Analysis Cover Sheet

DOCUMENT NO.:	REV.:	DEPARTMENT	
039-1755	A	☒ Electrical Engineering (EE)	☐ Propulsion Engineering (PE)
PROGRAM:	MISSION:	☐ Guidance, Navigation & Control (GNC)	☐ Software Engineering (SE)
OSP Minotaur I	ORS-3	☐ Integration & Test (I&T)	☐ Systems Engineering (SYS)
		☐ Mechanical Engineering (ME)	
WAIVER? ☐ YES ☒ NO		☒ Non-FOUO (If FOUO, Use FM52-001a)	

TITLE: ORS-3 RF Link Analysis	AUTHOR: Bill Kellett	DATE: 07-27-12

OBJECTIVE: Determine the RF Link Margins for the S-Band telemetry and GPB down-links, UHF Flight Termination System (FTS), C-Band Range Tracking System (RTS) up-link and down-link and the global Positioning System (GPS).

ASSUMPTIONS: 1. Selected FTS RTS and Telemetry ground sites will be available for the mission.
2. S-band antenna patterns are identical to those for the Pegasus 50 inch diameter vehicle.
3.UHF and C-Band antenna pattern 95% coverages are identical to those for the Pegasus 50 inch diameter vehicle.

RESULTS:
S-Band Telemetry: Positive margin exists from at least one receive station until 800 seconds when the link to Antigua 10 falls below the required margin. A drop out occurs at the Wallops 9M site from 188 to 199 seconds but the other sites maintain link during this outage.

S-Band GPB: Positive margin exists from at all ground stations from AOS until the GPB is turned off at 543 seconds.

Flight Termination: The Wallops link drops out from 187 to 201 seconds but the Coquina and Bermuda links maintain good margin for the duration of the drop out. All links are above the required margin out past 544 seconds at which time stage 3, containing the flight termination system, is separated from the vehicle. Bermuda is shown for backup, it may not be used for this mission.

Range Tracking: Engineering Analysis 003-1758 shows that the power from Wallops Radars 3, 5 and 18 radars at the vehicle is higher than the allowable 20 V/m. These sites must have their powers reduced per this analysis or per range analysis. Required margin is maintained from at least one site for both Up and Down links. All Links drop below the required margin at specific mission times with the exception of Coquina Radar 11 which maintains positive margin from 33 to 599 seconds.

CONCLUSIONS: All RF links have acceptable performance margins.

REFERENCES:

1. Wallops Flight Facility Range User's Handbook
2. Pegasus Launch Vehicle Antenna Pattern Measurements Final Report, PSL/RF-90/36, New Mexico State University
3. TM-22527, MINOTAUR I SIMULATED ANTENNA PATTERNS
4. TM-3575, Telemetry Applications Handbook
5. EWR 127-1, Eastern Western Range Safety Requirements
6. Flight Termination Receiver PN 9600-4092 specification
7. Transponder specification TM-14327
8. EA 039-1683 Rev -, Appendix A
10. Bermuda parameters, Goddard Space Flight Center drawing 5K 855 BDA-38 from Shad K. Combs, NASA Wallops Flight Facility
11. 45th Space Wing Geodetic Coordinates Manual
12. Wallops Capability Matrix, Issue Date 2/23/98

ARE ADDITIONAL ANALYSES REQUIRED: ☐ YES ☒ NO	THIS SECTION TO BE COMPLETED FOR WAIVERS ONLY
DESCRIBE:	CRITICALITY: ☐ NOT FLIGHT CRITICAL ☐ FLIGHT CRITICAL
PREPARED BY: Bill Kellett 100851 (ISO 9001 ENG A 3) DATE: 07-27-2012	APPROVED BY:
REVIEWED BY: Richard Blakley 103444 DATE: 8/22/2012	DIR OF ENG: DEPT:
REVIEWED BY: DATE:	DIR OF ENG: DEPT:

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PROG MANAGER: DEPT: _____ _____

FRB REQUIRED ☐ YES ☐ NO FRB DATE: _____

DISTRIBUTION: _____

ATTACH BODY OF ANALYSIS

Analysis Cover Sheet

REVISION SUMMARY			
REV	DATE	CHANGE	PAGE
A	08-15-2012	Corrected Vehicle Telemetry bit rate to 2 Mbps and ground station recever bandwidth to 2.4 MHz. Updated link graph accordingly. Corrected GPB bit rate from 1.536 Mbps to 0.128 Mbps and GPB ground station receiver bandwidth from 1500 MHz to 300 MHz. Correct bit rate and receiver bandwidth were used for link margin graphs.	5,6,9

ORS-3 Link Margin Analysis

Overview

ORS-3 will be launched from the Mid-Atlantic Regional Spaceport (MARS) at Wallops Island, Virginia. Analyses were performed for the S-Band Telemetry (TLM), S-Band GPS Positioning Beacon (GPB) , Range Tracking System (RTS) and Flight Termination System (FTS). Telemetry is needed for payload separation through 715 seconds. FTS and RTS are needed up to stage 3 separation at 518 seconds. Vehicle trajectory data was obtained from the Orbital GN&C dept.

The Matlab file used was located in:
/nas01/osp/ors3/gnc/petersj/6246-337_1.6/run0_RFLinkMargin_nrtsim1.1.mat

The mission event times are found in the GN&C file ors3_timeline_nrtsim1.1.txt located in the same directory as the trajectory file and are as follows:

Mission Event Times (seconds):

- launchtime = 0
- s2ign = 61.4350
- s3ign = 135.5750
- rfswitchover = 147.7000
- s3burnout = 208.5100
- s4ign = 555.2050
- s4burnout = 620.9250
- payload sep = 741.6550
- eom = 1800

MATLAB programs were developed to automate the link margin calculation process. The margins predicted in this report are conservative given that worst case values are utilized for component insertion loss and conservative modeling of plume attenuation is employed.

Analysis Guidelines

The following definitions and quantities are required to determine margins for the ORS-3 RF system. The values provided in the Link Worksheets are used in the following equations to determine the Link Margin.

(1) Effective Isotropic Radiated Power (EIRP)

Transmit EIRP is calculated for each vehicle and ground station transmit link as follows:

$$EIRP = transmitter\ power - passive\ losses + antenna\ gain$$

Antenna pattern measurements may contain passive cable and coupler losses. These losses are removed from the antenna pattern data and replaced with the actual losses from each RF system on board the launch vehicle. In the far field of an antenna array, the power from both antennas is present so the 3 dB splitting loss is also removed from the antenna pattern data. Each coupler does have a specified maximum insertion loss that is added to each system loss.

(2) Antenna System Gain and Coverage

Antenna pattern testing for S-Band and C-Band was performed at Physical Science Laboratory for the OSP and Pegasus programs (Ref 2). For the FTS, antenna pattern testing was completed by Haigh-Farr Corp and documented in TM-22527 Rev -, MINOTAUR I SIMULATED ANTENNA PATTERNS (Ref 3).

The RTS and FTS link analyses use a 95% coverage value for vehicle antenna gain. For the Telemetry System, electronic antenna pattern data is employed. The antenna gain data is taken in 2° increments in theta (nose to tail) and phi (roll). The Matlab program determines the location in the antenna pattern that is in line with each receive or transmit station and returns the value of gain at that location of theta and phi.

