

TRW

PRESS INFORMATION



Space Shuttle

FIRST FLIGHT OF THE COLUMBIA

Section 1 -- S-Band Communications for the Space Shuttle

Section 2 -- Orbiter S-Band Communications Subsystem
Technical Information

Section 3 -- TRW's Roles in the Space Shuttle Program

TRW

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S-BAND COMMUNICATIONS FOR SPACE SHUTTLE

TRW's S-band communications system is the primary means of communications between the orbiter and the ground tracking stations during the ascent, orbital, and entry phases of the flight.

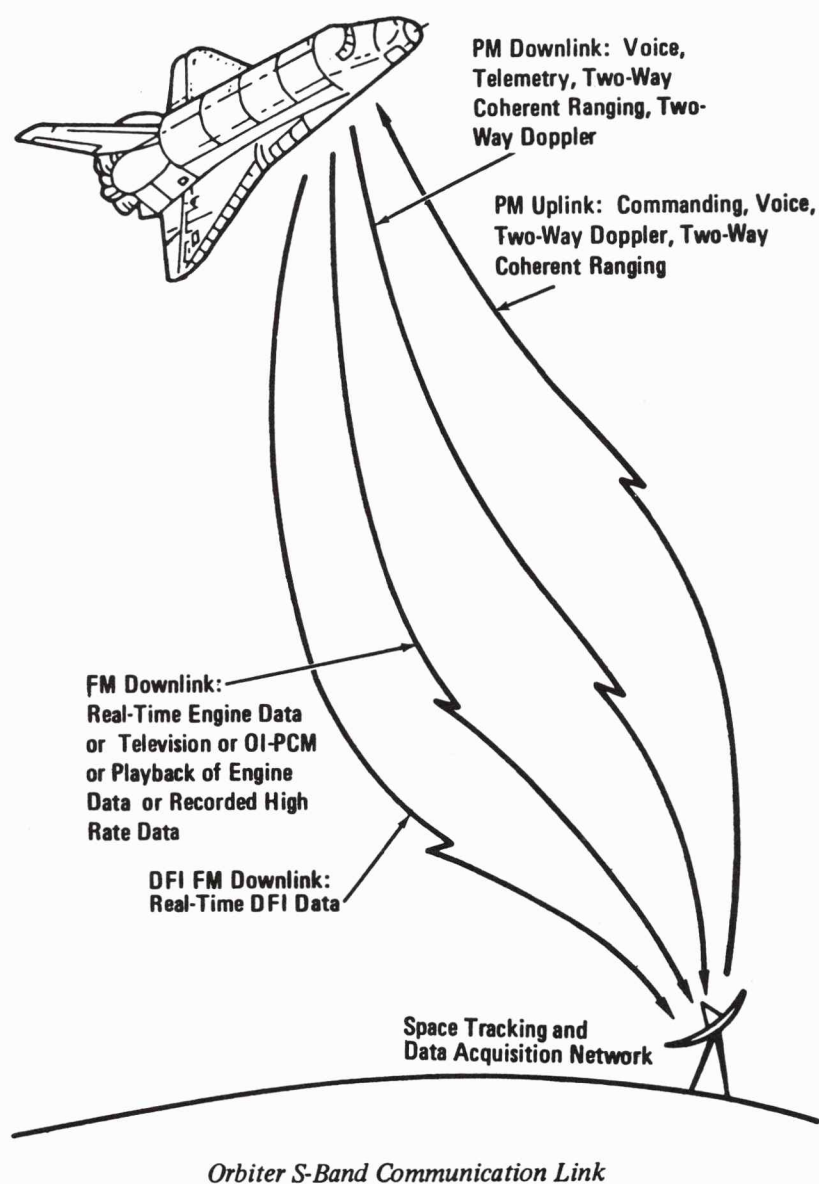
There is one uplink from the ground tracking stations to the orbiter, which is phase-modulated (PM) and provides commands, voice and a coherent ranging signal to the orbiter.

There are three downlinks from the orbiter to the ground tracking stations. One is PM and provides voice, telemetry, two-way doppler, and a coherent ranging signal. The other two are frequency modulated (FM) and are used for transmission of wideband data. One FM downlink provides operational real-time Space Shuttle main engine data during ascent, real-time video (television), or operations reorder dump data. The remaining FM downlink provides real-time development flight instrumentation (DFI) data.

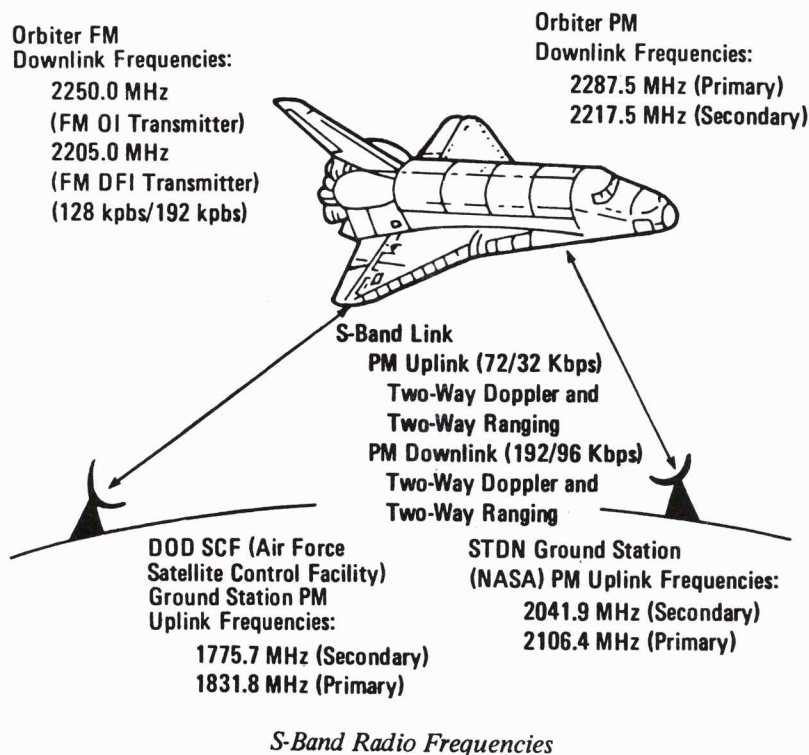
In addition to S-band, the orbiter has an ultra-high frequency (UHF) communication system which is used only for an air-to-air and air-to-ground voice communications and a Ku-band communications system, which will be used in conjunction with the TRW Tracking and Data Relay Satellite (TDRS) systems in later flights.

In the prelaunch phase, the orbiter flight crew utilizes the launch umbilical for communications with the ground support and operations personnel until the moment of liftoff.

S-BAND SYSTEM. The S-band operates in the radio frequency spectrum of 1700 to 2300 MHz.



The uplink from the ground tracking stations will be phase-modulated on a center carrier frequency of either 2106.4 MHz (primary), or 2041.9 MHz (secondary) for the NASA Space Tracking and Data Acquisition Network (STDN) ground stations and 1831.8 MHz (primary) or 1775.7 MHz (secondary) for the (Air Force Satellite Control Facility-SCF) ground stations.



The orbiter can transmit a PM downlink and two FM downlinks simultaneously. The PM downlink will be on a center-carrier frequency of 2287.5 MHz (primary) or 2217.5 MHz (secondary) for the SCF ground stations and

2287.5 MHz (primary) or 2217.5 MHz (secondary) for the NASA STDN ground tracking stations. The FM downlinks are on a center carrier frequency of 2250.0 MHz (FM operational transmitter) and 2205.0 MHz (DFI transmitter).

The PM uplink provides for commanding and voice transmissions from the ground stations to the orbiter. The PM downlink provides for telemetry and voice transmissions from the orbiter to ground stations.

The TRW S-band system is the only system for command reception until the Ku-band system is installed in later flights for use in conjunction with the TDRS. All MCC-H (Mission Control Center-Houston) uplink commands are multiplexed with digital voice and transmitted on the S-band PM uplink. The S-band system removes the voice and transfers the commands to the onboard orbiter computers. The computers route the commands to the intended systems.

The S-band PM uplink originates from an STDN remote station, NASA, or at a DoD SCF remote station. Each type of remote station has a choice of two uplink frequencies for data transfer. The frequency selection is under MCC-H control. The S-band uplink transfers the high data rate of two voice channels and commands (72 kbps-kilo bits per second) or low data rate of one voice channel and commands (32 kbps), two-way doppler, and two-way tone ranging.

The S-band PM downlink can originate from one of two S-band transponders aboard the orbiter. Each transponder can downlink on a frequency of 2217.5 MHz or 2287.5 MHz, but not both at the same time. The S-band PM downlink transfer high-data-rate telemetry plus two voice channels (192 kbps) or low-data-rate telemetry and one voice channel (96 kbps) and two-way doppler, and two-way ranging.

