility has recently been adapted to assist in the evaluation of advance Infrared Focal Plane Arrays.

As with optical testing, the senor test facility will be employed by design engineering to ensure cost-effective testing is achieved.

Electro-Optical Design Programs Relevant to Optical ISL Programs

Space Based Infrared

Over the past five years, Spar has worked in conjunction with the Defence Research Establishment Valcartier (DREV) to study the feasibility of space based infrared surveillance. Recent studies have led to the formulation of an analytic model designed to predict the system performance for a variety of space based optical systems. The analytic model development has been supported by a parallel activity consisting of a number of trade-off studies.

These studies were designed to assess the technology state-of-the-art. Topics examined include optical telescopes, optical scanning methods (pushbroom/whisk broom/step-stare), focal plane arrays, laser countermeasures and space qualified cryogenic cooling techniques.

Optical Intersatellite Link Study

EOSD is a team member, together with Spar S&CSD, CAL Corporation and EG&G, engaging in the examining of the feasibility of establishing a laser based communication link between a variety of space satellites. For this ongoing program, Spar EOSD is examining CO_2 laser based system as well as supplying optical systems engineering support to Spar Montreal.

Optical System Design for MSS

In conjunction with the manned Space Station program, Spar EOSD is currently engaged in defining the camera, illumination and target requirements for OTCM. This work includes system definition, selection of space qualified components and the integration and test of an optical breadboard system.

LWIR Scanning Spectrometer

Under contract to the US Navy, Spar EOSD designed and manufactured a brassboard infrared scanning spectrometer to serve as a naval chemical warfare scanning alarm. Special features oft his design include a fast optical design and a Littrow spectrometer which is cryogenically cooler to 77K. A schematic of the optical spectrometer design is illustrated in Figure 5.

Infrared Target Generator

An infrared target generator was designed and fabricated to generate a scene whereby the motion and IR signature of an aircraft and countermeasure were simulated. As illustrated in Figure 6, the system consisted of large diameter optics (10-16" dia.) which were mechanically scanned to mix two IR radiation beams representing the aircraft and countermeasure. High temperature blackbody sources were also employed, with their output modulated in intensity and timing using a series of rotary neutral density filters and shutters to chop and attenuate the beam.