(3) Path Loss, Plume Attenuation and Incident Signal Strength

Using the wavelength (λ) and slant range (R), path loss is calculated for each trajectory sample point as:

$$PathLoss = 10Log\left(\frac{4\pi R}{\lambda}\right)^2 = 20Log\left(\frac{4\pi R}{\lambda}\right)$$

Plume data sets from Minuteman II motors on stages 1 & 2 and Orion motors on stages 3 & 4 were used to model plume attenuation equations based on vehicle aspect angle.

Minuteman II Plume Attenuation = -13.418*log(aspect angle) + 55.701 (dB)
Orion Plume Attenuation = 91.1*exp(-0.1313*aspect angle) (dB)

The aspect angle is the angle in degrees between the vehicle aft direction and a line of site vector pointing toward the receiving or transmitting ground asset for which the link margin is to be determined.
The received isotropic signal power incident on the receive station antenna is determined as follows:

Incident Signal Strength = EIRP – Space Loss – Atmospheric Loss – Plume Attenuation

(4) G/T (figure of merit), Received Signal to Noise Ratio and Telemetry Link Margins

S-Band telemetry link margins are determined by the difference between the received and required signal to noise ratios. The received signal to noise ratio present at each of the telemetry receiving stations is calculated as follows:

$$\frac{S}{N}(dB) = \textit{Incident Signal Strength} + \frac{G}{T} - kB$$

Where
k = Boltzmanns Constant = 1.38×10^{-23} J/K
B = Receiver IF Bandwidth

Required signal to noise ratios were obtained from TM-3575, Telemetry Application Handbook (Ref 4), and represent the signal to noise ratio required to maintain a bit error rate of 10^{-6} for an RNRZ-L signal with a 1.44 Mbps bit rate for Telemetry and a 0.128 Mbps bit rate for GPS Rerad.

(5) Flight Termination (FTS) and Radar Tracking (RTS) Systems

Link margins for Flight Termination and Radar Tracking systems are determined as follows:

Link Margin = Incident Signal Strength – Receiver Threshold Sensitivity – Required Safety Margin

The FTS required margin indicates the minimum amount by which received signal power must exceed flight termination receiver threshold sensitivity. This value is 12 dB as required by EWR-127-1, the Eastern and Western Range Safety Requirements (Ref 5). The Flight Termination Receiver PN 9600-4092 specification (Ref 6) states a threshold sensitivity of -107dBm for the CR-123 FTS receivers integrated on ORS-3.

The RTS required margin indicates the minimum power needed at the vehicle for the uplink and at the ground stations for the downlink. This value of 0 dB is also called out in EWR-127-1. The common hardware C-Band transponder PN 9000-6801-001 specification (Ref 7) TM-14327 states a threshold of -70 dBm.

Ground station EIRP for the FTS and RTS links were obtained from the Wallops Flight Facility Range User's Handbook (Ref 1).

(6) Graphs and Tables of Results

- Each link is graphed and the parameters shown in tables.
- The results in the table are for the time specified at the top of the each table.
- The time that the vehicle reaches the program requested 1° above the Line of Sight Horizon (LOSH) point and the Radio Horizon (RH) point are shown in the tables.
- The graphs show the margins with respect to the required SNR so that 0 dB on the graph is the required SNR level for that particular link; 13 dB for S-Band, 12 dB for FTS and 0 dB for RTS.

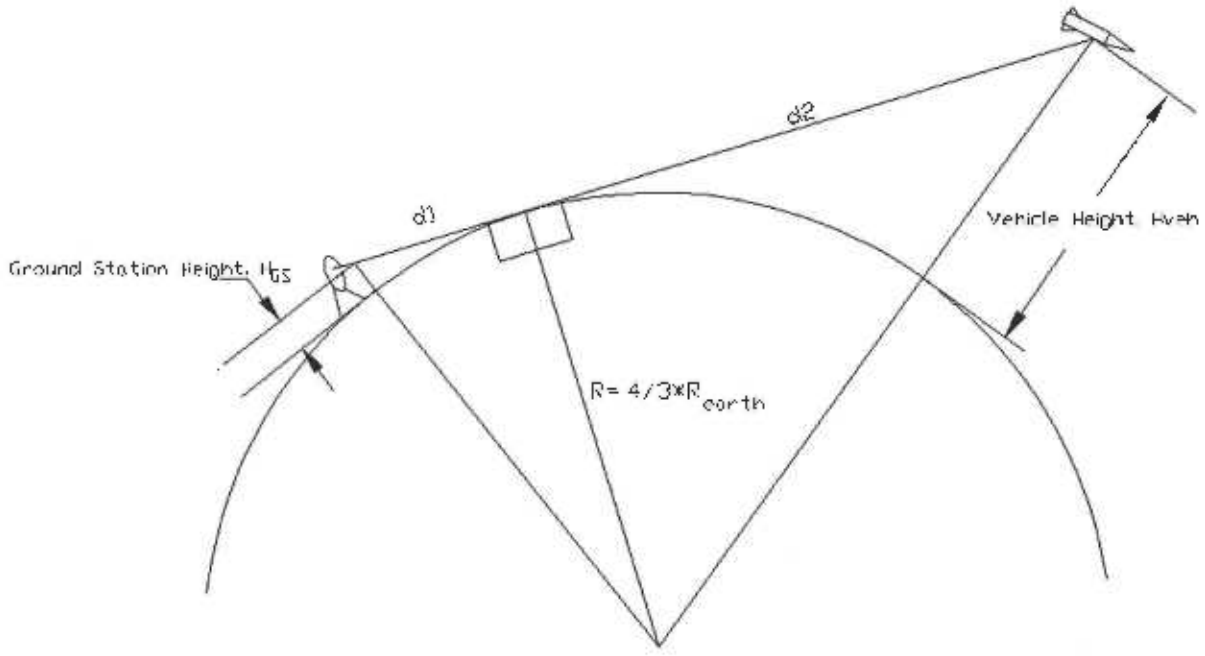
Each link is shown as a different line color or pattern during the time period where the link is above 1° above the LOSH. Once the link falls below 1° above the LOSH, the link line pattern changes to a light dashed line. At the point in time when the vehicle reaches the Radio Horizon, the link goes to zero on the graph. Although telemetry data may be obtained while the vehicle is above the Radio Horizon, phenomenon such as ducting and multipath may degrade or prevent reception. The margin during this time is shown to demonstrate that telemetry data might be obtained during but its integrity cannot be guaranteed. Below the Radio Horizon, complete loss of signal can be expected.

The Radio Horizon (RH) is calculated using a simple round earth model with a radius of 4/3 that of the actual earth radius and the equation:

$$RH = d1 + d2 \rightarrow RH := \sqrt{\left(\frac{4}{3}\cdot R_E + H_{GS}\right)^2 - \left(\frac{4}{3}\cdot R_E\right)^2} + \sqrt{\left(\frac{4}{3}\cdot R_E + H_{veh}\right)^2 - \left(\frac{4}{3}\cdot R_E\right)^2}$$

Where R_E = Mean Radius of the Earth = 6.37x10^6 m
H_{GS} = Height of the Ground Station
H_{veh} = Height of the vehicle above the surface of the Earth

Illustration of parameters used for Radio Horizon equation derivation.



