ORBITAL SUBORBITAL PROGRAM
ORS-3 SPACE LAUNCH VEHICLE
RF SYSTEMS SUMMARY

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RF SYSTEMS SUMMARY

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LIST OF ACRONYMS

AC	Alternating Current
BER	Bit Error Rate
DC	Direct Current
EE	Electrical Engineering
FM	Frequency Modulation
FTLU	Flight Termination Logic Unit
FTS	Flight Termination System
GCA	Guidance and Control Assembly
GFE	Government Furnished Equipment
GPS	Global Positioning System
IMOD	Intermodulation Distortion
IRIG	Interrange Instrumentation Group
LNA	Low Noise Amplifier
LSG	Launch Systems Group
OSP	Orbital Suborbital Program
PCM	Pulse Code Modulation
RF	Radio Frequency
RNRZ-L	Randomized Non-Return-To-Zero-Level
RTS	Range Tracking System
SLV	Space Launch Vehicle
SNR	Signal-to-Noise Ratio
SV	Space Vehicle
UHF	Ultra High Frequency
VAFB	Vandenberg Air Force Base

1. INTRODUCTION

1.1. Purpose

The purpose of this document is to provide a general description of the Orbital Suborbital Program (OSP) Minotaur I ORS-3 launch vehicle Radio Frequency (RF) systems. It is intended for use as a guide, which may be useful in the pre-mission setup of telemetry receiving and recording equipment and for post-mission data analysis.

1.2. ORS-3 Mission Overview

The OSP SLV ORS-3 mission objective is to provide a vehicle to deliver the Space Vehicle (SV) to the pre-determined orbit and inclination. 28 CubeSats will also be launched after the main payload. The vehicle will be launched from the Mid Atlantic Regional Spaceport (MARS) at Wallops Island, VA.

1.3. Scope

This document covers the following topics:

a. Overview and descriptions of the Ultra High Frequency (UHF) Flight Termination System (FTS), L1-band Global Positioning System (GPS), C-band Range Tracking System (RTS), and S-band Telemetry systems.

1.4. Applicable Documents

a. 039-1755, ORS-3 RF Link Analysis
b. 039-1756, ORS-3 IMOD Analysis
c. 039-1757, Electric Field at Payload from Launch Vehicle
d. 039-1758, Electric Field at Launch Vehicle from Range Emitters
e. 1047-0511, Interconnect Diagram, ORS-3
f. 039-944, S-band and C-band Radiation Hazards to Personnel from OSP SLV

1.5. General Description

The ORS-3 vehicle RF systems provide both uplink and downlink communications capabilities for telemetry, GPS, tracking and command destruct purposes. These systems support a UHF command uplink for the FTS, S-band vehicle telemetry data and S-band experiment telemetry data downlinks, an L1-band GPS link, and C-band RTS uplink/downlinks. Tables 2-1 through 2-6 provide information about the RF hardware and RF characteristics and data encoding schemes for each link. The vehicle RF system configurations are discussed in the following sections. Drawing number 1047-0511 can be referenced for a complete interconnect of the ORS-3 vehicle.

2. Flight Termination System (FTS) Uplink Description

The FTS is used to initiate destruction of the vehicle in the event of a gross malfunction during flight. This system is operable only through Stage 3 separation during the boost phase of the flight. A list of system hardware is shown in Table 2-1. The system is designed to receive a Frequency Modulation (FM) signal modulated by up to four pure-sine tones. The tone frequencies are in accordance with an Interrange Instrumentation Group (IRIG) Standard. The tones must be received in a specific sequence to initiate the destruct event, as shown in Table 2-2.

A block diagram of the FTS is shown in Figure 2-1. It consists of an antenna array containing two conformal microstrip antenna elements mounted on the skin at roll angles 39.8° and 219.8°. Coaxial cables, phased 90° apart, carry signals from the antenna elements to a 90° hybrid coupler. The coupler evenly splits the incoming signals and routes them to two command destruct receivers which decode the command tones and indicate their presence to two Flight Termination Logic Units (FTLUs). This configuration allows two receivers to use a shared antenna system while providing over 20 dB of RF isolation between receivers. The signal phasing between the antenna elements and the receivers is such that the elements are the same electrical length away from one receiver and one-half wavelength out of phase with respect to the other. This mitigates antenna pattern nulls and ensures at least one receiver remains locked. Therefore, the chance of the ground transmitter lying in a direction of poor antenna system gain for both receivers simultaneously is substantially reduced. Note that all components are located on the Stage 3 Forward Module.