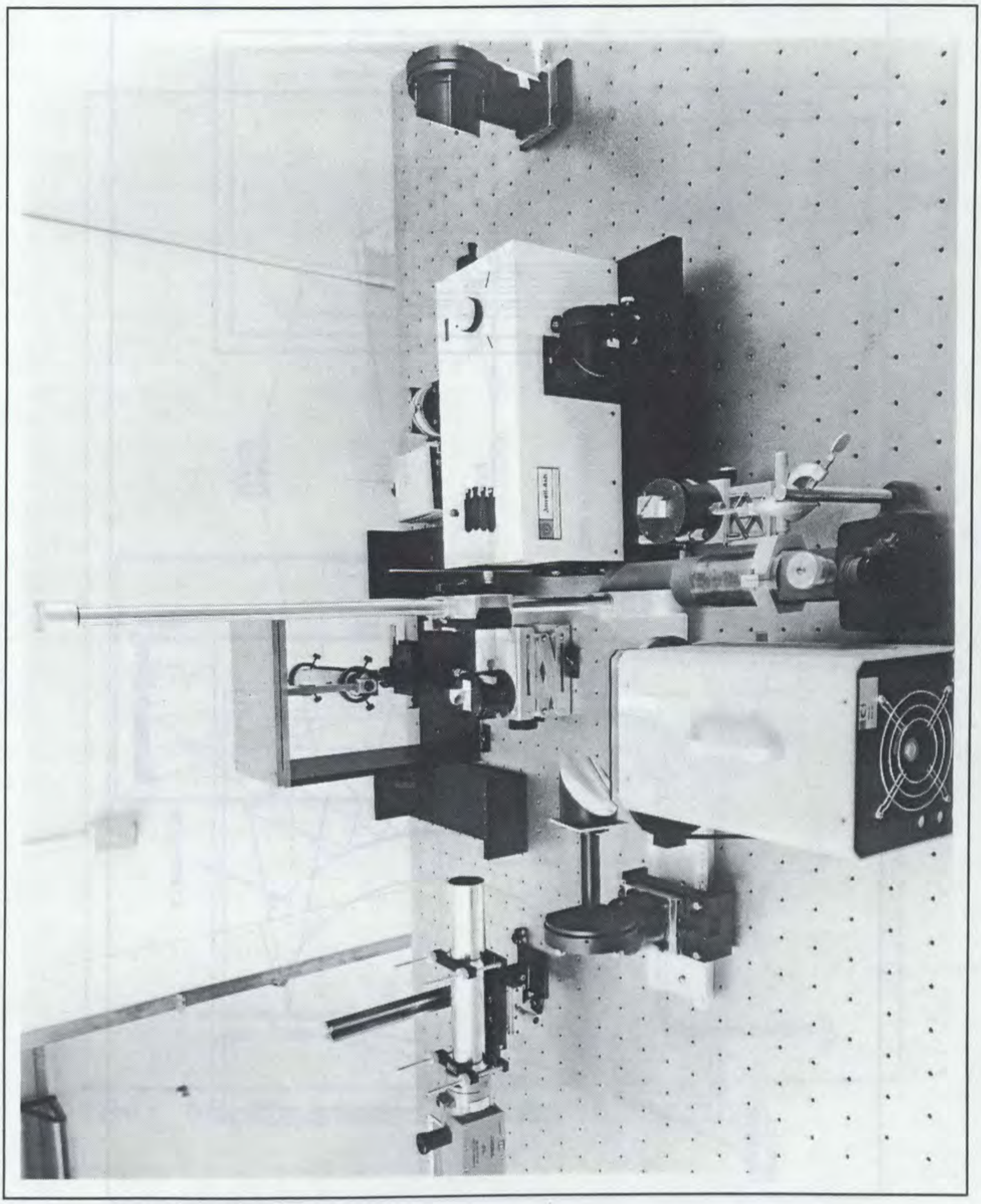

Figure 4   Detector Test Console

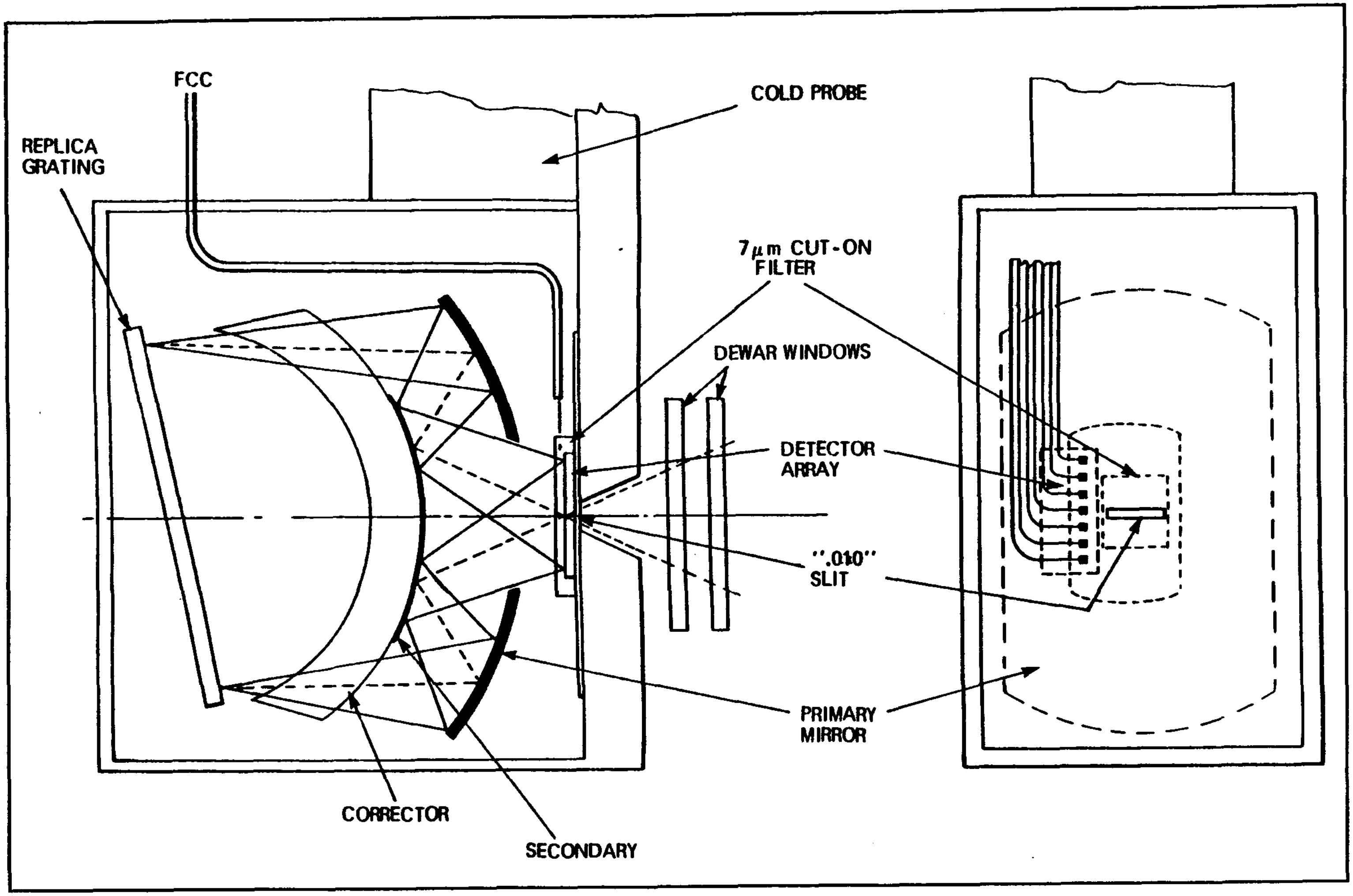

Figure 5 Optical Spectrometer Design

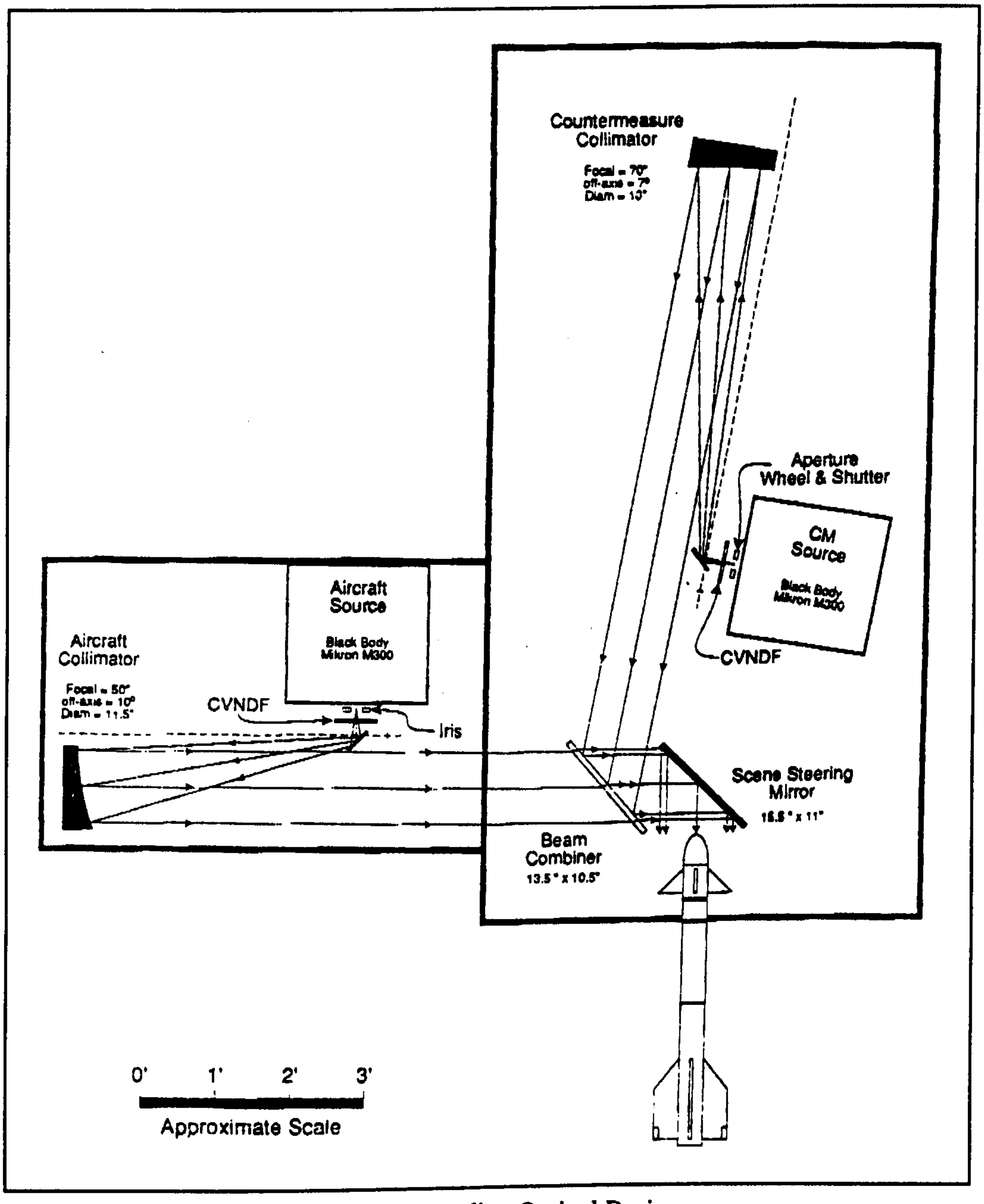

Figure 6 Infrared Target Generator Baseline Optical Design

Infrared Search and Target Designation (IRSTD-AN/SAR-8)

The AN/SAR-8 system, under development for the Canadian and United States Navies, is capable of automatically designating air targets including sea-skimmers, at ranges which exceed the requirements for engagement by most weapons systems. Being passive, the equipment cannot be detected or engaged by anti-radiation missiles and is not vulnerable to RF jamming. These features allow ships fitted with AN/SAR-8 to operate effectively in the presence of the impressive arming and silent operation capabilities of modern Soviet-bloc warships. It also provides a capability for navigation and station-keeping in darkness and bad weather, while operating under radio and radar silence.

To date, two EDM systems have been delivered to the US Navy and have undergone extensive field trials. Land and sea based performance tests conducted during the last 18 months have demonstrated performance better than specified limits.

Novel Concepts in Infrared Search and Surveillance

The continued development of advanced IR surveillance systems requires the constant infusion of new technology. This study examined several technologies such a lightweight stabilization techniques and infrared fibre optics to assess their performance improvement potential.