Analysis Results

S-Band Telemetry

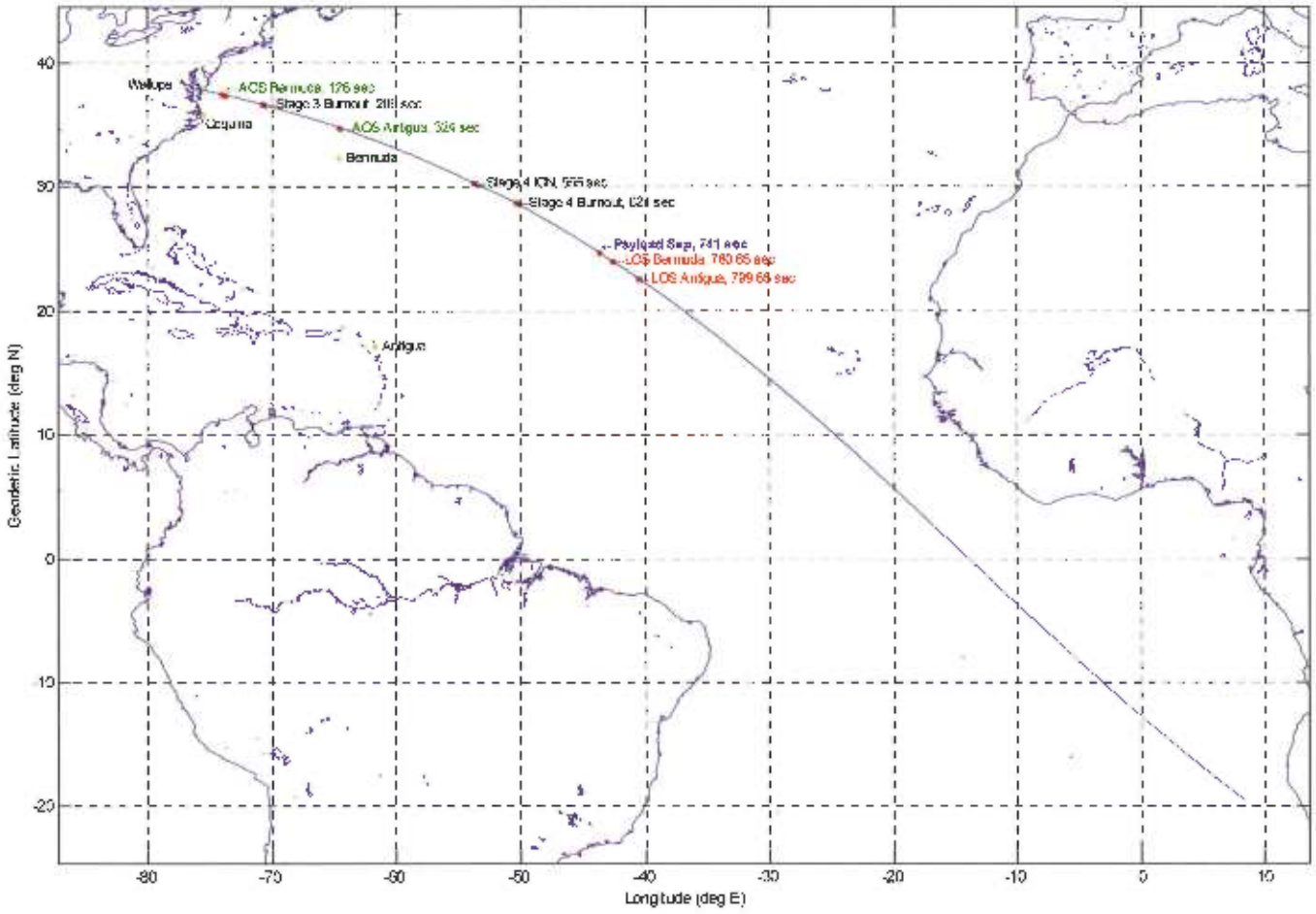
The telemetry receive sites included are the Wallops Flight Facility 9 Meter, BMRST mobile telemetry receiver at Coquina, the 80 ft dish at Antigua and the 7M dish at Bermuda. Wallops Flight Facility 8 Meter and 7.3 Meter will be used but the margins are not shown as the 9 Meter obtains the best link. Wallops ground station locations and parameters were obtained from Ref 1. Coquina parameters from Ref 12, Bermuda parameters from Ref 10 and Antigua station location from Ref 11.

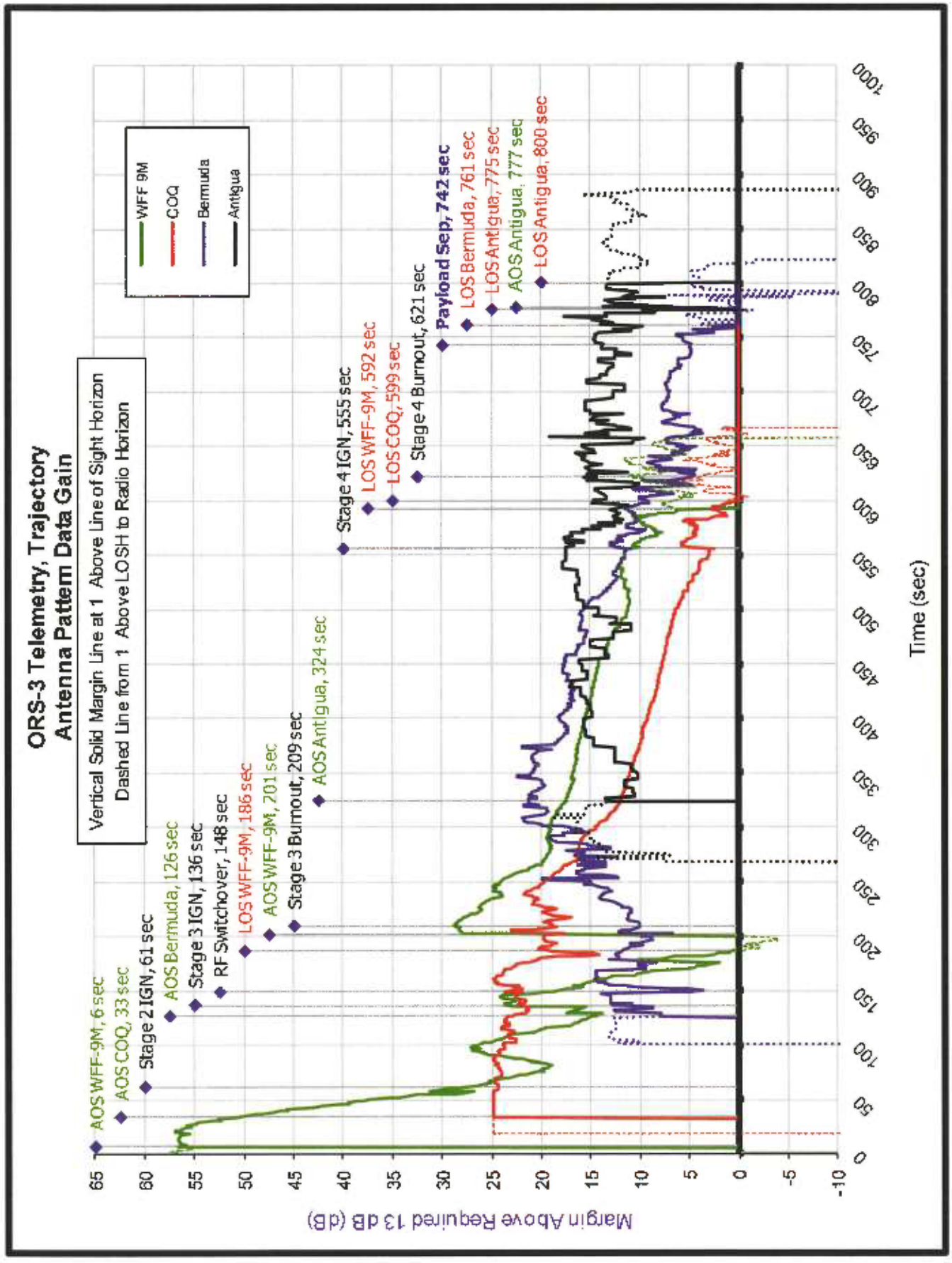
- Wallops 9M, 37.927359° N, 75.475001° W, 76.02 ft
- Wallops 8M, 37.923052° N, 75.477517° W, 73.19 ft
- Wallops 7.3M#1, 37.928361° N, 75.474188° W, 75.84 ft
- Coquina 7M Mobile, 35.8366° N, 75.5705° E, 0 ft
- Bermuda 7M Mobile, 32.351109° N, 64.65878° E, 12.07 ft
- Antigua 80 ft, 17.136625° N, 62.22571° E, 34.14 ft