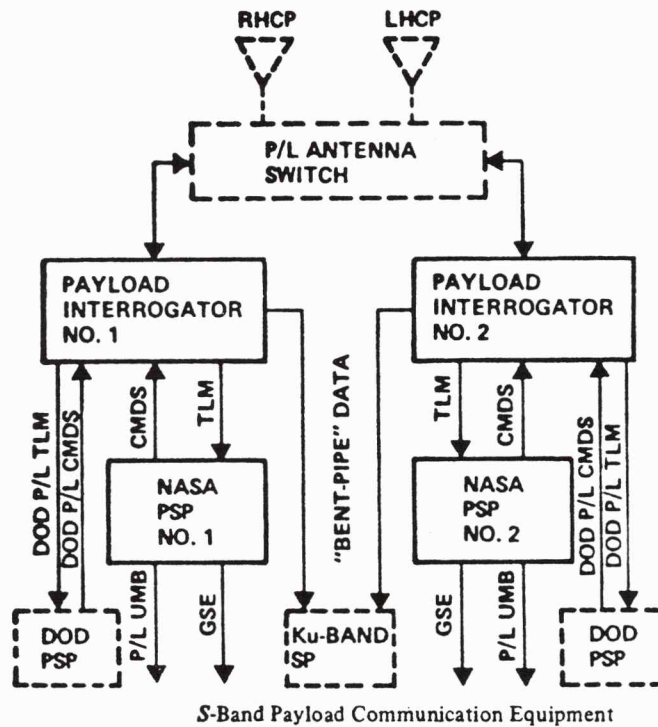
The S-band FM downlink can originate from three FM transmitters onboard the orbiter. Two are tuned to 2250.0 MHz and one is tuned to 2205.0 MHz. The S-band FM downlinks transfer real-time engine data or television or operational instrumentation PCM (128 kbps) or playback of engine data or recorded high-rate data (192 kbps) and DFI (128 kbps).

Having two S-band uplink and downlink frequencies prevents interference when two Space Shuttle orbiters are operating at the same time. One Space Shuttle orbiter could select the high set of frequencies and the other could select the low set of frequencies.

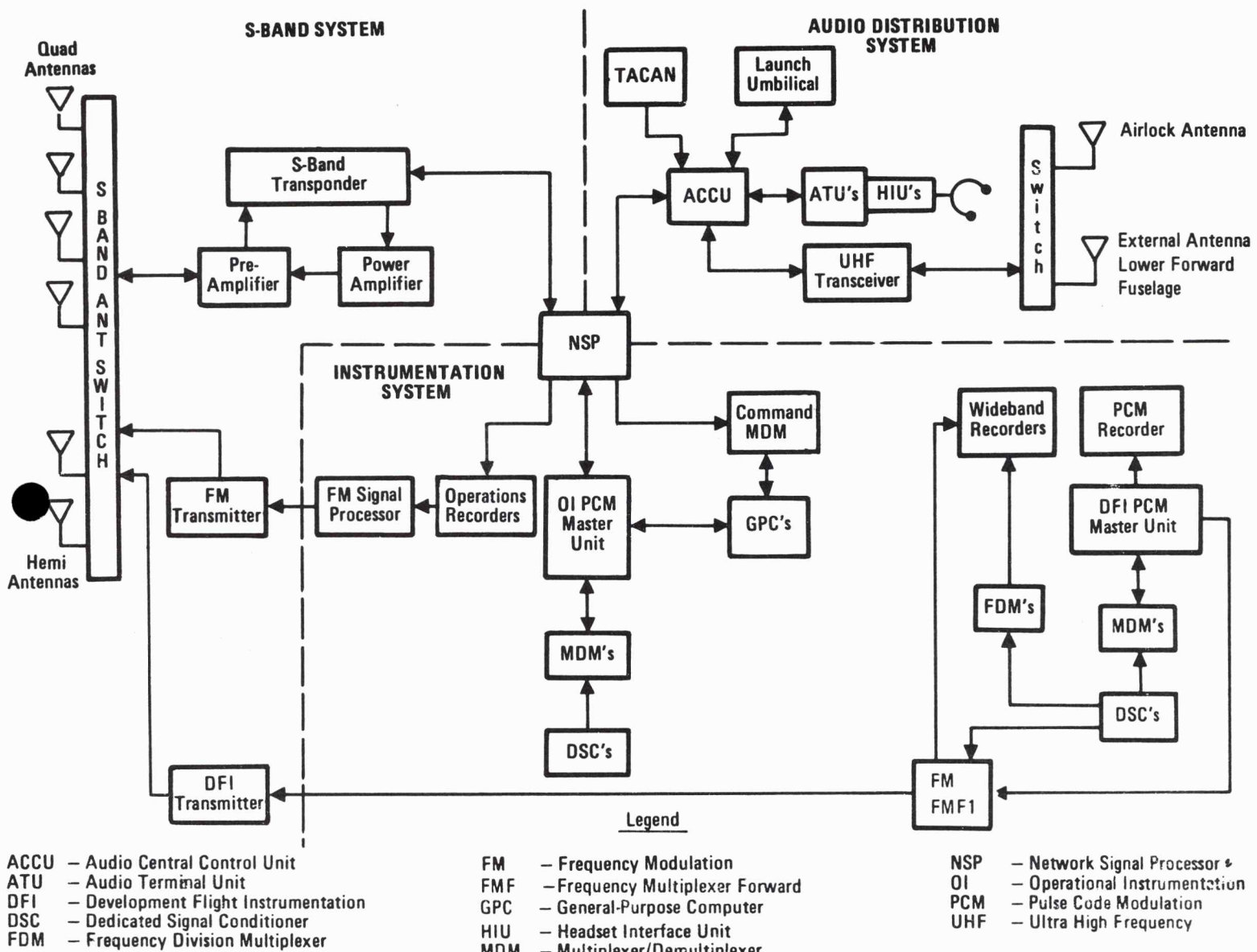
The two identical S-band transponders receive and transmit the PM uplink signal and downlink signal. Only one transponder operates at a given time; the other transponder is a redundant backup. The selected transponder transfers the uplink commands and voice to the TRW Network Signal Processor (NSP), receives the downlink telemetry and voice from the NSP, retransmits on a coherent frequency for the two-way doppler, and retransmits the two-way tone ranging signals.

The two onboard NSP's receive commands and transmit telemetry data to the selected S-band transponder. Only one NSP operates at a time. The selected NSP converts analog voice from the onboard audio central control unit (ACCU) to digital voice and multiplexes the same digital voice with operational instrumentation telemetry from the pulse code modulation master unit (PCMMU). The selected NSP converts digital voice to analog voice for the ACCU and crew intercommunication and decodes commands for the onboard computers.

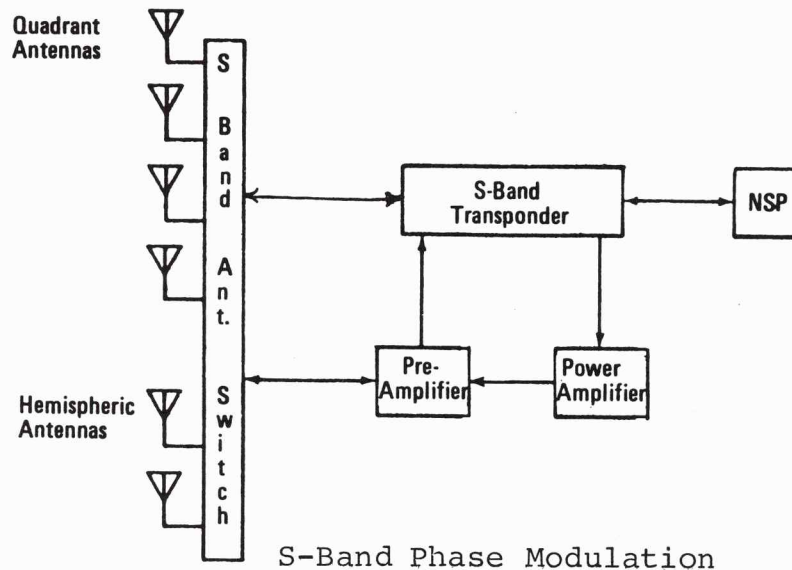
The PM uplink and PM downlink are normally coherent so that the frequency of the downlink is directly proportional to the uplink frequency. The S-band transponder provides a coherent turnaround of the uplink carrier frequency. This is necessary for the two-way doppler (change of frequency varying with velocity) data. By measuring the uplink frequency and knowing what downlink frequency to expect from the orbiter, the ground tracking station can measure the double-doppler shift that takes place and use that to calculate the radial velocity of the orbiter with respect to the ground station. These links are phase-modulated so that the S-band carrier center frequency will not be affected by the modulating wave. It would be impossible to obtain valid doppler data if the S-band carrier center frequency were affected by the modulating technique.



S-Band Payload Communication Equipment



Communications System



The S-band also provides a subcarrier for two-way tone ranging. The ground will uplink ranging tones at 1.7 MHz and compute vehicle slant range from the time delay in receiving the returned 1.7-MHz tones to determine orbiter range. Orbiter azimuth is determined from the ground tracking station antenna angles.