The lightweight stabilization study examined a variety of electronic stabilization techniques. The impact of coarse mechanical stabilization on data correction accuracy was included to determine the optimum pre-stabilization accuracy. Alternative techniques such as an inertial system were also examined.

The IR fibre study examined the feasibility of incorporating mid wave and long wave IR fibre optics into a dual band IR surveillance system. Performance predictions were made and a variety of IR scanner designs incorporating IR fibre bundles were presented.

This program has now entered a second phase in which a hardware feasibility demonstration is planned.

FLIR Jamming and Damage Study

The FLIR Jamming and Damage Study was performed to establish a Forward Looking Infrared radar's performance when subjected to varying levels of carbon dioxide laser radiation. The investigation focused on Spar's serian scan FLIR model #100216-1 (EDM-001), an early engineering prototype of the equipment currently being supplied to the canadian forces under the Night Observation device Long Range (NODLR) procurement. The study included the development of a computer model which was used to predict the saturation and damage thresholds for the FLIR and the HgCdTe detector array installed in the FLIR.

Design Study of the Integration of a CO_2 laser rangefinder with a FLIR

The purpose of this program was to study the feasibility of integrating a FLIR with a laser rangefinder. a variety of design options were examined which included a common telescope as well as an integrated detector/dewar. In all cases,the FLIR and rangefinder sensivity were predicted along with a size, weight and reliability analysis.

Electro-Optical Tracking System Study

Under contract to the Defence Research Establishment Valcartier, Spar conducted detailed design studies related to the development and fabrication of a naval infrared surveillance and tracking system for missiles and gun fire control. The first prototype of this system incorporating a large 24" stabilized mirror, illustrated in figure 7 and high energy DF and Nd:Yag laser was trialed aboard the Canadian ship Algonquin, demonstrating the ability to track both airborne and surface targets.

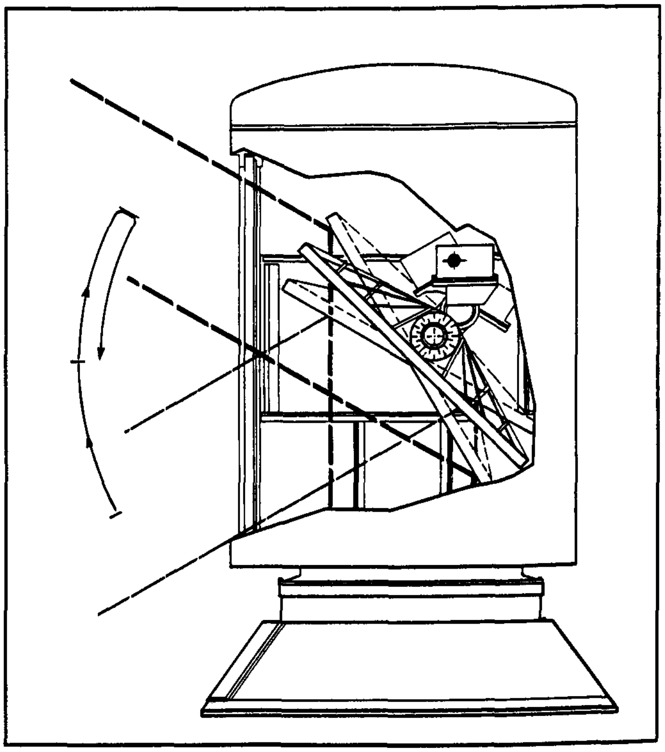

Figure 7 Electro-Optical Tracker

Ocean Surface Roughness Measurement system (OSRMS)

Under contract to the Defence Research Establishment Pacific, Spar produced an airborne laser line scanner for active (laser) detection of water turbulence caused by submerged submarines. This system was installed in an airborne patrol aircraft and extensively trialed off the Pacific Coast.

ATSG Engineering

As part of ATSG, EOSD has access to an Engineering Matrix organization with over 300 skilled Engineers and Designers. Within this group are Electrical Engineers, skilled in designing low noise IR detector electronics. Such skills are essential for designing high-precision IR surveillance systems.

Mechanical Engineering support is also available. ATSG has developed an international reputation developing space mechanisms for robotics and solar arrays. The same design team is available to EOSD to develop the special mechanisms required for space based optical instruments.

Further, finite element modelling using NASTRAN and PATRAN will ensure that excessive vibration from the cryocooler will not impact the performance of the optics or other instruments on the platform.

Optical scanning mirrors have been designed by Spar in previous programs. Most recently, in conjunction with the SBIR program, space based scanning mechanisms have been reviewed especially for larger field-of-view applications. For thermal analysis TRAYSYS and SINDA will be employed to ensure thermal optical stability together with thermal blankets and active and passive cooling techniques for space.

The Materials Engineering group at ATSG has extensive experience in the selection of space qualified materials. As a resource group, Materials Engineering support for the selection of appropriate optical materials is ensured.