The Telemetry Link Summary Tables show the time and slant range from each receive station for the following criteria.

• Acquisition of Signal (AOS)
Vehicle is at or over 1° above the line of sight horizon with margin greater than zero
• Loss of Signal (LOS)
Vehicle drops below 1° above the line of sight horizon and/or margin is zero or below

ORS-3 Ground Track





Telemetry Link Margins, Full Mission Timeline

The Vehicle Telemetry signal is presented in two categories: constant and variable parameters. Variable parameters change during mission time and receive station parameters while constant parameters do not.

Vehicle Telemetry	
Telemetry Constants	
Signal Parameters	
Datarate (Mbps)	2.000
Frequency (MHz)	2266.5
Wavelength (m)	0.131
Transmit Parameters	
Transmit Power (Watts)	5.00
Transmit Power (dBW)	6.99
Passive Losses (dB)	2.35
Atmospheric Attenuation(dB)	0.60
Multipath(dB)	0.00
Other Lossee (dB)	0.00
Receive Parameters	
Receive IF BW (kHz)	2400.00
kB	-164.60
Required S/N (dB)	13.00
Required Bit Error Rate	1.00E-08

Telemetry Variables				
Ground Station	**WFF 9M**	**Coquina**	**Bermuda**	**Antigua**
G/T (dB/K°)	24.00	18.50	18.00	765.00
Vehicle Parameters				
Mission Time (sec)	324.00	166.00	621.00	621.00
Slant Range (NM)	605.87	217.05	844.06	1024.80
Latitude N (deg)	34.82	36.97	26.74	26.74
Longitude E (deg)	-64.59	-71.84	-50.38	-50.38
Altitude (mi)	223	109	316	316
Aspect Angle, 0°=tail (deg)	129.00	147.00	117.00	60.00
Roll Angle (deg)	233.00	117.00	121.00	113.00
Transmit Parameters				
Antenna Gain, PTP (dBi)	-1.69	-1.23	-5.54	-2.45
Path Loss (dB)	160.63	151.72	163.51	165.20
Plume Attenuation (dB)	0.00	1.13	0.00	0.00
Receive Parameters				
Signal Strength (dBW)	-169.99	-162.21	-172.87	-174.56
S/N (dB)	18.80	21.09	9.92	17.64
Link Margin, Pattern Data (dB)	**17.52**	**20.26**	**4.79**	**15.59**

Telemetry Link Margin Parameter Tables

- Note: Selected mission times are to demonstrate positive link margin times, see graph and event times for more detail on AOS and LOS times.

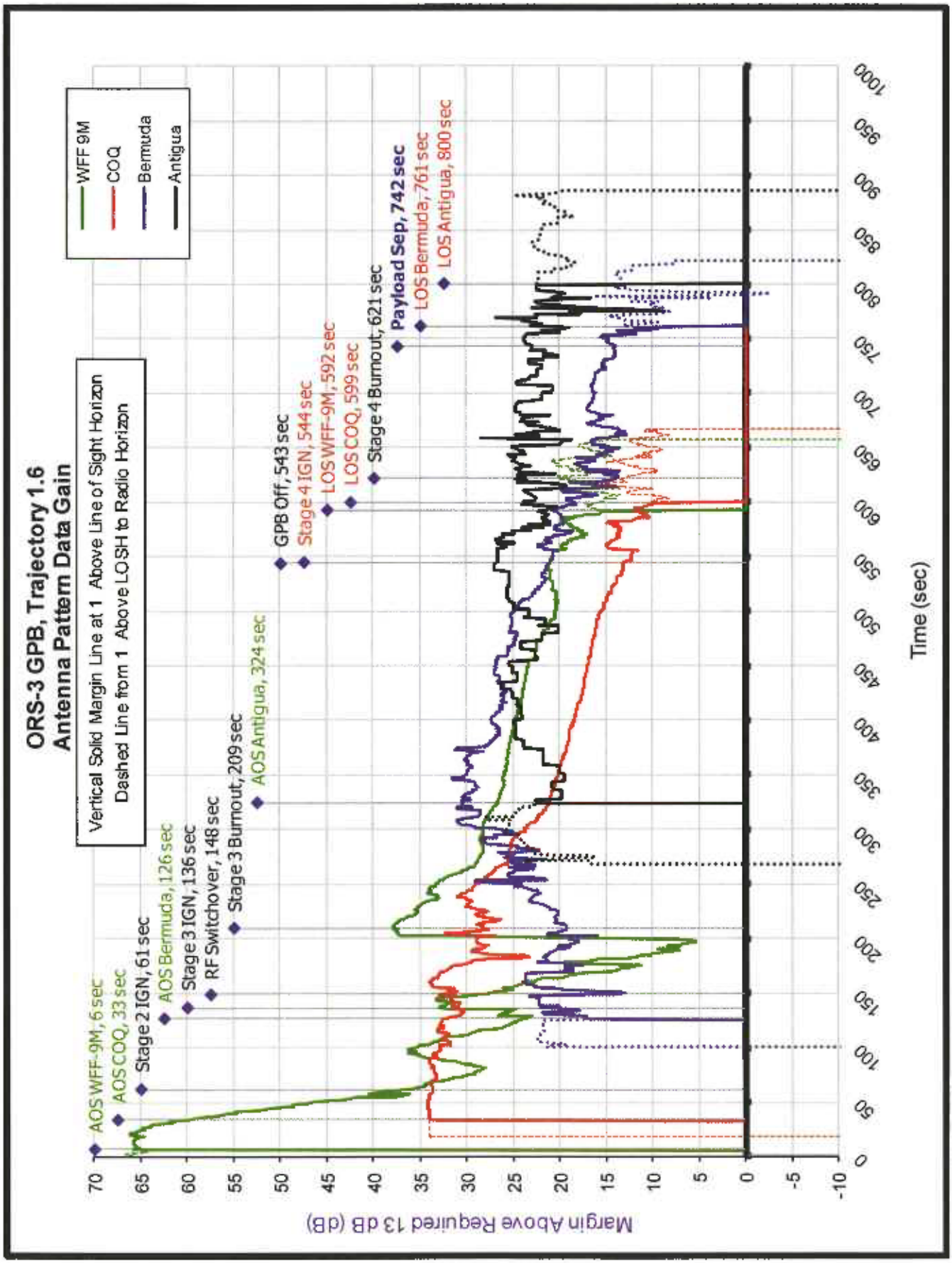
GPB S-Band Link Margin

The ORS-3 GPS S-Band system transmits at 2241.5 MHz to the same ground stations as the Vehicle Telemetry system. Ground station locations and parameters are also the same. The GPB S-Band system is no longer used after stage 3 separation.