Frequency modulation is an ideal method to use for transmission of wideband data such as real-time video (television) and this is why the orbiter also has FM downlinks. There are two FM downlinks because it would be difficult to put all the wideband data on one link. After the initial development flights, the DFI equipment will be reduced greatly to a limited system and there may no longer be a need for the additional DFI FM downlink.

The signals received from the FM signal processor are used to frequency-modulate the carrier in the FM transmitter for transmission via one of the S-band hemispheric antennas to the ground tracking stations on the S-band FM downlink. The FM transmitter is used to transmit real-time engine data, real-time video (television), or operations recorder dump data.

The frequency-modulated transmitter carrier operates on the S-band frequency of 2250.0 MHz. Whenever the FM transmitter is active, the S-band antenna mechanism will transfer the signal to whichever hemispheric antenna is closest to the most direct line of sight to the ground tracking station.

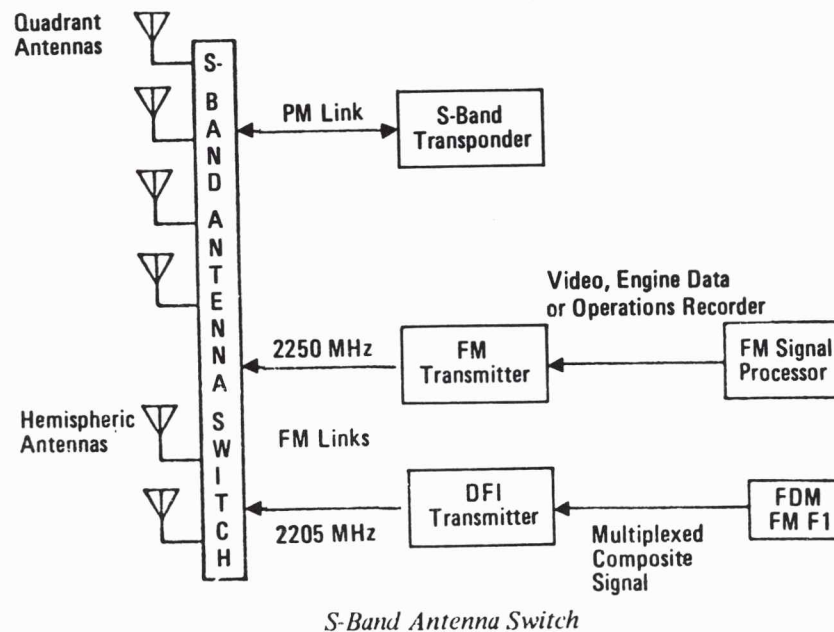
The multiplexed composite signal from the frequency division multiplexer (FDM) is used to frequency-modulate the carrier in the DFI transmitter for transmission, via one of the S-band hemispheric antennas to the ground tracking stations on the S-band DFI FM downlink. The DFI transmitter carrier operates on the S-band frequency of 2205.0 MHz. It transmits DFI data on the S-band DFI downlink. Whenever the DFI transmitter is active, the S-band antenna mechanism will transfer the signal along with the operational FM to whichever hemispheric antenna is closest to the line of sight to the ground tracking station.

The multiplexed composite signal from the frequency division multiplexer (FDM) is used to frequency-modulate the carrier in the DFI transmitter for transmission, via one of the S-band hemispheric antennas to the ground tracking stations on the S-band DFI FM downlink. The DFI transmitter carrier operates on the S-band frequency of 2205.0 MHz. It transmits DFI data on the S-band DFI downlink. Whenever the DFI transmitter is active, the S-band antenna mechanism will transfer the signal along with the operational FM to whichever hemispheric antenna is closest to the line of sight to the ground tracking station.

Both the FM transmitter and DFI transmitter can be active at the same time. If they are, there will be two S-band FM downlinks being transmitted to the ground simultaneously from the same hemispheric antenna.

The S-band antenna switch assembly provides the signal switching among the two S-band transponders and any one of four quadrant antennas and among the two FM transmitters and either of two hemispheric antennas. The quadrant and hemispheric antenna switchings are accomplished independent of each other. The proper quadrant and hemispheric antenna to be used is selected automatically under onboard computer control, by ground command, or manually by the flight crew utilizing displays and controls on the flight deck.

In the automatic mode, the onboard computer selects the proper quadrant antenna to be used whenever an S-band transponder is active and the proper hemispheric antenna to be used whenever an FM transmitter is active. The antenna selection is based upon the computed line of sight to the desired ground station. The antenna switching commands are sent to the switch assembly via multiplexer/demultiplexers (MDM's).



There are seven S-band antennas on the orbiter; four quadrant, two hemispherical, and one payload. The quadrant antennas are located on the forward fuselage on the outer skin approximately 90 degrees apart. In the orbiter on the flight deck looking out the front windows, the quadrant antennas are to the upper right, lower right, lower left, and upper left.

quadrant
The four/antennas are the radiating elements for the S-band PM downlink and for receiving the S-band PM uplink. The two hemispherical antennas are located on the forward fuselage on the outer skin approximately 180 degrees apart. On the flight deck, the hemispherical antennas would be above the head (upper) and below the feet (lower). The two hemispherical antennas radiate the S-band downlink. All the antennas are covered with thermal protection material.

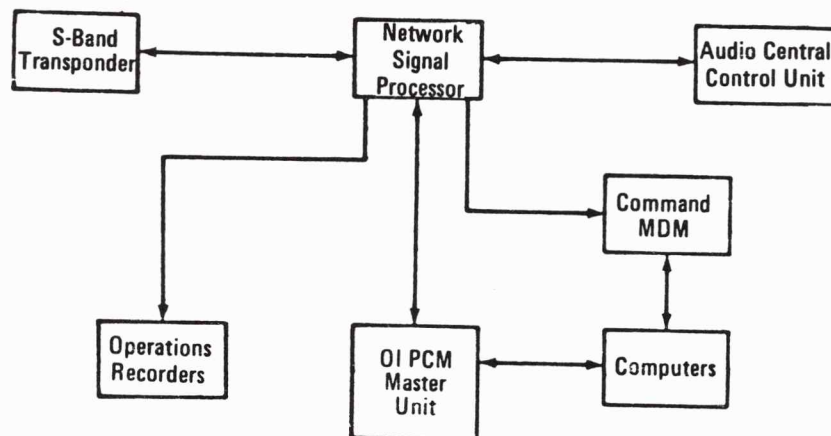
The basic difference between the two types of antennas is that the hemispheric antennas have a larger beam width, while the quadrant antennas have a higher antenna gain.

The payload antenna is located in the forward fuselage on the outer skin, just aft of the upper hemispherical antenna. It will be used as the radiating/receiving element for S-band payload forward, return links and with detached payloads. This antenna will be used in later flights.

The S-band RF link is pulse-modulated with the high-data-rate bit stream or the low-data-rate bit stream. The high data rate contains two 32 kbps digital voice channels multiplexed with the 128 kbps telemetry on the downlink and two 32 kbps digital voice channels multiplexed with 8 kbps command on the uplink. The low data rate contains one 32 kbps digital voice channel multiplexed with 64 kbps telemetry on the downlink and one 24 kbps digital voice channel multiplexed with 8 kbps command on the uplink.

The network signal processor provides the interface to the audio distribution system with the S-band communications link. The NSP receives either one or two analog voice signals from the ACCU's for downlink transmission, depending on whether one or both of the air-to-ground channels are being used.

The NSP converts these analog voice signals to digital voice signals, time-division-multiplexes them with PCM telemetry, and sends the composite signal to the S-band transponder. On the uplink, the NSP does just the reverse. It receives the composite signal from the S-band transponder and outputs either one or two analog voice signals to the ACCU. This composite uplink signal also has ground commands, which the NSP sends to the onboard computers.



Network Signal Processor

S-BAND COMMUNICATIONS SYSTEM

Prime Contractor

TRW Electronic Systems

1. Network Transponder
2. Signal Signal Processor
3. Payload Interrogator
4. Payload Signal Processor

Subcontractors

Power Amplifier
(Watkins Johnson)

Preamplifier
(AIL)

Switch Assembly
(Teledyne-Microwave)

FM Transmitter
(Teledyne-Electronics)

FM Signal Processor
(Conrac)

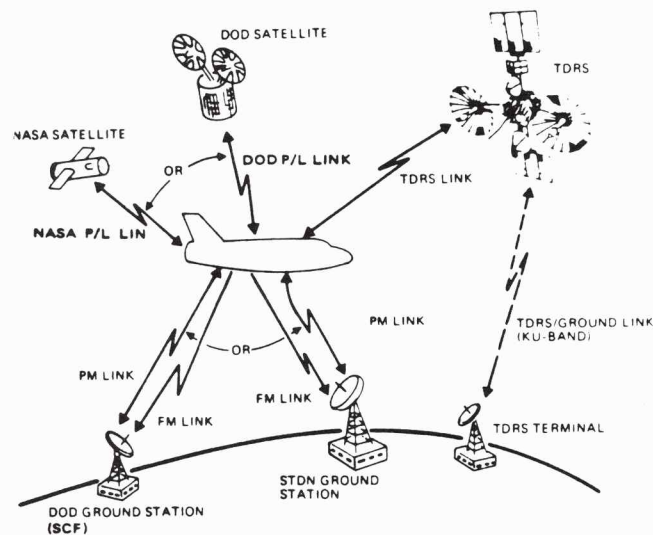
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ORBITER S-BAND COMMUNICATIONS SUBSYSTEM

TECHNICAL INFORMATION

The Space Shuttle Orbiter is being developed under NASA sponsorship with Rockwell International (RI) as prime contractor. TRW Electronics and Defense has been subcontracted to supply the Orbiter terminals for the S-band communication links. The network communications equipment provides voice, command and telemetry links, either direct or relayed by the Tracking and Data Relay Satellite (TDRS), between the Orbiter and ground stations. The payload communications equipment provides command and telemetry links between the Orbiter and payloads.