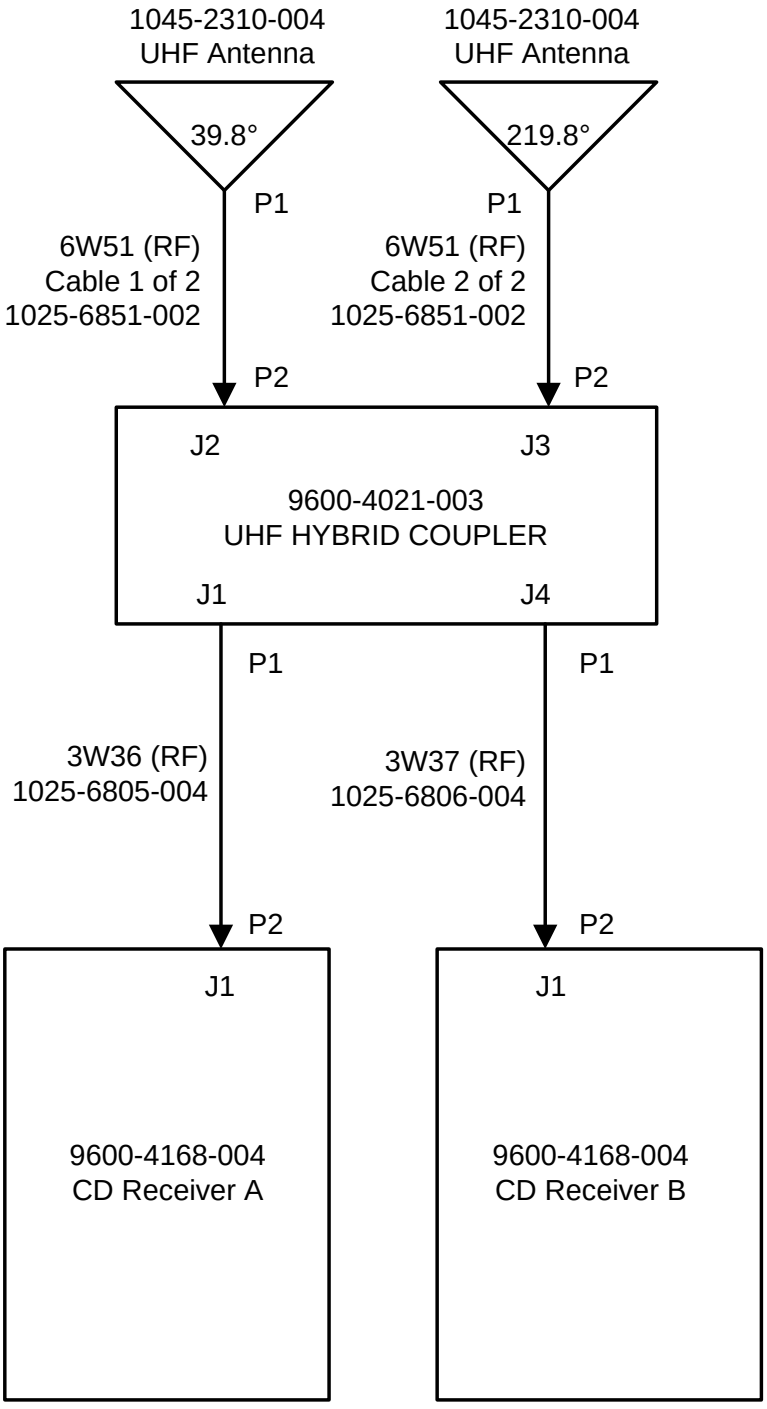

Figure 2-1 Block Diagram of the FTS RF System

TABLE 2-1. FLIGHT TERMINATION SYSTEM UPLINK RF HARDWARE

PART NAME	QTY	PART NUMBER	PART SOURCE
FTS ANTENNA	2	1045-2310-004	HAIGH-FARR
FTS CABLE	1	1025-6851-002 (1 of 2)	CEPA
FTS CABLE	1	1025-6851-002 (2 of 2)	CEPA
FTS COUPLER	1	9600-4021-003	MERRIMAC
FTS CABLE	1	1025-6805-004	CEPA
FTS CABLE	1	1025-6806-004	CEPA
FTS RECEIVER	2	9600-4168-004	L3 Comm.