Mechanical Design Experience Applicable to Optical ISL Programs

A brief review of the Coarse Pointing Assembly (CPA) requirements indicate that the following performance parameters must be met:

- low torque
- high accuracy
- low backlash
- low disturbance torque drive capabilities

ATSG has designed low torque positioning devices such as the ANIK C/D Antenna Positioning Mechanism and also very high torque high precision gearboxes such as SRMS. As a result of this experience, we have extensive background in the design of high precision, low noise, low to zero backlash gear sets of various types and sizes. The following data is a capsule summary of applicable experience and applications.

Drives

SRMS

- Designed built and flown a series of actuators involving brushless DC motors, high speed gearing with normal spur gear sets, and an output stage consisting of a highly optimized compound differential planetary with integral anti-backlash features.
- Typical performance of these joints is:
  - slew rate up to 4 degrees/sec
  - typical pointing accuracy 0.005 degrees
  - output torque 300 - 1000 ft-lb
  - stiffness approximately 400 000 in-lb/degree

Solar Array Drives

- designed and flown Hermes solar array drive
- designed and ground qualified a solar array drive for Intelsat
- Intelsat drive consists of a stepper motor with gear reduction
  - backlash less than 0.075 degrees
  - torque 24 Nm;
  - slew rate 0.5 degrees/sec.

Anik C/D Antenna Positioning Mechanism

- stepper motor, spur gears, level gears
- pointing to 0.002 degrees

Bearing Systems

- designed and flown bearing systems using:
  - wet and dry lubricants;
  - ball and roller bearings;
  - conventional race and wire race bearings;
  - large (to 14 inches diameter) and small (instrument size) bearings
- in house development of an ESA-originated model for coulomb torque hysteresis of bearing friction properties at very small angular displacements for pointing systems.

Cable Handling

- flexible cables used on all SRMS joints
- - travels up to +/- 440 degrees

Slip Rings

- specified and integrated slip rings for Hermes and Intelsat drives

Motors

- stepper motors used on Hermes and Intelsat solar array dries
- mini-stepping used on Intelsat drive
- brushless DC motors used on SRMS
- brush DC motors used on Olympus

Gears

- high precision stainless steel gears used for all of the above projects designed in-house and produced by Spar G&TD.
- have done development tests of Vespel gears, but have not used them on a flight program
- currently conducting R&D on gear lubricants to support Space Station long life requirements

Sensors

- optical encoders used on SRMS
- resolvers being used on CSSP and have been used on terrestrial programs

- potentiometers, microswitches, Hall effect sensors used on various programs.

In addition, we have experienced in the simulation of complex systems such as:

SRMS

- extensive non-real time and real time simulation including the flexible dynamics of the SRMS

Solar Arrays

- coupled array flexible dynamics/drive/spacecraft ACS simulations for Hermes and for Intelsat

Redundancy Management

- experience on SRMS and CSSP with the management of system architecture involving redundant motors, sensors and electronics

Computer Aided Engineering (CAE) and Manufacturing (CAM) Tools

This section briefly describes the Computer Aided Engineering (CAE) tools that will be used in the design and development of space based optical systems. The primary tools are listed in Figure 8.

Spar ATSG Facilities

Spar's world class electro-optical facility in Weston, Ontario, Canada, brings together the latest in equipment and technology in an environment designed to ensure that Spar's team of engineers and technicians remains at the leading edge of technology.

The facility provides for system and subsystem development, simulation, integration and test and complements the established optical manufacturing and support facilities of the Applied Systems Division in Kanata, Ontario.

Building

Situated on a 4.3 acre site on Ormont Drive in the City of North York, the 68,000 square foot building has been designed to house engineering, design facilities and a low rate manufacturing, integration and test capability for AN/SAR-8 under one roof.

Computer Facilities

Two full VAX mainframes exist within this facility, one of which is housed in an EMI shielded room. This computing facility meets the Federal and DSS Security requirements for use as a secure "Tempest" approved computing facility.

Optical Laboratory

In the optical laboratory, optical components and subassemblies undergo extensive evaluation and testing in a controlled illumination environment. Contained in this large area , large off-axis collimators and sophisticated interferometric test equipment for the measurement and evaluation of state-of-the-art optical subsystems.

Infrared Development Facility

The Infrared Development Facility (ID) is an internal R&D tool used for the acquisition and analysis of mid and long wavelength infrared signatures of background clutter and airborne targets.

The high performance front end optics and electronics are interfaced with a VAX computer via a programmable data acquisition frame buffer. This configuration, entitled IDATS* (Infrared Development and Test System) provides a real time data acquisition and replay capability that has been extensively used during the AN/SAR-8 trials.