Space Shuttle Orbiter S-Band Links

NETWORK COMMUNICATIONS SUBSYSTEM EQUIPMENT

The S-band network subsystem supports direct two-way PM communication between the Orbiter and USAF Satellite Control Facility (SCF) ground stations, both direct and TDRS-relayed two-way PM communications between the Orbiter and NASA Space-flight Tracking and Data Network (STDN) ground stations, and FM direct communications from the Orbiter to both SCF and STDN ground stations.

Each of the major elements in the system constitutes an avionics system "black box" termed a line replaceable unit (LRU).

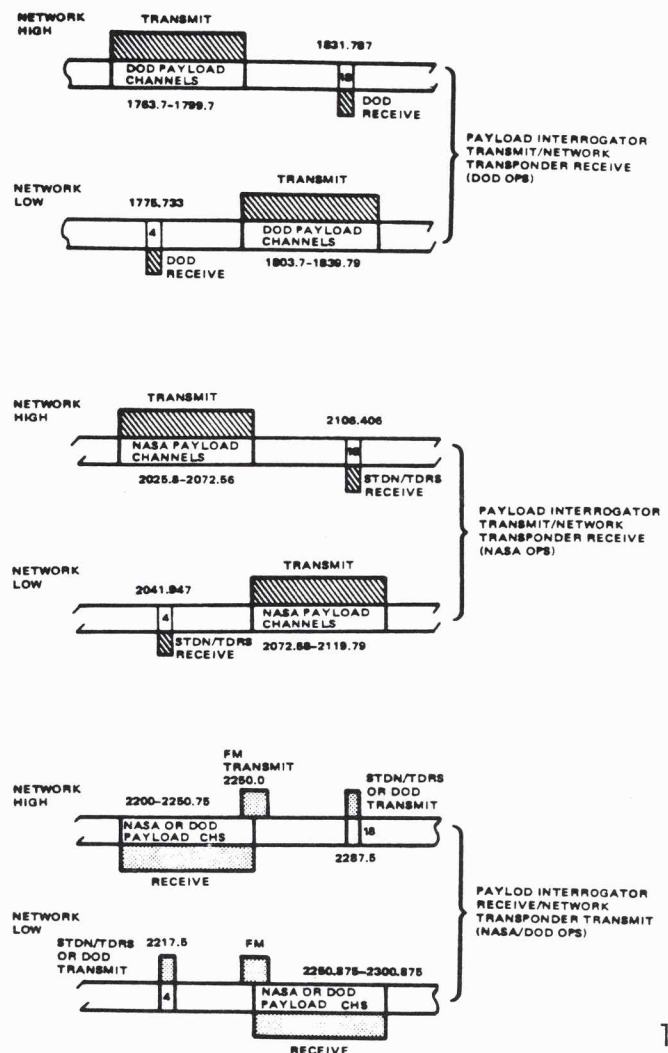
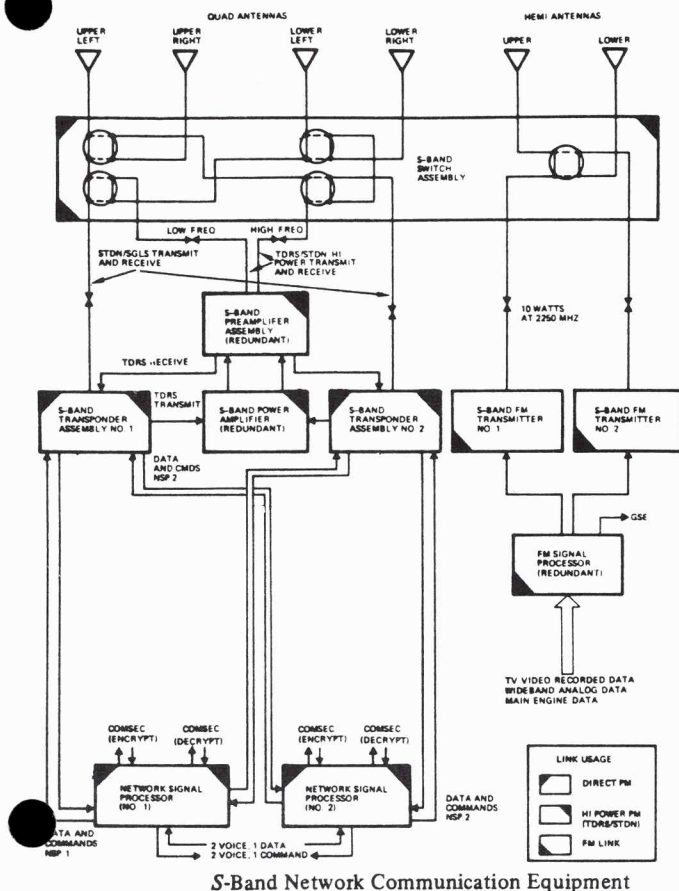
The two major network subsystem communication links are a PM link and an FM link. The PM link can be operated in either of two power modes. The low power PM mode is generally sufficient to support direct links to SCF or STDN ground stations, while the high power PM mode will be required to support TDRSS relay links.

A two-way PM link provides digital voice, command and telemetry services between the Orbiter and the SCF, STDN, and TDRSS. The direct links employ a residual carrier with a data modulation index $\beta = 1.1$ radians, and a tone ranging mod index of 1.0 radians or PSK data only, while the TDRSS relay link employs a suppressed carrier with phase shift keying (PSK).

In order to be able to provide payload communication with minimum interference to network communications, two band assignments, designated "high" and "low", are used for the S-band links.

The high network channel, centered at an Orbiter transmit frequency of 2287.5 MHz, will be used if a payload is to be addressed in the lower portion of the band, 2200 to approximately 2250 MHz.

The low network channel, centered at an Orbiter transmit frequency of 2217.5 MHz, will be used if a payload is to be addressed in the higher portion of the band, 2250 to 2300 MHz. When the payload subsystem is to receive data from a payload, the network receiver is configured to either the high or low band depending on whether the payload is in the low or high band respectively. The channel frequency selection is governed by whether the transmission originates from a DoD or NASA payload.



In normal operation, the transmit frequency is coherently related to the received frequency by either the DoD 256/205 or the NASA 240/221 transponding (turnaround) ratio. On the power-limited TDRSS relay links, convolutional encoding is required resulting in a symbol rate three times the information rate.

The spectrum of the forward TDRS link is further spread to reduce the power spectral density impinging on the Earth's surface by combining the coded data symbols with an 11.232 Mchip/s pseudo-noise (PN) sequence of length 1023.

DATA RATES FOR NETWORK PM LINKS

LINK	RATE	CHANNELS AVAILABLE	COMPOSITE LINK RATE	
			DIRECT (BIT RATE)	RELAY (RATE 1/3 CODED) (SYMBOL RATE)
FORWARD (Ground to Orbiter)	HIGH	Two 32 kbps Voice One 8 kbps Command	72 kbps	216 kbps
	LOW	One 24 kbps Voice One 8 kbps Command	32 kbps	96 kbps
RETURN (Orbiter to Ground)	HIGH	Two 32 kbps Voice One 128 kbps Telemetry	192 kbps	576 kbps
	LOW	One 32 kbps Voice One 64 kbps Telemetry	96 kbps	288 kbps

The S-band network link (direct link only, not TDRSS) may also include turnaround tone ranging on a 1.7 MHz sub-carrier, with a modulation index of 1.0 radian. The baseband modulation for all digital services is Biphase-L with the exception of the spread spectrum code which is NRZ-L.

The S-band FM link provides additional downlink capability from the Orbiter to ground stations (not TDRSS). The network FM signal, which is allocated to a 10 MHz bandwidth at 2250.0 MHz, may be modulated by any one of several sources, including television, three channel main engine data, wideband analog, wideband or narrowband digital data, recorder playback or real-time payload data (5 Mbits/s maximum). A separate FM antenna system provides isolation from the PM link antennas.