The GPS Link Summary Table shows the time and slant range from each receive station for the following criteria.

- Acquisition of Signal (AOS)
  Vehicle is at or over 1° above the line of sight horizon with link margin greater than zero
- Loss of Signal (LOS)
  Vehicle drops below 1° above the line of sight horizon and/or link margin is zero or below

From the GPS S-Band Link Table and Graph, it is shown that all links remain above the required margin from the time they are at 1° above the line of sight horizon to 543 seconds, when the GPB transmitter is turned off.



GPB Link Margin

The GPB Telemetry signal is presented in two categories: constant and variable parameters. Variable parameters change during mission time and receive station parameters while constant parameters do not.

GPB Telemetry						
GPB Constants		**GPB Variables**				
Signal Parameters		**Ground Station**	**WFF 9M**	**Coquina**	**Bermuda**	**Antigua**
Datarate (Mbps)	0.128	G/T (dB/K°)	24.00	18.50	18.00	765.00
Frequency (MHz)	2241.5					
Wavelength (m)	0.134	**Vehicle Parameters**				
		Mission Time (sec)	324.00	188.00	543.00	543.00
Transmit Parameters		Slant Range (NM)	605.87	217.05	624.23	966.00
Transmit Power (Watts)	5.00	Latitude N (deg)	34.82	36.97	30.60	30.60
Transmit Power (dBW)	6.99	Longitude E (deg)	-64.59	-71.84	-54.30	-54.30
Passive Losses (dB)	2.35	Altitude (mi)	223	109	313	313
Atmospheric Attenuation(dB)	0.60	Aapect Angle, 0°=tail (deg)	129.00	147.00	141.00	126.00
Multipath(dB)	0.00	Roll Angle (deg)	233.00	117.00	217.00	122.00
Other Losses (dB)	0.00					
		Transmit Parameters				
Receive Parameters		Antenna Gain, PTP (dBi)	-1.69	-1.23	-1.00	-0.63
Receive IF BW (kHz)	300.00	Path Loss (dB)	160.45	151.54	160.71	164.68
kB	-173.83	Plume Attenuation (dB)	0.00	1.13	0.00	0.00
Required S/N (dB)	13.00					
Required Bit Error Rate	1.00E-06	**Receive Parameters**				
		Signal Strength (dBW)	-169.81	-162.03	-170.07	-174.04
		S/N (dB)	28.02	30.30	21.76	27.19
		Link Margin, Pattern Data (dB)	**26.73**	**29.47**	**21.15**	**26.96**

GPB Link Margin Tables

- Note: Selected mission times are to demonstrate positive link margin times, see graph and event times for more detail on AOS and LOS times.

Flight Termination System Link Margin

The Flight Termination System (FTS) link margins were determined for the Command and Control Transmitters at Wallops, Coquina and Bermuda. Wallops ground station locations and parameters were obtained from Wallops Flight Facility Range User's Handbook (Ref 1). Coquina location and parameters were obtained from Ref 12. Bermuda location and parameters were obtained from Ref 10.

The FTS Links and Timeline graphs show the time from each receive station for the criteria stated above and also for the following criteria:

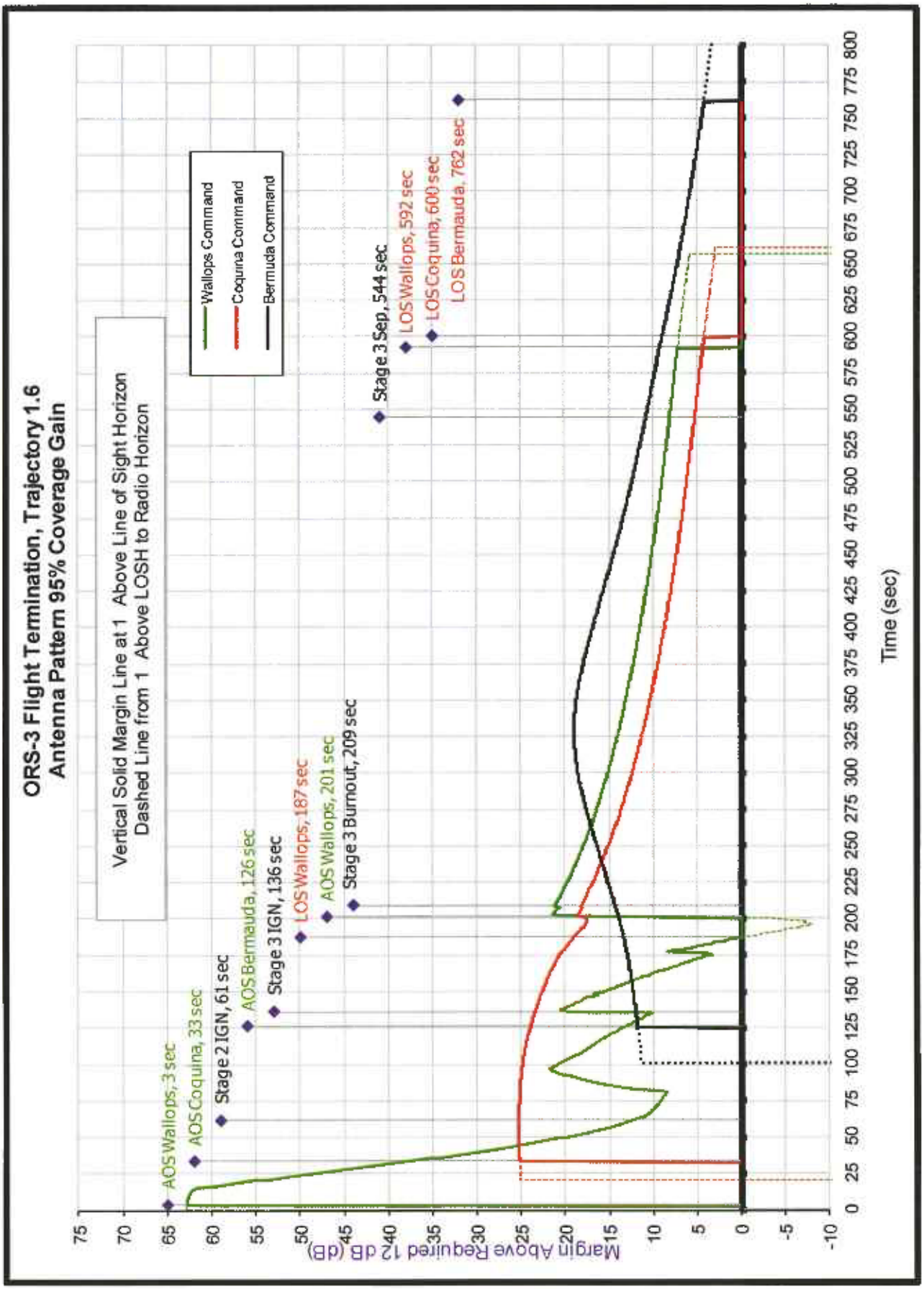
- Acquisition of Signal (AOS)
  Vehicle is at or over 1° above the line of sight horizon with margin greater than zero
- Loss of Signal (LOS)
  Vehicle drops below 1° above the line of sight horizon and/or margin is zero or below

NOTE: The Bermuda FTS site is shown as a backup, it may not be used for this mission.