In addition, extensive analysis and target modelling software has been developed by Spar. This

TOOL	SOFTWARE/PRODUCT	PLATFORM
Electro-Optic & System Design	Code V, TISCAP, IRST Simulation Tools*, Lowtran	VAX Host
Mechanical Design & Structural Analysis	UNIGRAPHICS, NASTRAN, PATRAN	Dedicated Workstations,VAX,PC
Electronic Design	VALID, PSPICE	Sun Workstations, PC
Control Systems & Mechanism Simulations VAX	MATRIX-X, CADSI (DADSI)	Silicon Graphics (IRIS) Workstations
Software Devel. & Requirements Capture	Teamwork, STATEMATE	Networked VAX Workstations
Technical Publications	INTERLEAF	Dedicated VAX Workstations
Manufacturing Resource Planning (MRP)	Custom ORACLE Database	VAX Host
Project Mgmt Control Systems (PMCS)	PRIMAVERA, AWARD, Micro-Frame CONTROL	PRIMAVERA "P3" Workstations, PC LAN Networked with VAX Micro-Frame
Mechanical 3-D Analysis	UNIGRAPHICS	
Orbital Thermal Analysis	TRASYS	VAX
Heat Flow Analysis	SINDA	VAX
Integrated Logistic Support Analysis	DILSA	PC

* Spar Proprietary Software

Figure 8 Key ATSG Software Tools

software permits the real and non-real time simulation and analysis of complete electro-optical systems and their individual components.

High resolution IR data acquired in real time, or other pre-recorded data can be processed by the IDF enabling end-to-end system performance verification. The IDF also permits the evaluation of hardware elements (e.g. signal processor) operating interactively with the computer simulator. Using this powerful interactive capability the design engineer can verify system performance throughout the development process.

Technology assessment of state-of-the-art focal plane processors, two-dimensional signal processors, target trackers, and target discrimination algorithms can be accomplished through the "hardware in the loop" simulation and analysis capabilities of the IDF and have been used extensively during both the AN/SAR-8 field trials and research and development activities.

Development Laboratory

The Development Laboratory is used for the reduction to practice and verification of conceptual designs at both the system and components level.

Complex software and electronics are an integral part of most electro-optical systems, the laboratory provides a comprehensive capability for development and verification of analog and digital electronics circuits and associated software, both discrete and embedded.

The laboratory is equipped for the development of very high throughput signal processors, both digital and hybrid, operating at speeds in the order of 3 x 10^8 arithmetic operations per second. A complete range of test equipment is available to support the development of advanced electro-optical systems, including measurement equipment required for the detailed characterization of new electronic designs.

Sensor Laboratory

In this Class 10,000 clean room, components such as discrete infrared detectors, focal plane arrays, dewars and cryogengines requiring clean room conditions are assembled into the sensor assemblies that form the front end of passive surveillance tracking systems. Prior to integration, very low noise electronic subassemblies are tested and evaluated in two shielded rooms within this laboratory.

The whole laboratory incorporates the latest electro-static control measures and provides for a clean room production assembly capability.

Integration and Test

Major systems and subsystems are integrated and tested n a 26 ft. high area equipped with an X-Y travelling crane covering the entire area. Two complete systems and one major subsystem can be simultaneously integrated and evaluated on three test stations. This area also provides for assembly and test of initial production quantities of electro-optical systems and is used for training and maintenance demonstrations.

Smaller components and subassemblies are integrated and screened for workmanship to MIL-STD-781-A in a special area equipped for random vibration and thermal cycle testing prior to system level integration.

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APPENDIX E

PROJECT DESCRIPTIONS

Pointing and Tracking System
Project Description

Objectives

To design, build and test a CCD based ISL laser acquisition, pointing and tracking system with the point ahead function integrated into the tracking system. This reduces system mass, power, and complexity and also improves reliability.

Scope

Develop a prototype for Test Bed demonstration.

Phase 1

Complete a conceptual design and baseline the CCD's.

Build a prototype of the CCD-image acquisition and beam steering control system electronics.

Integrate the electronic acquisition and control electronics with the test bed optical bench including the beam steering assemblies, laser sources and detectors.

Demonstrate the feasibility of the approach using typical parameters for platform vibration and relative satellite motions.

Fine Pointing/Point-Ahead Mirror Assembly Project Description

Objectives

Investigate the design of actuators for the combined fine tracking/point-ahead steering mirror assembly, to ensure the design can accommodate the combined functional requirements.

Scope

Investigate piezo-electric and inductive actuators, build and test a prototype model.

Phase 1

Review existing actuator methods, and explore the applicability of piezo-electric actuators.

Select a technology and incorporate a prototype design.

Build a prototype and verify that the deflection characteristics meet the steering mirror requirements.

Coarse Pointing Assembly
Project Description

Objectives

To design, build and test the telescope steering motor and position encoding assembly, an extension of the previous work on Alternative Telescope design for ESA SILEX.

Scope

Review existing proposed designs (for SILEX), optimize, build and test breadboard and then prepare for a Qualification model.

Phase 1

Select the telescope steering motor technology

Select the telescope angular position encoder method

Design a preliminary motor/encoder module assembly

Assemble a CPA prototype for incorporation into the TEST BED, to examine the unit's response when integrated with the telescope prototype.

Refine the prototype design for qualification model.