ANTENNA SWITCHING

Antenna switching is accomplished with full transmitter power on. This unique switch is capable of performing a minimum of 500,000 switching cycles without contact deterioration. It can switch 175 watts of rf energy. Until this switch was developed, transmitter power was usually turned off or greatly reduced during switching. This power on switching permits continuous transmission.

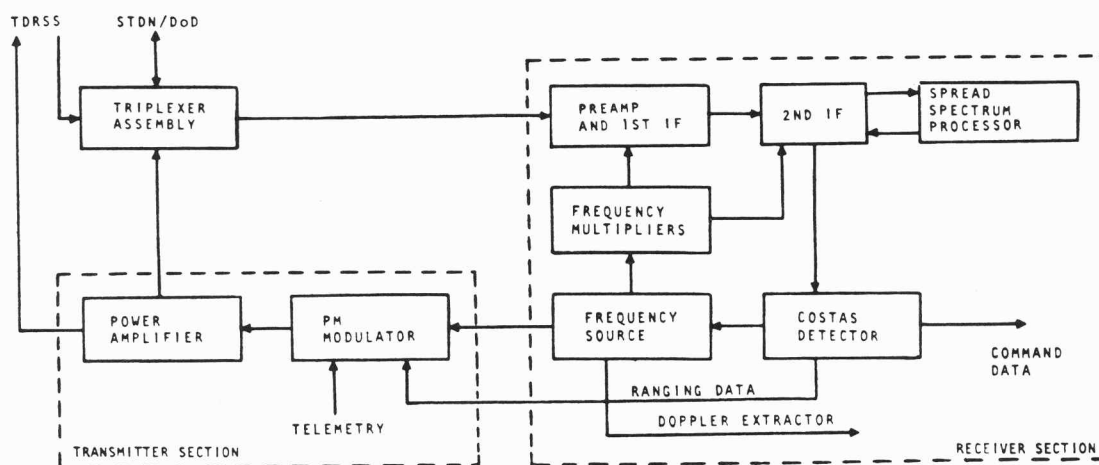
The switch assembly provides switching between the Orbiter Quad antennas located circumferentially around the Shuttle cabin and the redundant transponders in the DoD/NASA (low power) modes and the redundant parametric amplifier in the preamplifier assembly in the TDRS/NASA (high power) modes.

Any of the four Quad antennas can be switched to any of the common receiver-transmitter ports or the preamp assembly. The assembly also provides switching of the redundant S-band FM transmitters to either of the roughly hemispherical coverage FM antennas.

RF transfer switches are part of an integral LRU assembly with its connectors attached directly to the front panel, thus minimizing interconnection losses. The switch assembly contributes 0.6 dB insertion loss at a VSWR of 1.25:1 across the transmit band for the PM links, and has a maximum switching time of 25.0 ms. The LRU is capable of performing for a minimum of 500,000 cycles.

Network Transponder

The transponder is a multimode S-band communications transceiver unit which operates in three primary modes (DoD direct, STDN direct, and STDN High Power/TDRS relay) and several secondary modes. The transponder supports full-duplex communication in any of the primary modes, provides Doppler turnaround during coherent operation, and provides tone ranging turnaround in two of the primary modes. Turn-around ranging is accomplished exclusively with tones on the 1.7 MHz subcarrier. The receive-only mode supports uplink data reception and provides a coherent oscillator output for one-way Doppler extraction.



Network Transponder

The transponder receiver searches for, acquires, tracks, and coherently demodulates either residual carrier PM signals in the DoD or STDN modes or suppressed carrier PSK signals in the TDRSS mode. Acquisition of the spread spectrum code in the TDRSS mode is accomplished prior to carrier acquisition.

TRANSPONDER LRU PERFORMANCE SPECIFICATIONS

<u>RECEIVER (AMBIENT TEMPERATURE)</u>			
Noise Figure		8	dB Max
Doppler Accommodated		± 55	kHz
Doppler Rate Accommodated		± 5	kHz/s Max
Tone Ranging Response (± 1 dB)		1.5 to 1.9	MHz
Tone Ranging Delay		1.1	μ s Max
Tone Ranging Delay Variation		78.0	ns Max
Dynamic Range		-30 to -122	dBm Min
<u>TRANSMITTER</u>			
RF Power	SGLS/STDN 2:1 Load	2 to 6 W	
Output	TDRS-Matched Load	1 W \pm 1.8 dB	
Phase Noise (during Vibration)		8° rms Max	
ACQUISITION PROBABILITY >0.9 IN 6 SECONDS			
		MINIMUM SIGNAL LEVEL INTO TRANSPONDER	
MODE	MODULATION	32 kbps	72 dbps
STDN/SGLS	Bi- ϕ -L, PSK (No Ranging)	-117.0 dBm	-116.0 dBm
STDN HI Power	Bi- ϕ -L, PSK* (No Tone Ranging)	-102.0 dBm	-101.0 dBm
TDRS*	Bi- ϕ -L, PSK	-103.0 dBm	- 98.8 dBm
TDRS*	Carrier Only	-104.5 dBm	-100.3 dBm
The tone ranging uplink signal shall be turned off during acquisition. Center frequency \pm 50 kHz.			
* Input noise power spectral density of -151 dBm/Hz, acquisition probability >0.9 in 12s for TDRS LO & HI data.			
PN ACQUISITION TIMES			
P_r/N_o (dB-Hz)	Average Acquisition Time (Seconds)		Average Time To UnLock (Seconds)
	96 ksps	216 ksps	
49.5	≤ 60	$\leq N/A$	≥ 3600
51	≤ 20		≥ 3600
53		≤ 30	≥ 3600
54	≤ 10.0	≤ 10.0	≥ 3600

NETWORK SUBSYSTEM BIT ERROR RATE (BER)
PERFORMANCE MEASUREMENTS

TRANSPONDER/NSP BER							
Mode	Receiver Input Port	Modulation	Maximum BER	Required Input Levels			
				32 kbps		72 kbps	
				C/N ₀ (dB-Hz)*	Power (dBm)	C/N ₀ (dB-Hz)*	Power (dBm)
SGLS/STDN-Lo	COMM	PSK	10 ⁻⁴	58.8	-107.2	62.3	-103.7
SGLS/STDN-Lo	COMM	PSK	10 ⁻⁶	60.9	-105.1	64.4	-101.6
SGLS/STDN-Lo	COMM	PM Composite	10 ⁻⁴	62.1	-103.9	65.6	-100.4
SGLS/STDN-Lo	COMM	PM Composite	10 ⁻⁶	64.3	-101.8	67.7	- 98.3
STDN-Hi	TDRS	PSK	10 ⁻⁴	58.8	- 92.2	62.3	- 88.7
STDN-Hi	TDRS	PSK	10 ⁻⁶	60.9	- 90.1	64.4	- 86.6
STDN-Hi	TDRS	PM Composite	10 ⁻⁴	62.1	- 88.9	65.6	- 85.4
STDN-Hi	TDRS	PM Composite	10 ⁻⁶	64.2	- 86.8	67.7	- 83.3
TDRS	TDRS	PSK	10 ⁻²	49.8	-101.2	53.6	- 97.4
TDRS	TDRS	PSK	10 ⁻⁴	51.6	- 99.4	55.6	- 95.4
TDRS	TDRS	PSK	10 ⁻⁶	52.7	- 98.3	56.6	- 94.4

* COMM Port - Noise density corresponding to 8 dB noise figure assumed.
TDRS Port - Noise density of -151 dBm/Hz added to input signal.

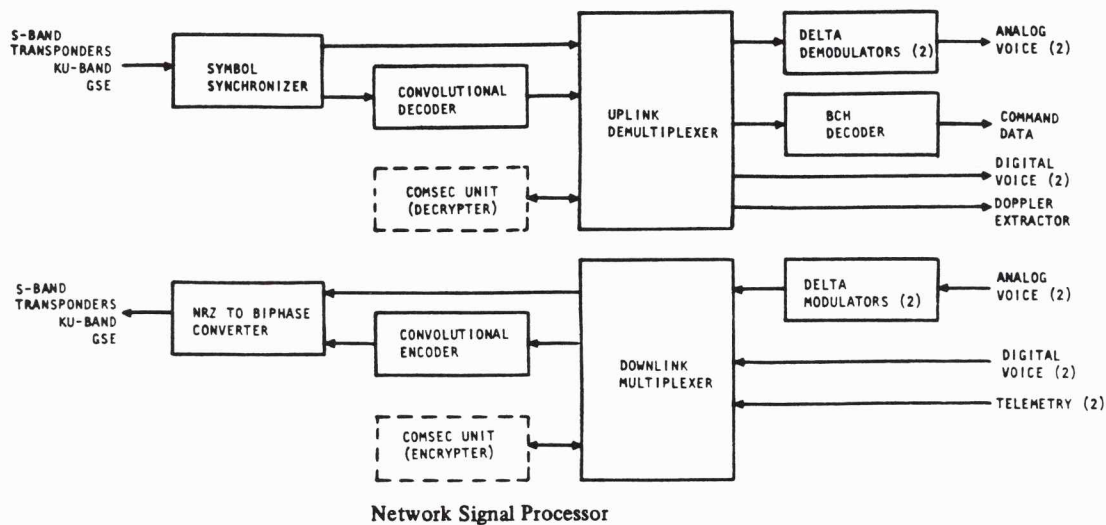
NOTE: BER in TDRS Mode is for convolutionally-coded link at the output of the Viterbi decoder.
Zero Doppler rate assumed for all modes.