The Wallops link drops out from 187 to 201 seconds but the Coquina and Bermuda links maintain good link margins for the duration of the drop out.

All links are above the required margin out past 544 seconds at which time stage 3, containing the flight termination system, is separated from the vehicle. The graph displays the continued link if stage 3 separation fails and shows good margin out to 761 seconds where the vehicle is at 1° above the LOSH from the Bermuda site.

The FTS Link Table shows that the signal from the Wallops Command sites is above the required 12 dB margin out past 534 seconds when stage 3 separates from the vehicle.



FTS Link Margins

The FTS signal is presented in two categories: constant and variable parameters. Variable parameters change during mission time and receive station parameters while constant parameters do not.

Flight Termination System					
FTS Constants		**FTS Variables**			
Signal Parameters		**Ground Station**	**Wallops**	**Coquina**	**Bermuda**
Frequency (MHz)	421	Antenna Gain (dBi)	18.00	18.00	15.00
Wavelength (m)	0.71259				
		Vehicle Parameters			
Transmit Parameters		Mission Time (sec)	544.00	544.00	761.65
Transmit Power (Watts)	1000.00	Slant Range (NM)	1210.10	1185.40	1341.90
Transmit Power (dBW)	30.00	Latitude N (deg)	30.58	30.58	24.00
Atmospheric Attenuation (dB)	0.30	Longitude E (deg)	-54.25	-54.25	-42.54
Multipath Loss (dB)	0.00	Altitude (mi)	313	313	314
Other Losses (dB)	1.50	Aspect Angle, 0°=tail (deg)	136.00	140.00	142.00
Receive Parameters		**Transmit Parameters**			
Antenna Gain (95%)	-8.20	Path Loss (dB)	151.94	151.76	152.83
Passive Losses (dB)	4.48	Plume Attenuation (dB)	0.00	0.00	0.00
Receiver Threshold (dBm)	-107.00				
Required Safety Margin (dB)	12.00	**Receive Parameters**			
		Incident Signal Strength (dBm)	-104.24	-107.06	-108.13
		Received Power (dBm)	-116.91	-119.73	-120.81
		Link Margin, 95% Coverage (dB)	**8.09**	**5.27**	**4.19**

- Selected mission times are to show positive link margin. See FTS Link Margin graph for specific AOS and LOS times.
- Although plotted as dashed lines below 1° above the line of sight horizon, the links will be above the margin from one or more ground stations at liftoff due to the effect of the Radio Horizon.

FTS Link Margin Parameter Tables
Wallops, Coquina and Bermuda Command Sites

Range Tracking System Link Margin

The Range Tracking System (RTS) link margins were determined for the uplink frequency of 5690 MHZ and down link frequency of 5765 MHZ for Wallops Radars 3, 5 and 18 and Coquina Radar 11. Ground station locations and parameters were obtained from Wallops Flight Facility Range User's Handbook (Ref 1).

The FTS Link Summary Graphs and Timelines show the time and margin from each RTS ground station fro the following criteria.

Acquisition and Loss of signal criteria:

- Acquisition of Signal (AOS)
  Vehicle is at or over 1° above the line of sight horizon with margin greater than zero
- Loss of Signal (LOS)
  Vehicle drops below 1° above the line of sight horizon and/or margin is zero or below

Engineering Analysis 039-1758 demonstrates that the emitter power from Wallops Radars 3, 5 and 18 at the vehicle is higher than the allowable 20 V/m. The power from these three emitters must be reduced as follows:

- Wallops Radar 3 must be attenuated by 30 dB until T+61
- Wallops Radar 5 must be attenuated by 34 dB until T+119
- Wallops Radar 18 must be attenuated by 13 dB until T+70

NOTE: The Bermuda RTS site is shown for backup if needed. It may not be used on this mission.

All Links drop below the required margin at specific mission times with the exception of Wallops Radar 3 which maintains positive margin from 33 to 543 seconds. See RTS Uplink and Downlink graphs and AOS and LOS details.

NOTE: The system passive loss is calculated as follows:
System Loss, including coupler, from Antenna Pattern Test = -5 dB (PSL/RF-90/36, p 69) (Ref 2)
Actual ATP worst case data including coupler loss = - 5.0731 dB
-5 dB - - 5.0731 dB = +0.0731 dB
In the farfield of the antenna array, the power combines so the 3 dB splitting loss of the coupler is not present. The coupler has a maximum insertion loss of 0.7 dB.
0.0731 dB + 3 dB – 0.7 dB = +2.3731 dB

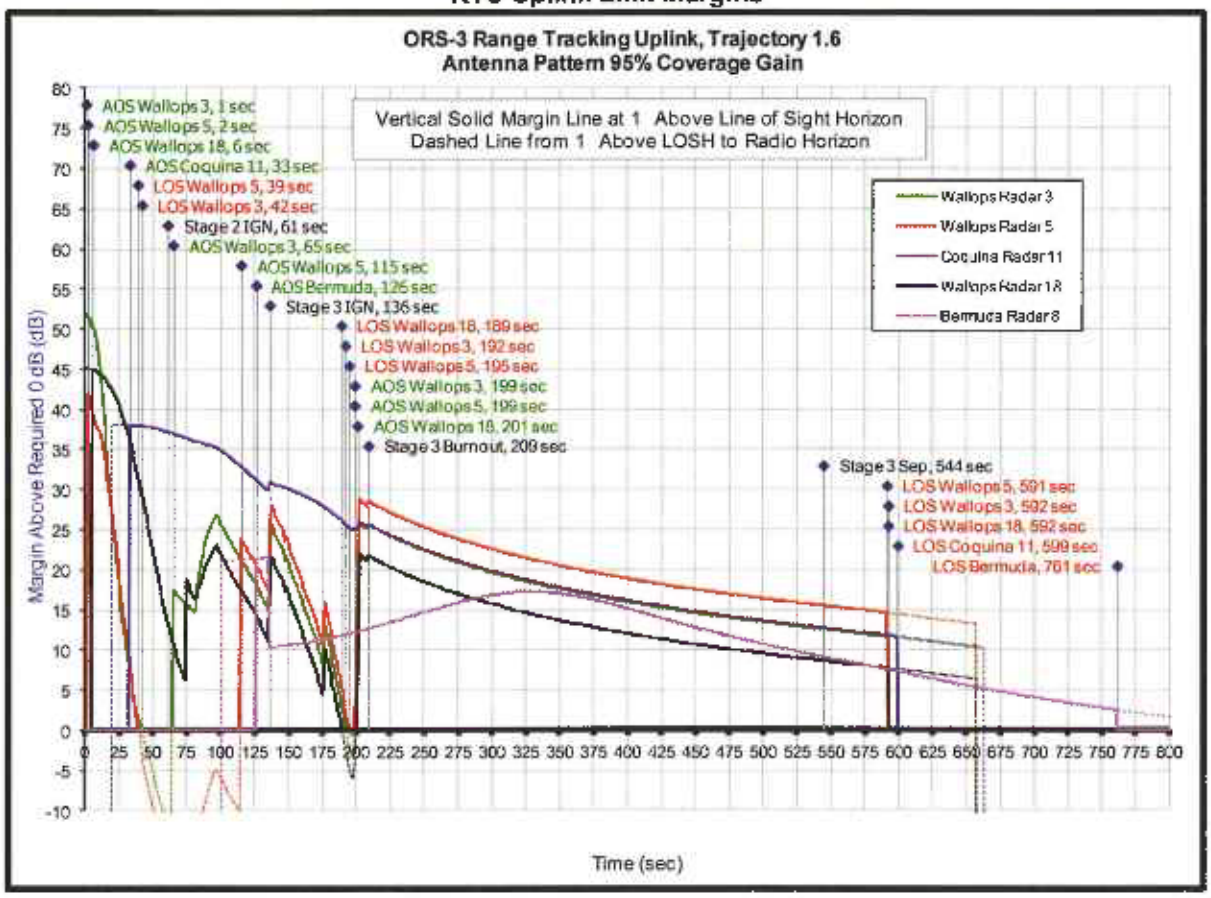
The system loss for the RTS is a positive value. Because the Matlab program needs a positive loss value, the 2.3731 dB is entered as a negative value. This is the reason for a negative loss value in the RTD Up and Down link parameter tables.