Multiplexer/Demultiplexer Project Description

Objectives

To design, build and test Canadian patented multiplexing scheme to allow multiple wavelength operation, using a compact, integrated optical block design.

Scope

Review the existing proposed designs (for SILEX), optimize if necessary, liaise with EG&G for interface requirements on the Source and Detectors, build and test breadboard and then qualification models.

Phase 1

Design, breadboard and characterize on Test Bed, optimization - qualification models.

Spectral Isolator
Project Description

Objectives

To provide low loss beam splitting components

Scope

Review existing proposed designs (for SILEX), optimize if necessary, liaise with Spar on the Optical Bench layout, build and test breadboard and then qualification models.

Phase 1

Design, breadboard and characterize on Test Bed, optimization - qualification models.

Dichroic Filters
Project Description

Objective

In those areas requiring Dichroic filters or other thin film designs, to design develop and test appropriate units, to capitalize on previous work done on SILEX.

Scope

Depending upon the final system design, some Dichroic filters may be required. CAL proposes to exploit the existing design approach, materials and test methods already employed in the support of SILEX and the Alternative Telescope Study for ESA, for the provision of thin film coating design, fabrication and testing, particularly A/R coating work.

Phase 1

To design, fabricate and test thin film coating designs for Dichroic filters and other surface coated optical devices including A/R coating requirements.

Telescope Objective
Project Description

Objectives

To provide the smallest, lightest telescope objective possible for the required aperture, re-using the experience gained from previous projects and in particular, SILEX.

Scope

To design, build and test a Telescope Objective that ultimately is qualifiable. Includes structure, and mirrors, stray-light and thermal control. Also it may include the embedded coarse pointing mechanisms in pointable telescope design.

Phase 1

Design and initial build to Elegant Breadboard and characterize on Test Bed, but capability is available to go to Qualification model and flight.

Telescope Eyepiece Project Description

Objectives

To provide a light-weight eyepiece to complement the objective design to the required focal length and magnification.

Scope

Design, build and test a matching eyepiece, to the corresponding model standard as the objective, taking into full account the optical, thermal, mechanical and other constraints.

Phase 1

Design and initial build to Elegant Breadboard and characterize on Test Bed, but capability is available to go to Qualification model and flight.

Thermal Control Window
Project Description

Objectives

To provide essential assistance to the thermal control of the telescope and down-stream optics, with the provision of a Thermal Control Window on the telescope input.

Scope

To continue previous work conducted for ESA, in customizing the optical design for the current requirements, and then optimization for transmission. For the smaller aperture telescopes, the use of pellicles could be revisited.

Phase 1

Extension of the previous work by designing the window against the latest requirements, fabricate and test.

Beacon Laser Source
Project Description

Objectives

To produce a high power beacon source optimized for use with silicon CCD's. Target high reliability at 1W C.W. with a suitable beam profile.

Scope

Quantum-well, strained-layer InGaAs, ridge waveguide lasers. Packaged to give optimum direct hermetic coupling to optical fibers for beam combining.

Phase 1

Design, build and test candidate device structures and combiners.

Optimize for fiber combining. Supply to CAL for Beacon Telescope.

Heterodyne Laser Driver
Project Description

Objectives

To design, build and test a suitable drive circuit and optically-locked loop for wavelength stabilization and phase or frequency modulation of semiconductor lasers.

Scope

Initially breadboard, then PCB or hybrid.

Phase 1

Design, build and evaluate a prototype.

Refine design.

Build and test an engineering model representative in mass, volume and power consumption.

Direct Detection Laser Driver
Project Description

Objectives

To design, build and test high extinction ratio laser drivers for the modulation of semiconductor lasers up to 300 Mb/s and Yt:YAG at up to 1 Gb/s.

Scope

Hybridized circuits using space qualifiable designs and commercial components.

Phase 1

Design, build and test drivers.

Use suitable semiconductor lasers at 300 Mb/s

Use suitable modulators at 1 Gb/s (Hoechst Celanese?)

Semiconductor Laser Sources Project Description

Objectives

Design, build and test high power single mode lasers suitable for ISL use.

Scope

Quantum-well, strained-layer InGaAs, ridge waveguide lasers. Packaged with ancillary optics to give a circular, collimated output.

Phase 1

Design, build and test candidate device structures and ancillary optics. Evaluate for power, efficiency, reliability and wavefront quality.

Solid State Laser Sources
Project Description

Objectives

Design, build and test a diode-pumped solid state laser suitable for ISL use. Target 1W. output power.

Scope

Concentrate on 940 nm pumped Yb:YAG lasing at 1032 nm.

Build ISL configuration prototype.

Phase 1

Design laser pump source as extrapolation of current 980 nm. pump. Design laser configuration.

Build and test prototype.

Refine design.

Build and test engineering model, representative in power, mass and volume.

Direct Detection RFE Project Description

Objectives

Design, build and test a direct detection RFE (Receiver Front End) with 100 to 300 Mb/s capability. Address higher data rate implications.

Scope

Engineering model using PCB and hybrid construction.