Network Signal Processor

This LRU performs the digital processing functions for the PM links. All receiver input data passes first through the symbol synchronizer. Convolutionally encoded TDRSS-relayed data passes to the Viterbi decoder and encrypted DoD data are output to an external COMSEC device, the output of which then goes to the frame sync decoder. Unencrypted input data go directly to the frame sync decoder, the output of which drives the demultiplexer (demux).

Voice data from the demux are rate-buffered to either 24 kbits/s or 32 kbits/s to the delta demodulators or to the payload station when receiving digital voice data in the DoD mode.

Command data are buffered to a BCH (Bose-Chaudhuri-Hoc-quenghem) error detection/correction decoder at a net 6.4 kbit/s rate.



On-board analog voice signals are delta modulated using a modified ABATE algorithm and multiplexed with telemetry data. Data to be TDRSS-relayed are convolutionally encoded (rate 1/3, constraint length 7). All digital output data are converted from NRZ-L to Bi-phase-L prior to being transferred to the S-band transponder, Ku-band system or Ground Support Equipment (GSE) umbilical.

NETWORK SIGNAL PROCESSOR AND DOPPLER EXTRACTOR PERFORMANCE

NSP BIT SYNCHRONIZER							
Acquisition and Tracking Threshold SNR				-5 dB			
Hard Decision Uncoded Data Detection (-5 dB ≤ SNR ≤ 10.6 dB)				< 0.6 db from theory			
Acquisition Time							
Uncoded, SNR > 0 dB				1 s Max			
Coded, SNR > -3 dB				2 s Max			
NSP VITERBI DECODER							
For BER 10 ⁻¹ to 10 ⁻⁶				< 1 dB from theory			
NSP BCH COMMAND DECODER							
Probability of Undetected Error				10 ⁻¹⁸ Max			
DEX MEASUREMENT ACCURACIES							
Interval (s)	0.1	0.5	1.0	2.0	10.0	30.0	60.0
3σ Noise (S-band Cycles)	0.3	0.3	0.4	0.5	2.3	6.5	13.0

Power Amplifier

The power amplifier assembly supplies high power amplification of the network transponder output for the TDRS/STDN (high power) modes, providing a minimum of 100W RF output power into a 2:1 load mismatch. The assembly contains redundant traveling wave tubes (TWT's) and associated power converters with a transfer switch for cross-strapping at the assembly input. A leveling circuit at the LRU input permits maximization of tube performance around specific narrow TWT power input levels independent of LRU absolute input powers within a 5.5 dB range. A circulator and dummy load at the TWT outputs enables the LRU to survive either a short or an open circuit at the output without damage.

PERFORMANCE SPECIFICATIONS OF
TDRS/HI POWER STDN LRU'S

POWER AMPLIFIER (EACH CHANNEL)									
RF Output Power (into 2:1 Load Mismatch)	100 W Min &								
(Input between 26.0 - 31.5 dBm)	175 W Max								
Primary Power (+28 Vdc)	400 W Max								
Gain Ripple (.5 dB P-P)	10 MHz								
Phase Fluctuation - Added	20 mrad Max								
AM/PM Conversion	14°/dB Max								
Output Maximums									
Harmonic	2	3	4	5	6	7	8	9	10+
Level (dBm)	+42	+32	+27	+22	+17	+12	+7	+2	-3
PREAMPLIFIER (EACH CHANNEL)									
						Receive		Transmit	
Passband	MHz					24 (3 dB)		5 (1 dB)	
Gain Ripple (1 dB)	MHz					16 (1 dB)		5 (1 dB)	
Self Interference									
Rejection	(dB)					103 at f_{tr}		115 at f_{rec}	
Noise Figure	(dB)					2.6			
Gain	(dB)					20 - 26			
Input Dynamic Range	(dBm)					-130 to -55			
Transmit Channel									
Attenuation	(dB)							1.3 Max	
Maximum Input Power	(W)							200.0 Max	

Preamplifier

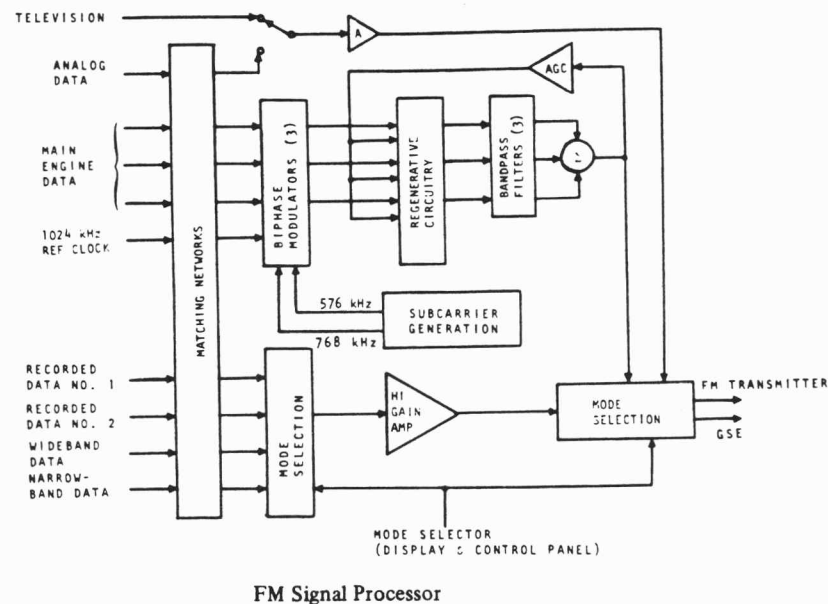
The preamplifier assembly provides multiplexing for the TDRS/STDN (high power) modes between the high power transmit and the receive channels. It also provides low-noise amplification of the high and low band receive signals using uncooled parametric amplifiers, with an overall LRU noise figure of 2.6 dB. The unit is internally redundant and provides input and output cross-strapping for the preamplifiers and cross-strapping of the high-power inputs from the power amplifier assembly.

Included in the preamplifier assembly are two diplexers, for high band and low band, respectively. Each is a three-port network consisting of a six-section receive filter and a five-section transmit filter connected to a common junction. The cavity sizes, aperture-coupled combined structures, are optimized under volume constraints to minimize in-band insertion losses. Diplexer design criteria also included minimizing payload interference and also the effect of the higher power amplifier harmonics.

FM Signal Processor and FM Transmitter

The FM signal processor is a self-contained, fully redundant unit that provides the interface functions between the various Orbiter data sources and the FM transmitter. Analog data and television are wideband NASA payload data. Shuttle main engine data, and other NASA or DoD payload data are conditioned, selectively modulated on sub-carriers, and operationally enabled to form the input to the FM transmitter.

The output of either redundant half of the FM signal processor drives a common GSE output for ground checkout. Isolation between the multiple inputs and between inputs and outputs is provided to minimize SNR degradation.



FM Signal Processor

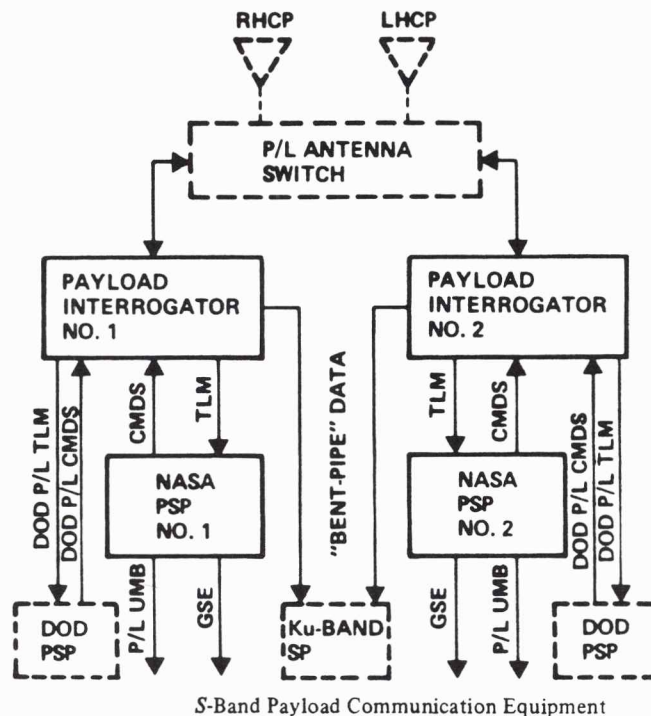
The FM transmitter produces 10 W minimum output, frequency modulated by the FM signal processor output. The input modulates a 98.5 MHz oscillator and mixes with the eighth harmonic of a stabilized oscillator. The resultant 750 MHz mixer output is then multiplied by 3 to provide the input for the output power circuit. The output power amplifier consists of a three-stage microwave integrated circuit, which then drives into an isolator 160 MHz bandwidth filter.