Engineering analysis 039-1758, Electric Field at Vehicle from Range Emitters, demonstrates that the power from Wallops radars 3, 5 and 11 may cause an electric field at the vehicle which exceeded the 20 V/m limit.

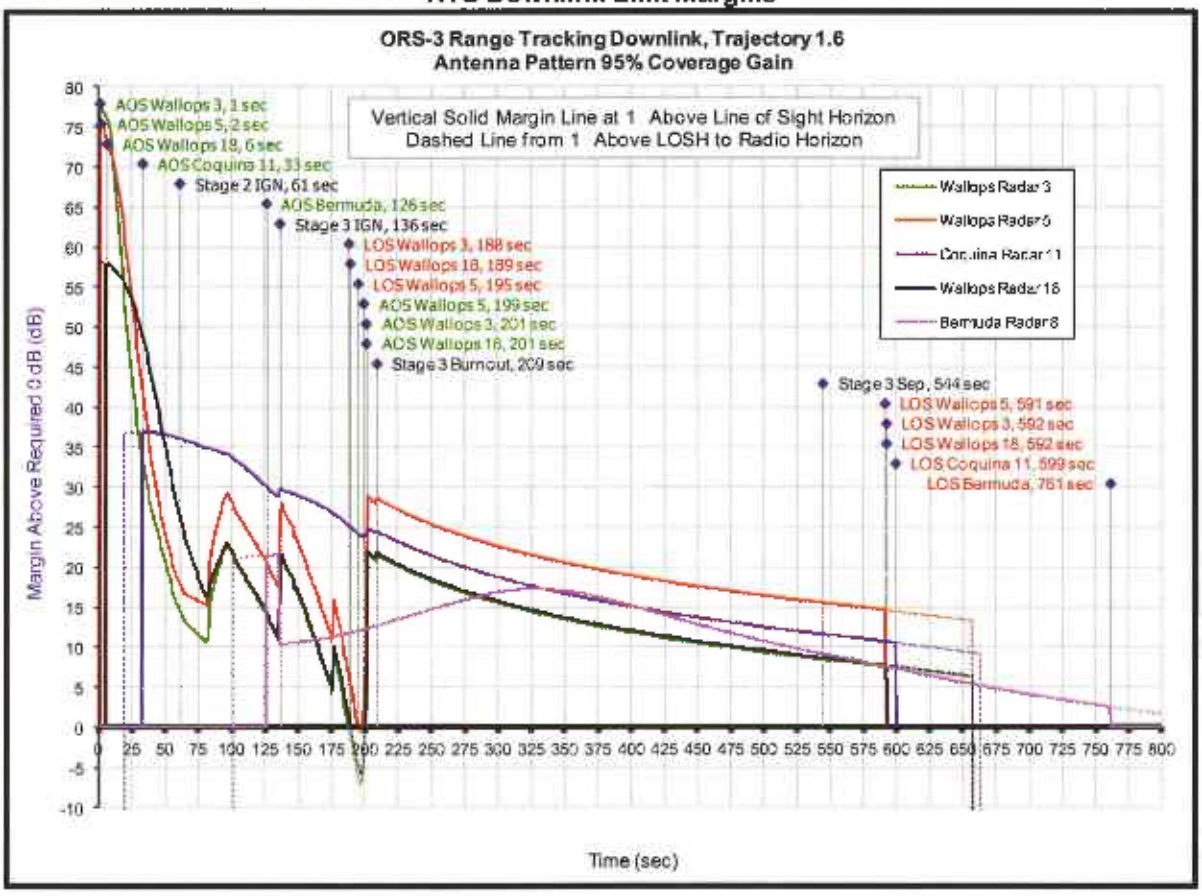
Wallops Radar 3 must be attenuated by 30 dB until T+61
Wallops Radar 5 must be attenuated by 34 dB until T+118
Wallops Radar 18 must be attenuated by 13 dB until T+70

This will ensure the 20 V/m limit electric field at the vehicle is met throughout flight.

RTS Uplink Link Margins



RTS Downlink Link Margins



Range Tracking System Up Link								
RTS Up Link Constants			**RTS Up Link Variables**					
Signal Parameter			**Ground Station**	**Wallops Radar 3**	**Wallops Radar 5**	**Coquina Radar 11**	**Wallops Radar 18**	**Bermuda Radar 8**
Frequency (MHz)	5765.00		Antenna Gain (dBic)	43.50	53	46	46	38
Wavelength (m)	0.0520		Transmit Power (Watts)	1000000	2500000	1000000	1000000	1000000
Transmit Parameters			**Vehicle Parameters**					
Transmit Power (dBW)	63.96		Mission Time (sec)	51	78	101	126	178
Transmit Passive Loss (dB)	0.00		Slant Range (NM)	14	35	125	84	485
Atmospheric Attenuation(dB)	1.00		Latitude N (deg)	38	38	38	37	37
Other Losses (dB)	1.50		Longitude E (deg)	-75	-75	-75	-74	-72
			Altitude (mi)	13	28	46	64	100
			Elevation Angle (deg)	53	45	18	35	6
Receive Parameters			**Transmit Parameters**					
Antenna Gain (95%)	-17.00		Path Loss (dB)	135.76	143.85	154.94	152.50	166.73
Passive Losses (dB)*	-2.37		Plume Attenuation (dB)	27.15	30.63	-2.50	16.42	0.00
Required Safety Margin	0.00							
Receiver Threshold (dBm)	-70.00		**Receive Parameters**					
			Incident Signal Strength (dBm)	-60.91	-60.51	-50.44	-63.92	-69.73
			Received Power (dBm)	-75.53	-75.13	-65.07	-78.55	-84.36
			Link Margin (dB)	**24.47**	**24.87**	**34.93**	**21.46**	**15.64**