TABLE 2-2. COMMAND/DESTRUCT UPLINK SIGNAL CHARACTERISTICS

1.	**RF CHARACTERISTICS:**	
	RF CARRIER CENTER FREQUENCY	421.0 MHz
	RECEIVER IF BANDWIDTH (60 dB)	360 kHz
	RECEIVER IF BANDWIDTH (3 dB)	180 kHz
	MODULATION TYPE	Tone Modulated FM
	PEAK DEVIATION (per tone ±10%)	30 kHz
	RECEIVER SENSITIVITY (max.)	-107 dBm
2.	**BASEBAND CHARACTERISTICS:**	
	NUMBER OF MODULATING TONES	4
	TONE FREQUENCIES (±10%)	(IRIG TONE 1) 7.5 kHz (IRIG TONE 2) 8.46 kHz (IRIG TONE 4) 10.76 kHz (IRIG TONE 5) 12.14 kHz
3.	**RECEIVER DATA CHARACTERISTICS:**	(SEQUENTIAL LOGIC)
	a.) APPLICATION OF IRIG TONE 1 AND IRIG TONE 5 ARMS THE RECEIVER	ARM CONDITION
	b.) REMOVAL OF IRIG TONE 5 AND APPLICATION OF IRIG TONE 2 GIVES A RECEIVER DESTRUCT OUTPUT	DESTRUCT CONDITION

3. S-band Telemetry RF System Description

There are two vehicle telemetry systems, the vehicle telemetry and the GPS Tracking Experiment telemetry. The vehicle telemetry system is located on the avionics module located on Stage 4 and the experiment telemetry system is located on Stage 3 forward.

A block diagram showing the S-band vehicle telemetry system and GPS Tracking Experiment telemetry system is shown in Figure 2-2. Each system has a telemetry transmitter, an S-band 90° hybrid coupler and a pair of cavity-backed flush mounted slot antennas, separated in the roll plane by 180°. The systems are connected via an RF switch. During the boost phase, the vehicle telemetry signal is routed to the Stage 3 antenna array via RF Switch 1 through port 1 of the S-band hybrid coupler. The Stage 3 GPS Tracking Experiment telemetry signal is routed to the Stage 3 antenna array via port 4 of the S-band hybrid coupler. After fairing separation at approximately 150 seconds, RF Switch 1 routes the vehicle telemetry signal to the Stage 4 antenna array via the Stage 4 hybrid coupler.

A list of hardware is included in Table 2-3 and Table 2-4, and signal characteristics for each telemetry system are shown in Table 2-5.