S-BAND FM PERFORMANCE SPECIFICATIONS

FM SIGNAL PROCESSOR	
TV Channel Input	EIA TV Standard RS 170
TV Channel Gain	19 dB + 0.8 to -0.25 dB
TV Channel Dynamic Range	51 dB + 0.25 dB
Freq. Response + 0.25 dB	dc to 4.5 MHz
& Phase Ripple $\pm 1.0^\circ$	
CCIR K Factor	<2%
Main Engine	
Data in 3 Channels	60 kbps BPL
Sub Carrier Frequencies	576 kHz, 768 kHz, 1024 kHz
Sub Carrier Modulation	$\pm 180^\circ$ at $\pm 15^\circ$
Analog Data Bandwidth	300 Hz to 4 MHz
Wideband Digital Data Rate	200 bps to 5 Mbps NRZ or 200 bps to 2 Mbps BPL
Recorded Data-2 Channels	
Data Rate	25.5 kbps to 1024 kbps
Narrow Band DoD Digital	
Data Rate	250 bps to 256 kbps
Input Common Mode Voltage (dc to 2MHz)	1V Max
FM TRANSMITTER	
Frequency	2250.0 MHz + 0.003%
Output Power (into 1.5:1 Load)	10 W Min, 15 W Max
Deviation Sensitivity (for Deviation up to ± 4.5 MHz Peak)	1 MHz/V Peak $\pm 10\%$
Frequency Response ± 1 dB	dc to 5.0 MHz
Incidental AM	5% Max over Input Range
Incidental PM	<5 kHz rms over Modulation BW
Intermodulation Distortion (2-Tone Equal Amplitude)	≥ 40 dBd with Frequency Deviation ± 1 MHz

PAYLOAD COMMUNICATIONS SUBSYSTEM EQUIPMENT

The TRW payload communication equipment provides two-way duplex PM communication of command and telemetry data between the Orbiter and detached payloads. The equipment consist of the payload interrogator (PI) and the payload signal processor (PSP).



TRW's payload communication equipment is configured to either a NASA or DoD mode of operation, as controlled by external command. In addition, analog or digital data can be received at S-band to be turned around for retransmittal at the Orbiter Ku-band port. The payload subsystem is capable of operating at any one of the 851 full duplex channels, or one of four receive-only channels, or any one of six transmit-only channels. The full duplex channels have their transmit and receive frequencies related by the same NASA or DoD turnaround ratios as for network communications but are not coherent.

PAYLOAD SUBSYSTEM SIGNAL CHARACTERISTICS

RECEIVE PM CHARACTERISTICS (TELEMETRY DATA)	
<u>NASA (STDN/DSN)</u>	
Data Rate	1,2,4,8 or 16 kbps
Subcarrier Waveform	1.024 MHz PSK
Modulation Index	1.0 rad
<u>DoD (SGLS)</u>	
Data Rate	Up to 256 kbps
Subcarrier Waveform	1.024 MHz PSK and/or 1.7 MHz FM/FM
Modulation Index	0.3 or 1.0 rad
<u>Ku-Band</u>	
Any of NASA or DoD above or baseband modulated analog signals up to 4.5 MHz or 3 Mbps digital data (Bi-Phase-L or NRZ-L) PM onto carrier.	
TRANSMIT PM CHARACTERISTICS (COMMAND DATA)	
<u>NASA (STDN/DSN)</u>	
Data Rate	125/16, 125/8, 125/4, 125/2, 125, 250, 500, 1000, 2000 bps
Subcarrier Waveform	16 kHz PSK
Modulation Index	1.0 rad
<u>DoD (SGLS)</u>	
Data Rate	1 k-baud or 2 k-baud
Subcarrier Waveform	Ternary FSK/AM (65, 76 or 95 kHz)
Modulation Index	0.3 to 2.5 (linear with AM on subcarrier)

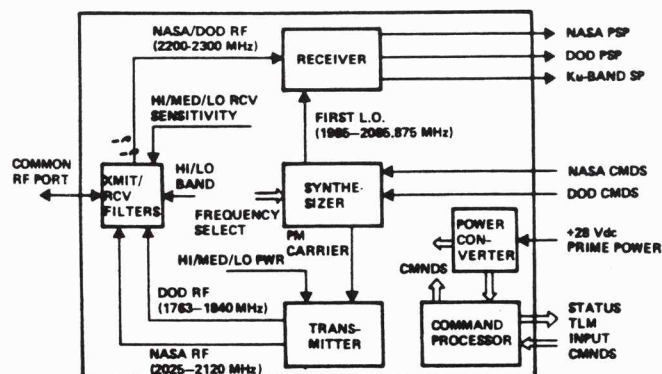
PAYLOAD SUBSYSTEM CHANNELIZATION

	Frequency Range (MHz)	No. of Channels	Channel Spacing (kHz)
STDN			
Transmit	2025.833-2118.7	808	115
Receive	2200-2300.875	808	125
DSN			
Transmit	2110.243-2119.792	29	341.049
Receive	2290.185-2299.814	27	370.37
SGLS			
Transmit	1763.721-1839.795	20	4004
Receive	2202.5-2297.5	20	5000

Payload Interrogator

The Payload Interrogator (PI) performs the RF processing for the payload subsystem, and as such is basically a single channel simultaneous receiver/transmitter.

The design is centered around a digital frequency synthesizer. The synthesizer is composed of two 2nd order phase lock loops (PLL's). The first generates the required downconverter local oscillator (L.O.) frequencies for the receiver's first IF mixer. The second PLL is used to generate the required transmitter carrier frequency. The acquisition time of both loops, at which frequency stability is $< \pm 0.001\%$ ranges, from 15 ms to 100 ms depending on the frequencies involved. Modulation of the subcarrier is performed in the synthesizer onto a constant 320 MHz tone. This is then mixed with the output of the second PLL to generate the desired transmit frequency. The capability to sweep the transmitter at two rates and ranges is provided to accommodate DSN and near Earth payload receivers.



Payload Interrogator

The receiver section uses a standard 2nd order phase lock loop for carrier demodulation. This is possible since all received signals are heterodyned to provide a single IF, and since it is not required to receive suppressed carrier waveforms. The PLL has a noise bandwidth of 1 kHz, and accommodates a maximum acquisition and tracking range of ± 87 kHz and Doppler rate of 17 kHz/s. The probability of achieving phase lock in three seconds or less is at least 0.9 for carrier component levels of -122.2 dBm at the LRU input. The tracking threshold, at which the mean time to lose lock is no less than 10 s, is -129.2 dBm in the carrier component. Three stages of coherent AGC amplification provide 110 dB dynamic range, with a response time of 200 ms. The PLL phase error and lock indication are provided for telemetry.

The transmitter provides amplification necessary to produce the maximum LRU interface power output of 5 W. Internally matched power transistors are used in two separate amplifier modules, one for the NASA band and one for the DoD band. Thermal considerations drive the design. The current temperature design limit is 125° C. The capability exists to inhibit all transmission. Power output level selection is accomplished by collector supply variation and pin diode switching.

All discrete mode and frequency control commands from the Shuttle display and control (D&C) panel are routed through the command processor. BCD channel numbers are converted to

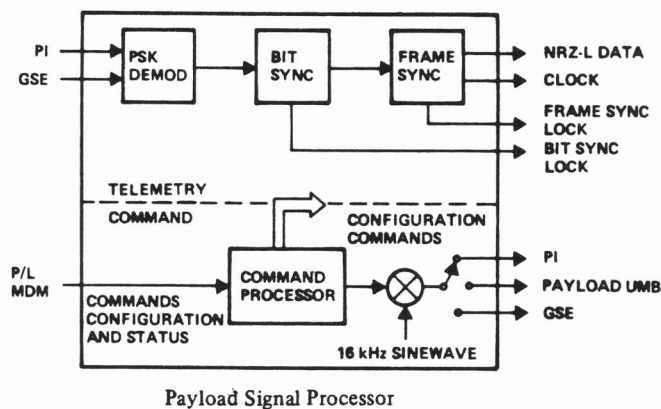
the required synthesizer binary format using a programmable read only memory (PROM). The capability exists to detect frequency unassigned input states from the D&C panel and inhibit transmission and reception as required.

The transmit/receive filter network, or triplexer, provides required isolation between the high and low frequency bands, as in the network subsystem. The design is driven by the requirement to produce no more than 0.1 dB receiver sensitivity degradation in either the network or payload subsystems. The unit incorporates six bandpass filters (four transmit and two receive) calling for 7 to 9 pole Chebyshev designs. Due to volume constraints, large insertion losses are incurred (1.5 to 2.0 dB), resulting in over half the 7 dB noise figure being absorbed in filter, switch and line losses. Similarly, the insertion losses in the transmit filter path affect the required 5 W output power at the LRU level. The enclosure dimensions are comparable to those required for the payload interrogator. Shown are the interconnected filter sections and associated switches and coupling.