RTS Uplink Margin Parameter Tables
Wallops 5, 18, 3, Coquina 11 and Bermuda 8

Range Tracking System Down Link								
RTS Down Link Constants			**RTS Down Link Variables**					
Signal Parameter			**Ground Station**	**Wallops Radar 3**	**Wallops Radar 5**	**Coquina Radar 11**	**Wallops Radar 18**	**Bermuda Radar 8**
Frequency (MHz)	5690.00							
Wavelength (m)	0.0527		Antenna Gain (dBic)	43.50	53	46	46	38
Transmit Parameters			**Vehicle Parameters**					
Transmit Power (Watts)	400.00		Mission Time (sec)	51	76	100	115	179
Transmit Power (dBW)	26.02		Slant Range (NM)	14	35	125	79	484
Transmit Passive Loss (dB)*	-2.37		Latitude N (deg)	38	38	38	38	37
Atmospheric Attenuation(dB)	1.00		Longitude E (deg)	-75	-75	-75	-74	-72
Other Losses (dB)	1.50		Altitude (mi)	13	28	45	56	101
			Elevation Angle (deg)	53	45	17	38	7
Receive Parameters			**Transmit Parameters**					
Antenna Gain (95%)	-17.00		Path Loss (dB)	135.64	143.74	154.80	150.80	166.59
Passive Losses (dB)	0.00		Plume Attenuation (dB)	27.15	30.63	-2.59	14.89	0.00
Required Safety Margin	0.00							
			Receive Parameters					
			Incident Signal Strength (dBm)	-152.40	-163.96	-141.81	-155.30	-156.19
			Received Power (dBm)	-109.40	-112.96	-95.81	-112.30	-116.19
			Receiver Threshold (dBm)	-112.5	-109.0	-112.5	-112.5	-112.5
			Link Margin (dB)	**23.50**	**19.00**	**37.09**	**20.83**	**14.71**

RTS Downlink Margin Parameter Tables
Wallops 5, 18, 3, Coquina 11 and Bermuda 8

- Selected mission times are to show positive link margin. See RTS Link Margin graphs for specific AOS and LOS times.
- *The system loss for the RTS is a positive value. Because the Matlab program needs a positive loss value, the 2.3731 dB is entered as a negative value. This is the reason for a negative loss value in the RTD Up and Down link parameter tables.

GPS L-Band Link

Using the recommended C/No for the JNS-100, the minimum statistical antenna gains required for the GPS link can be established. For JNS-100 signal tracking, a specified minimum Carrier to Noise ratio of 30dB-Hz is required and the specified input level to the JNS-100 is -130 dBm minimum. The minimum required input level for acquisition is -123 dBm corresponding to a C/No of 37 dB-Hz.

The L-Band system noise temperature of the ORS-3 GPS system is determined from the maximum LNA noise figure of 2.4 dB and a front end cable loss of 0.57 dB (measured, rounded to 0.6 dB). This results in a calculated system noise temperature of 288.63° K. An additional antenna noise of 150° K is added to the system noise for a total noise temperature of 438.63° K. The high gain and low noise figure of the LNA will render the noise of the JNS-100 insignificant so 2nd stage noise is not considered. Using the required C/No, carrier power and system noise, the required minimum statistical antenna gain can be established. A C/No of 37dB-Hz is required for acquisition while a C/No of 30 dB-Hz is required for tracking.

The antenna system gain minimum requirements are -5.18 dBi and -12.18 dBi for acquisition and tracking, respectively. Calculations are supplied in EA 039-1683 Rev -, Appendix A (Ref 8). The GPS link margin uses the minimum required antenna gain to achieve a C/No of 37dB-Hz and 30 dB-Hz. GPS system parameters are listed below.

Statistical Antenna Coverage
Statistical antenna coverage for -5.18 dBi and -12.18 dBi is 68% and 96% respectively. The JNS-100 is required to acquire and track at least 4 satellites. 100% antenna percent spherical coverage is required if only 4 satellites are visible. The antenna percent spherical coverage required with 8 satellites visible drops to a much more realistic 50%. The antenna system gain required to achieve a C/No of 37dB-Hz is -5.18 dBi. At this gain, the antenna coverage is 68%. At 68% coverage, 6 satellites are required to be visible in order to acquire a minimum of 4 satellites. The antenna system gain required to achieve a C/No of 30 dB-Hz is -12.18 dBi. At this gain, the antenna coverage is 96%. At 96% coverage, 5 satellites are required to be visible in order to acquire a minimum of 4 satellites. Typically at least 12 satellites in the GPS constellation are visible, giving the GPS system a wide margin. Refer to table 4-1 for % coverage verses antenna gain, refer to table 4-2 for % coverage verses visible satellites required.

Receiver Dynamic Range
The specified dynamic range for the receiver is between -123 dBm and -100 dBm for acquisition and -130 dBm and -100 dBm for tracking. The maximum signal at the receiver terminals is determined by incident signal power, antenna system gain, LNA gain and antenna system losses.

The maximum antenna system gain for this system is 0.37 dBic at bore sight and represents about a 10% coverage area. The LNA gain is 30 dB nominal ±3 dB. The total maximum antenna system gain is (0 .37 dB + 0.7 dB (see note) + 30 dB) ±3db or 28 to 34 dB. With a nominal input signal level of -130 dBm the highest signal present at the JNS-100 is -96 dBm. Levels of 2 dB above nominal can be expected from GPS satellites greater than 5 degrees over the horizon. With a GPS signal level of -128 dBm the signal level at the input of the JNS-100 would be -94 dBm. This is +6 dB above the recommended power level of -100 dBm. No data exists that indicates the effects of exceeding -100 dBm. Several Orbital missions have flown this configuration with no GPS anomalies.

Note: ORS-3 L-Band configuration has approximately a 0.7 dB higher antenna system gain due to lower cable losses compared to the TACSAT-3 configuration.

L-Band GPS link conclusion

The vehicle L-Band antenna system will provide more than the required 4 GPS satellite links necessary for an accurate, reliable GPS solution from the JNS-100.

GPS System Parameters:

GPS signal power	=	-160 dBW
Antenna Temperature (external noise)	=	150° K
Cable Loss,	=	0.6 dB
LNA NF	=	2.4 dB
Total NF	=	3.0 dB, Thermal Noise = 288.63 ° K
Total Thermal noise:		
Antenna Noise Temperature	=	150° K (external noise)
System Noise	=	288.63
Total Noise	=	438.63° K

Table 4-1 L-Band Antenna System Percent Spherical Coverage Verses Gain

Percent Coverage	Gain
95	-11.5
85	-9.5
75	-5.7
65	-4.8
55	-3.7

Table 4-2 Antenna % Coverage vs Satellites available

Number of Satellites Available	% Coverage Required
4	100
5	80
6	66.6
7	57.14
8	50
9	44.4
10	40

Parameter	Value		Comment
	Acquisition	**Tracking**	
Incident GPS Signal Power (dBW)	-160.00	-160.00	GPS ICD Downlink Power for L1 C/A Code
Antenna Temperature (deg k)	150.00	150.00	
Minimum Required Antenna System Gain (dBic)	**-5.18**	**-12.18**	
Antenna Percent Coverage	**91.00**	**96.00**	
Cable Loss, Antenna to LNA (dB)	0.60	0.60	Measured cable loss
LNA Gain (dB)	30.00	30.00	Specified
LNA Noise Figure (dB)	2.40	2.40	Specified over temperature
Effective Noise Temperature (deg k)	288.63	288.63	
Effective Noise Figure (dB)	3.00	3.00	
System Temperature (deg k)	438.63	438.63	
System Temperature (dB-deg k)	26.42	26.42	
G/T Figure of Merit (dB)	-31.60	-38.60	
Received C/No (dB-Hz)	37.00	30.00	SNR at L-Band Input
C/No Required (dB-Hz)	37.00	30.00	Acquisition of GPS signal
Margin (dB)	**0.00**	**0.00**	

JNS-100 Link Margin