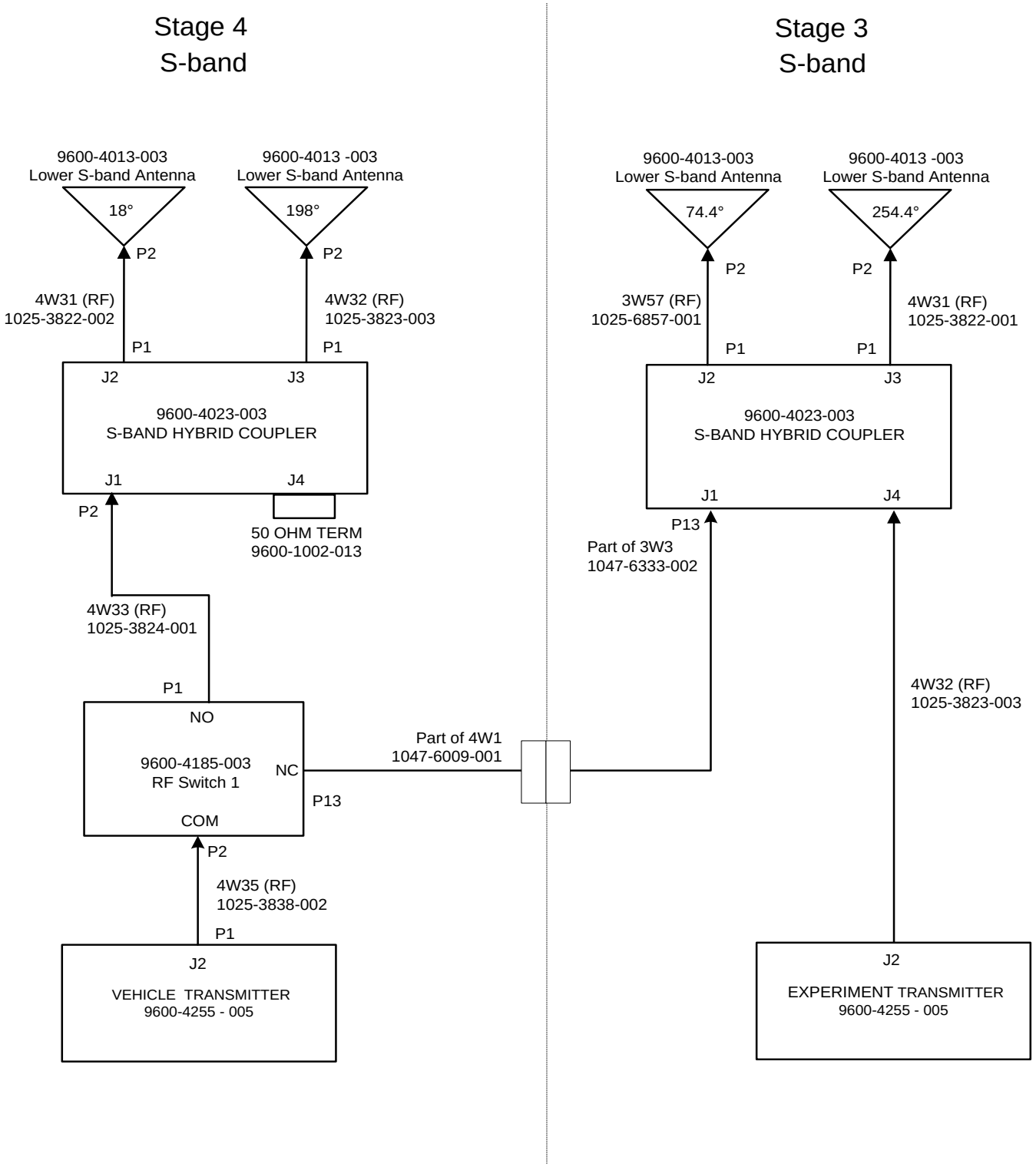

Figure 3-1 Block Diagram of the S-band Vehicle Telemetry and GPB

Table 3-1 S-BAND STAGE 4 VEHICLE RF TELEMETRY SYSTEM HARDWARE

PART NAME	QTY	PART NUMBER	PART SOURCE
ANTENNA	2	9600-4013-003	UB CORP
RF CABLE	1	1025-3822-002	CEPA
RF CABLE	1	1025-3823-003	CEPA
HYBRID COUPLER	1	9600-4023-003	MERRIMAC
RF CABLE	1	1025-3824-001	CEPA
50 OHM TERMINATION	1	9600-1002-013	MA-COM
RF SWITCH	1	9600-4185-003	DOW-KEY
VEHICLE TELEMETRY TRANSMITTER	1	9600-4255-005	L3 COMMUNICATIONS

Table 3-2 S-BAND STAGE 3/GPB RF TELEMETRY SYSTEM HARDWARE

PART NAME	QTY	PART NUMBER	PART SOURCE
ANTENNA	2	9600-4013-003	UB CORP
RF CABLE	1	1025-6857-001	CEPA
RF CABLE	1	1025-3822-001	CEPA
HYBRID COUPLER	1	9600-4023-003	MERRIMAC
RF CABLE	1	1025-3823-003	CEPA
EXPERIMENT TRANSMITTER	1	9600-4255-005	L3 COMMUNICATIONS