Phase 1

Extrapolate SILEX flight model design (50 Mb/s NRZ) to cover data rates up to 300 Mb/s. Build and test 100 Mb/s version. Examine design of a 1 Gb/s version.

Heterodyne RFE
Project Description

Objectives

Design, build and test a heterodyne RFE with 1 Gb/s capability. The receiver to work at 82 nm.

Scope

Prototype breadboard build. Engineering model design.

Phase 1

Design and breadboard a 1 Gb/s heterodyne receiver including local oscillator and OLL (Optical Locked Loop). The receiver will operate at 820 nm, unless a decision is taken to concentrate on YAG laser wavelength.

Optical Preamplifier RFE
Project Description

Objectives

To design, breadboard, and test an optical preamplifier: PINFET combination for use at 1032 nm. To design an engineering version.

Scope

The work extends to a deliverable breadboard version in Phase 1.

Phase 1

Review optical preamplifiers. Design 1032 nm optical preamplifier.

Design pump source, amplifier, filter, isolator and 1 Gb/s PINFET subassemblies.

Pump source extrapolates current 980 nm products.

Optical amplifier/filter/isolator section is an extrapolation of previous work reported by other groups at other wavelengths.

1 Gb/s PINFET is a redesign of current EG&G development projects.

Modulator
Project Description

Objectives

To build modulators at 300 and 1000 Mb/s to accept digital inputs and encode the signals to give the coding scheme required for the optical ISL. Eg., NRZ to QPPM, addition of error coding etc.

Scope

Implementation in ECL logic.

Phase 1

Design, build and test required modulator functions.

Design conceptual ASIC example to address pros and cons.

Demodulator
Project Description

Objectives

To build demodulators at 300 and 1000 Mb/s to accept amplitude stabilized analogue outputs from an RFE, demodulate the digital signal, and, where necessary, code convert back to the original data stream. Direct detection and heterodyne demodulators may or may not be identical, depending on the ISL modulation format.

Scope

Implement in ECL logic.

Consideration of GaAs ASIC options.

Phase 1

Design, build and test required demodulator functions.

Design conceptual ASIC example to address pros and cons.

CCD Acquisition & Track Project Description

Objectives

To design, build and test a suitable silicon CCD detector, including software routines for acquisition and track.

Scope

Deliverable breadboard.

Phase 1

Design, build and test a suitable CCD area array.

Design, build and test suitable signal processing circuits.

Implement electronics in commercial TTL.

Design, write, implement and test suitable acquisition and track algorithms.

Integrate and test CCD, electronics and software.

Outline design of ASIC implementation of electronics.

Position Sensitive APD Project Description

Objectives

To investigate the pros and cons of position sensitive APD alternatives to CCD's.

Scope

Study and measurement of available concepts and devices.

Phase 1

Calculate of relative ments of CCD's and Position Sensitive APD's, including appropriate electronic requirements.

Measurement of currently available samples.

Report on pros and cons.

If appropriate, build further APD prototypes and associated electronics in suitable breadboard form. Test and deliver.

Hybrid (Refractive and Diffractive) Telescope and Eyepiece Design Project Description

Objectives

Design and build small to medium aperture hybrid telescopes for low rate OISL applications. Design and build Hybrid eyepieces for use on low to high data rate OISL telescopes. (This program of work could also examine the feasibility of employing a holographic beam combiner to separate the transmit and receive laser beams).

Phase 1

Design and build a small aperture hybrid telescope. Evaluate for optical blur spot performance, laser light scattering and transmission efficiency.

Telescope Design Using Composite Materials
Project Description

Objectives

Design and build medium to large aperture reflective telescope structures using composite materials.

Phase 1

Design and build a simple cassegrain miror with a composite support structure. Evaluate optical performance at room temperature and at temperture extremes. Verify optical stability after subjecting the unit to vibrations representative of loads applied during launch.

Advanced Fine Pointing Mirror Design
Project Description

Objectives

Design and build 2-axis fine pointing mirrors employing techniques such as flexure mounting with PZT drives or magnetially suspension with electromagentic actuators.

Phase 1

Design and build brassboard units. Evaluate pointing error, range of travel and stability using OISL "test bed" facility.

Coarse Pointing System Design
Project Description

Objectives

Evaluate the competing technologies such as Coude, stabilized mirror and gimballed telescope. Correlate the stabilization technique versus application and select one technology for prototype demonstration and evaluation.

Phase 1

Design and build a brassboard stabilization system. Integrate with the lightweight telescope prototype (see above) and evaluate the range of travel, pointing error and stability using the OISL "test bed".

3-D Optical Breadboard Layout
Project Description

Objectives

Examine novel packaging techniques for reducing the size and weight of the optical payload. Technologies to be investigated include fiber optics, combining the point ahead function with the fine pointing sensors and designing compact monolithic beam splitters and combiners for wavelength multiplexed systems.

Phase 1

Design and build brassboard prototype structures and assemblies. Evaluate perforamnce using the OISL "test bed".

DATE DUE

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