Table 3-3 TELEMETRY DATA DOWNLINK SIGNAL CHARACTERISTICS

1.	**RF CHARACTERISTICS:**	**STG 4 TLM**	**STG 3/GPB**
	RF CARRIER CENTER FREQUENCY (MHz)	2288.5	2241.5
	TRANSMITTER RF POWER (WATTS)	5	5
	RECEIVER IF BANDWIDTH (MHz)	2.4	0.3
	MODULATION TYPE	PCM/FM	PCM/FM
	PEAK DEVIATION (kHz)	700	44.8
	TRANSMITTER COUPLING	AC	AC
2.	**DATA CHARACTERISTICS:**		
	PCM CODE	RNRZ-L	BIPHASE-L
	BIT RATE	2.0 Mbps	0.128 Mbps
	DATA ORDER	MSB FIRST	MSB FIRST
	BITS PER WORD	8	8
	WORDS PER MINOR FRAME	250	78
	MINOR FRAMES PER MAJOR FRAME	100	20
	WORDS PER MAJOR FRAME	25,000	1560
	MINOR FRAMES PER SECOND	1000	200
	MAJOR FRAMES PER SECOND	10	10
	FRAME SYNC (HEX)	FE6B2840	FAF320

4. GPS System Description

A block diagram of the GPS system is shown in Figure 2-3 and a list of hardware is included in Table 2-6. It consists of two patch antennas mounted on Stage 3, forward, separated in the roll plane by 180°. The GPS signal is fed from each antenna via a coaxial cable and is then amplified by the LNA/Filters. This amplified signal is then fed via a coaxial cable to the hybrid coupler, through a DC block and another coaxial cable to the GPS receiver.

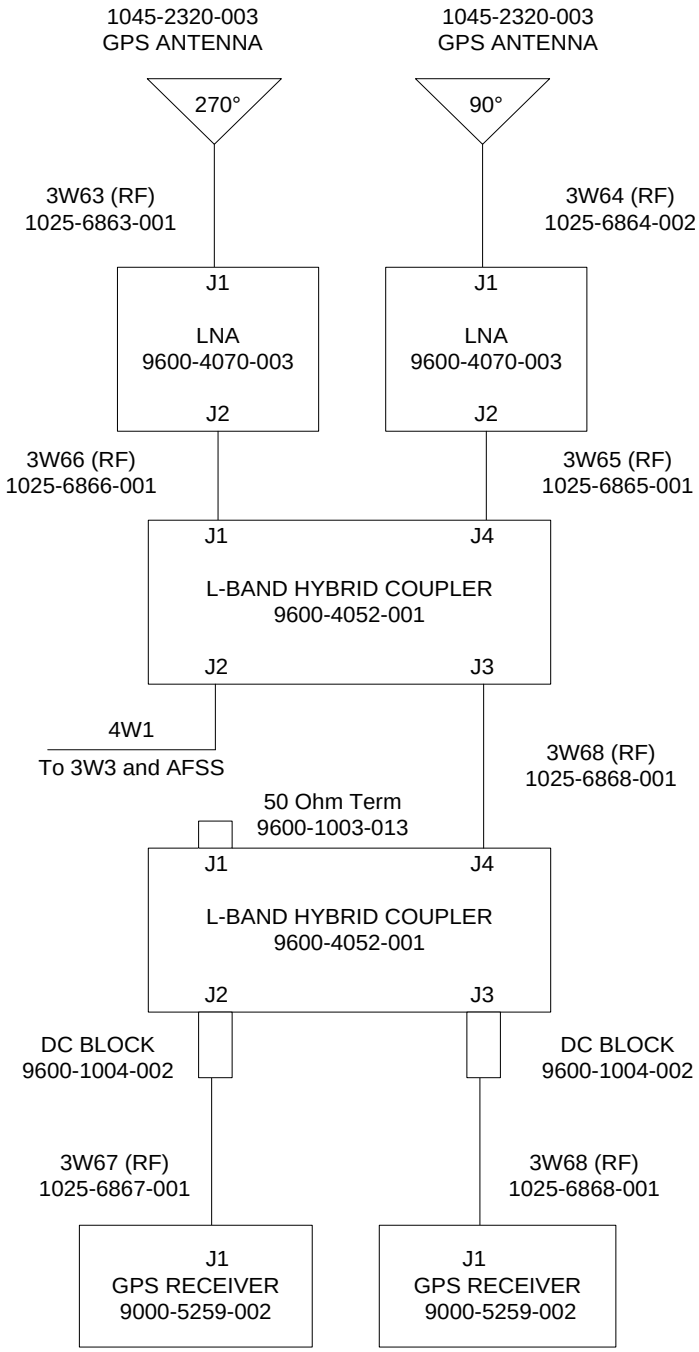

Figure 4-1 Block Diagram of the GPS System

Table 4-1 GPS RF HARDWARE

PART NAME	QTY	PART NUMBER	PART SOURCE
ANTENNA	2	1045-2320-003	HAIGH-FARR
RF CABLE	1	1025-6863-001	CEPA
RF CABLE	1	1025-6864-002	CEPA
LNA/FILTER	2	9600-4070-003	SPECTRUM MICROWAVE
RF CABLE	1	1025-6866-001	CEPA
RF CABLE	3	1025-6868-001	CEPA
HYBRID COUPLER	2	9600-4052-001	MERRIMAC
RF CABLE	1	1025-6867-001	CEPA
4W1 (to 3W3 and AFSS)	1	1047-6333-002	ORBITAL
DC BLOCK	2	9600-1002-013	XMA CORPORATION
GPS RECEIVER MODULE ASSY	2	9000-5259-001	JAVAD

5. RTS System Description

The C-band RTS system is used to allow active radar tracking of the flight vehicle. The vehicle mounted transponder accepts a dual pulse interrogation signal. If the spacing between the dual interrogation pulses is the proper interval, the transponder transmits a high power reply pulse after a fixed time delay. The reply pulse is transmitted at a different frequency than the interrogation pulse to enhance system sensitivity. The reply pulse then travels to the interrogating ground radar where range is calculated. This arrangement has an advantage over traditional "skin-track" radars which rely on radio pulses reflected from the vehicle for tracking. Table 2-8 shows the transponder signal characteristics.

A block diagram of the vehicle C-band RTS system is shown in Figure 2-4. A list of hardware is included in Table 2-7. The system consists of two cavity-backed flush mounted slot antenna elements where the elements are separated by 180° in the roll plane. Coaxial cables carry signals between the antenna elements and a 90° hybrid coupler. The 90° hybrid coupler is connected to a C-band transponder via coax cable. The unused input on the hybrid coupler is terminated with a 50 ohm termination. Note that all components are located on the Stage 3 Forward module Forward module and continue to radiate after stage 3 separation..

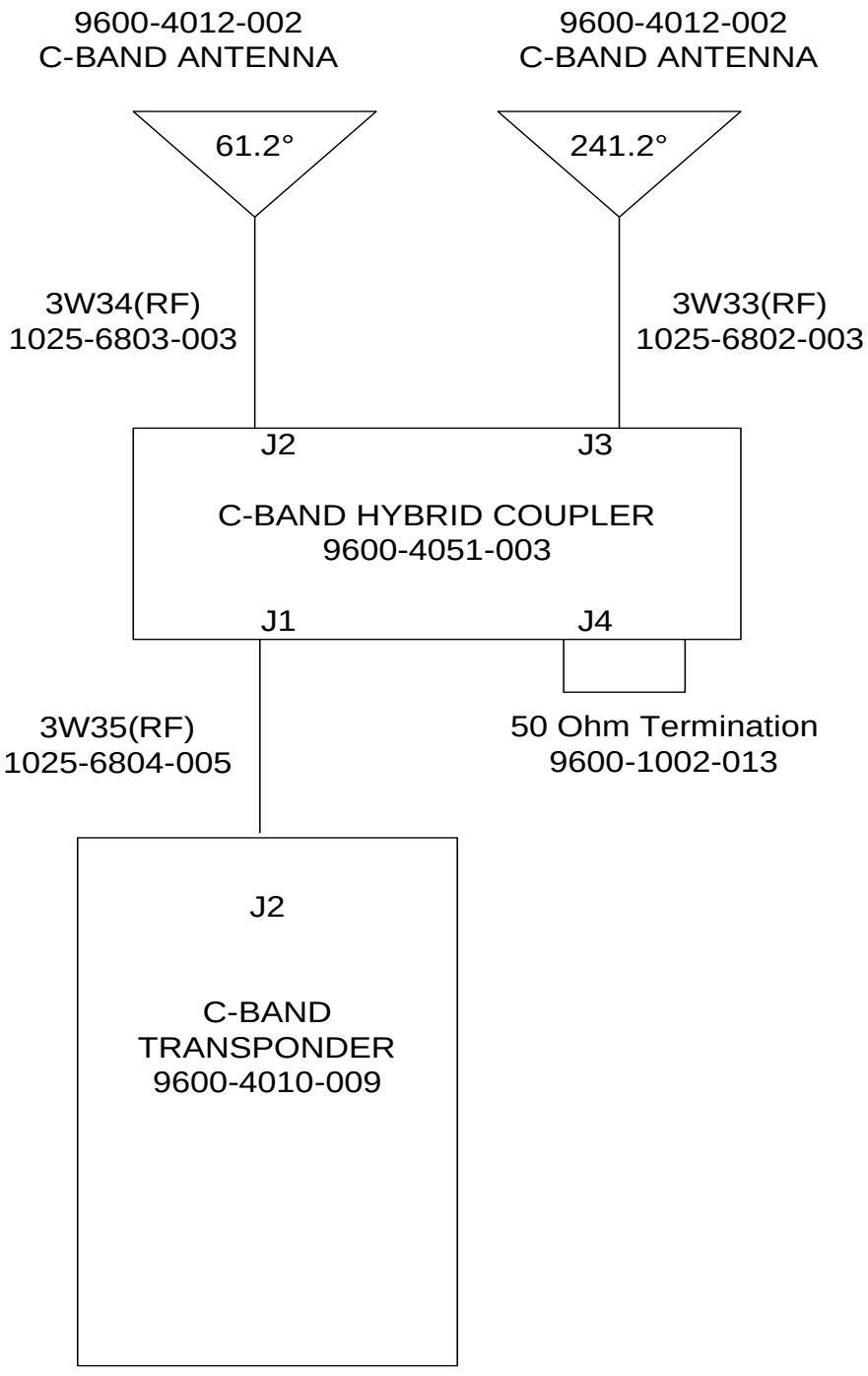

Figure 5-1 Block Diagram of the RTS System

Table 5-1 RTS RF HARDWARE

PART NAME	QTY	PART NUMBER	PART SOURCE
ANTENNA	2	9600-4012-002	UB CORP
RF CABLE	1	1025-6802-003	CEPA
RF CABLE	1	1025-6803-003	CEPA
HYBRID COUPLER	1	9600-4051-003	MERRIMAC
50 Ω TERMINATION	1	9600-1002-013	MA/COM
RF CABLE	1	1025-6804-005	CEPA
TRANSPONDER	1	9600-4010-009	HERLEY

Table 5-2 TRANSPONDER SIGNAL CHARACTERISTICS

1.	**UPLINK RECEIVER CHARACTERISTICS:**	
	RF CARRIER CENTER FREQUENCY	5690 MHz
	RECEIVER RF SENSITIVITY (MAXIMUM)	-70 dBm
	INTERROGATION FORMAT	DUAL PULSE
	INTERROGATION PULSE WIDTH	0.5 μS
	INTERROGATION CODE SPACING	9.0 μS
2.	**DOWNLINK TRANSMITTER CHARACTERISTICS:**	
	RF CARRIER CENTER FREQUENCY	5765 MHz
	TRANSMITTER RF POWER (MINIMUM)	400 W
	REPLY FORMAT	SINGLE PULSE
	REPLY DELAY	2.5 μS
	PULSE WIDTH	0.5 μS

6. COMPLIANCE MATRIX

Table 3-1 shows the compliance matrix and the method of compliance. The completion of the requirements shall be accomplished by the methods of Test (T), Analysis (A), Similarity (S) or Inspection (I). If similarity is used, the previous mission used for similarity is indicated.

Table 6-1 OSP SLV ORS-3 COMPLIANCE MATRIX

REQUIREMENT	COMPLIANCE METHOD	DOCUMENTATION
The RF Systems Design Engineer shall recommend optimized hardware mounting.	I	Minotaur I ORS-3 Mission
Common hardware components shall be used wherever possible.	I	1047-0511
When interfering signals can cause GPS band intermodulation products within the LNA front end, a filtered LNA shall be used to reduce the interfering signal by reducing the signals at constituent frequencies.	I	9600-4070 1047-0511
The RF Systems Design Engineer shall analyze all flight air links and launch pad ground links to establish link margin.	A	039-1755
The RF Systems Design Engineer shall run an IMOD analysis including all on board RF systems and all launch site RF systems.	A	039-1756
The RF systems engineer shall perform a GPS link margin analysis which demonstrates that the C/No present at the receiver input is sufficient for acquisition, tracking or a high quality state vector or “navigation solution”. Additionally, the analysis will demonstrate that the input signal power is within the receiver dynamic range.	A	039-1755
The final RF Design Document shall be completed before launch.	A	TM-23373
Perform interference analysis	A	039-1758
Perform antenna pattern analysis/measurement	A	Various[1]
Perform vehicle radiated power hazards analysis for personnel	A	039-944

[1] Various documents used depending on the antenna system specified, including: TM-22527 Minotaur I Simulated Antenna Patterns, PSL/RF-94/37 Pegasus XL Antenna Pattern Measurements Final Report, May 1994, PSL/RF-90/36 Pegasus Launch Vehicle Antenna Pattern Measurements Final Report, April 1990, TM-18106 Engineering Evaluation Test Report for the OBV Antenna Systems and TM-14569, OSP PSL UB Antenna Pattern Measurements.

7. COMPONENT QUALIFICATION MATRIX

Table 7-1 FTS COMPONENT QUALIFICATION (from 039-1585)

COMPONENT	LOCATION	QUALIFICATION TESTS			
		RANDOM VIBRATION	SHOCK	THERMAL	THERMAL VACUUM
UHF ANTENNA 1045-2310-004	STAGE 3 FORWARD	TM-21690	TM-21690	TM-21690	TM-21690
UHF HYBRID COUPLER 9600-4021-003	STAGE 3 FORWARD	TM-17372	TM-17372	TM-17372	TM-17372
FTS RECEIVER 9600-4168-004	STAGE 3 FORWARD	TM-21752	TM-21752	TM-21752	TM-21687

Table 7-2 GPS COMPONENT QUALIFICATION (from 039-1585)

COMPONENT	LOCATION	QUALIFICATION TESTS			
		RANDOM VIBRATION	SHOCK	THERMAL	THERMAL VACUUM
L-BAND ANTENNA 1045-2320-003	STAGE 3 FORWARD	QTP-8250-92	QTP-8250-92	QTP-8250-92	QTP-8250-92
GPS (L1) - BAND LNA/FILTER 9600-4070-003	STAGE 3 FORWARD	TM-22020, TM-19049, WAIVER	TM-22020, TM-19049, WAIVER	TM-22020	TM-22020
L-BAND HYBRID COUPLER 9600-4052-001	STAGE 3/4 INTERSTAGE	TM-18077	TM-21119	TM-18077	TM-18077
GPS RECEIVER MODULE 9000-5259-001	STAGE 3/4 INTERSTAGE	TM-19411	TM-19411	TM-19411	TM-19411

Table 7-3 TELEMETRY SUBSYSTEM COMPONENT QUALIFICATION (from 039-1585)

COMPONENT	LOCATION	QUALIFICATION TESTS			
		RANDOM VIBRATION	SHOCK	THERMAL	THERMAL VACUUM
S-BAND ANTENNA 9600-4013-003/ 9600-4013-009	AVIONICS MODULE/ STAGE 3 FORWARD	TM-13831	TM-13480	TM-13831	039-310
S-BAND HYBRID COUPLER 9600-4023-003	AVIONICS MODULE & STAGE 3/4 INTERSTAGE	TM-17372, TM-18108, TM-18316	TM-17372	TM-17372	TM-17372
RF SWITCH 1027-2072-007	AVIONICS MODULE	TM-14385, 044-376	TM-14385	TM-14385	TM-14385
5 W S-BAND TRANSMITTER 9600-4255-005	AVIONICS MODULE	TM-18911	TM-18911	TM-18911	TM-18911
5 W S-BAND TRANSMITTER 9600-4255-005	STAGE 3/4 INTERSTAGE	TM-18911	TM-18911	TM-18911	TM-18911

Table 7-4 RTS COMPONENT QUALIFICATION (from 039-1585)

COMPONENT	LOCATION	QUALIFICATION TESTS			
		RANDOM VIBRATION	SHOCK	THERMAL	THERMAL VACUUM
C-BAND ANTENNA 9600-4012-002	STAGE 3 FORWARD	TM-13833	TM-13479	TM-13833	039-310
C-BAND HYBRID COUPLER 9600-4051-003	STAGE 3 FORWARD	TM-17372, TM-18316	TM-17372	TM-17372	TM-17372
C-BAND TRANSPONDER 9600-4010-009	STAGE 3/4 INTERSTAGE	TM-18866	TM-18866	TM-18866	TM-18866