Payload Signal Processor

The payload signal processor (PSP) performs the required NASA digital data processing for the payload communication equipment subsystem. A separate processor for DoD payload data processing will be provided by the DoD. The PSP consists of a telemetry and a command processing subsection. The telemetry section receives the PSK 1.024 MHz subcarrier from

the interrogator or GSE, demodulates the subcarrier, establishes bit and frame synchronization, and delivers digital data to the payload data interleaver (PDI). The command processing section configures the PSP as specified in the configuration message it receives from the Orbiter general purpose computer via the payload multiplex/demultiplex (P/L MDM) unit. It rate buffers the command data, and modulates the 16 kHz sinewave subcarrier at variable and command data rates.



The modulation is digitally implemented using a ROM, digital-to-analog (D/A) converter and lowpass filter. The current status of the PSP is also periodically supplied to the P/L MDM for validation. The various telemetry and command PCM formats, data rates and other performance parameters are given in a diagram entitled Signal Payload Processor Performance at end of this section.

The telemetry section uses a Costas loop with a hard-limited in-phase channel to perform the PSK subcarrier demodulation. To accommodate the thirty possible combinations of data rates (1, 2, 4, 8 or 16 kbits/s) and PCM

(Bi-phase-L, -M, -S, NRZ-L, -M, -S) requires six switchable first order low pass filters in each arm. (These have bandwidths 1.5 times the data rate, with Bi-phase taken as twice-rate NRZ.) The loop uses a second order filter with loop noise bandwidth of 75 Hz.

The bit synchronizer is a microprocessor implementation of the digital tracking loop algorithm. The necessity to process so many data rates and formats makes the fully programmable implementation attractive. Also performed in the microprocessor is the matched filter detection, conversion of data formats to NRZ-L, and frame synchronization. The bit synchronizer algorithm does not require a numerically controlled oscillator. A baseline correction loop compensates for dc offsets in the NRZ data, and an additional loop accommodates data rate uncertainties up to 0.5%. Averaging filters are used to normalize the SNR-dependent error curve associated with the DTTL algorithm. Preliminary simulation results indicate that the bit synchronizer will produce no more than 0.15 dB BER degradation over a 2 - 11 dB SNR range and transition densities as low as 12.5%. The acquisition time is less than 2 s for a subcarrier to noise density ratio (D/N) of 34 dB-Hz.

HARDWARE SUMMARY

The Orbiter intercabling and antennas are provided by RI. Each LRU is completely interchangeable with other LRUs of the same type without the need for on-line adjustments. A highly

modularized packaging approach with minimum weight and maximum ease of maintenance as key objectives was used. The housing of each LRU consists of a solid mounting base plate through which excess heat passes on to a Shuttle liquid-cooled shelf (except where DC power is <20 W) and an environmentally-sealed envelope for protection of the LRU internal elements from the Orbiter cabin's corrosive atmosphere.

Each LRU is designed to perform its functions for a minimum of 20,000 hours before refurbishing or replacement. With preventive maintenance, servicing and replacement of all sensitive materials on a scheduled basis, the LRUs will function at least 12 years.

**PAYLOAD INTERROGATOR PERFORMANCE
SPECIFICATIONS**

RECEIVER (AMBIENT TEMPERATURE)			
Noise Figure	7		dB Max
Doppler Accommodated	+75		kHz
Doppler Rate Accommodated	44		kHz/s
Static Phase Tracking Error	+3°		
Mean Phase Tracking Error	≤15°		
Acquisition Threshold (Carrier Component)	-122.2		dBm
Acquisition Time (Probability 0.9)	≤3		s
Tracking Threshold (Carrier Component)	-129.2		dBm
Mean Time to Lose Lock	>10		s
Dynamic Range	110		db
	Low	Medium	High
Receiver Sensitivity (Max. No damage input)	36 dBm	30 dBm	20 dBm
Minimum Signal Level (Modulated)	-87 dBm	-107 dBm	-120 dBm
TRANSMITTER			
	Low	Medium	High
RF Power Output (2:1 load) 4 dBm (minimum)		27 dBm	37 dBm
Transmit Frequency Stability	≤ ±0.001 %		
Sweep Capability			
Wide	+50 kHz @ 35 kHz/s		
Narrow	+30 kHz @ 0.6 kHz/s		
Phase Noise (steady state)	4° rms		

LRU WEIGHT AND POWER SUMMARY

LRU	WEIGHT (lbs)	POWER (W)
Network Transponder	34.7	63
Network Signal Processor	17.8	30
Doppler Extractor	16.2	16.2
Power Amplifier	31.6	400
Preamplifier	25.6	25 (one side on)
FM Transmitter	6.6	120
FM Signal Processor	11.5	9 (with GSE on)
Switch Assembly	6.5	2 (steady state)
Payload Interrogator	39.0	97.4
Payload Signal Processor	18.0	26

PAYLOAD SIGNAL PROCESSOR PERFORMANCE SPECIFICATIONS

PSP COMMAND PROCESSING SECTION	
<u>PSP - P/L MDM COMMAND INTERFACE</u>	
Mode	Half Duplex
Data Rate	1 Mbps
PCM Format	Bi-Phase-L
<u>COMMAND DATA OUTPUT</u>	
Bit Rate	125/16, 125/8, 125/4, 125/2, 125, 250, 500, 1000 or 2000 bps
PCM Format	NRZ-L, NRZ-M or NRZ-S
Modulation	PSK on 16 kHz sinewave
Data Asymmetry	≤2%
Phase Jitter	≤3%
PSP TELEMETRY PROCESSING SECTION	
PCM Format	NRZ-L,-M,-S,Bi-Phase-L,-M,-S
Data Word Length	8 bits
Data Frame Length	1,2,.....1023 or 1024 words
Frame Sync Word:	
Pattern	Programmable
Length	8,16,24 or 32 bits
<u>SUBCARRIER DEMODULATOR/BIT SYNCHRONIZER</u>	
Subcarrier Frequency	1.024 MHz
Subcarrier Stability	0.01%
Bit Rate	1,2,4,8 or 16 kbps
Bit Rate Stability	0.1%
Transition Density	≥64 transitions in 512 bits ≤64 consecutive bits w/o transition
Acquisition Threshold SNR (Bit Sync)	4 dB
Tracking Threshold SNR (Bit Sync)	2 dB
Hard Decision Data Detection (2 dB ≤SNR ≤11 dB)	<1.5 dB from theory
Acquisition Time (0.9 Probability)	2 s Max
Mean Time to Loss Lock (Subcarrier Demod)	≥10 s Min

S-BAND COMMUNICATIONS SYSTEM

Prime Contractor

TRW Electronic Systems

1. Network Transponder
2. Signal Signal Processor
3. Payload Interrogator
4. Payload Signal Processor

Subcontractors

Power Amplifier
(Watkins Johnson)

Preamplifier
(AIL)

Switch Assembly
(Teledyne-Microwave)

FM Transmitter
(Teledyne-Electronics)

FM Signal Processor
(Conrac and Transco)

TRW FACT SHEET

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TRW'S ROLES IN THE SPACE SHUTTLE PROGRAM

TRW's broad support to NASA's Space Transportation System (NASA's name for the overall Shuttle program) includes design and development of onboard orbiting communications hardware, overall systems engineering of the telecommunications system, and payload development and integration.

The company's work on Shuttle began in 1969 when TRW served as avionics subcontractor to McDonnell Douglas during early Shuttle study phases. The many communications and electrical systems concepts developed at that time led to TRW's selection as the Orbiter S-band communications subcontractor to Rockwell International, and avionics subcontractor to Boeing on the Inertial Upper Stage (IUS). Since 1969, TRW has worked with NASA, DoD and international organizations on more than 90 contracts to prepare for the Space Transportation System (STS).

S-Band Communications System

TRW's Electronics System Division and Colorado Electronics subsidiary, under contract to Rockwell, developed the S-band communications system, the primary voice and data communications link between Shuttle Orbiter and the ground tracking stations during ascent, orbital and entry phases of the flight.

- more -

The S-band system provides all voice communications for the astronauts. The multi-channel system is also used for all telemetry, command and control functions on board the Shuttle, and transmits the wideband television that will be used by ground controllers to observe the Shuttle mission.

Once the Tracking and Data Relay Satellite System is operational (the first is to be launched on STS flight #5), these S-band communications links will operate either directly (air-to-ground) or will relay signals via TDRS between the orbiter and the ground stations.

Tracking and Data Relay Satellite System (TDRSS)

TDRSS, owned and operated by the Space Communications Co. (jointly owned by Western Union, Fairchild Industries and Continental Telephone Co.), will relay data to and from the Shuttle Orbiter, other Earth-orbiting spacecraft, and the TDRSS-dedicated Earth Station at White Sands, New Mexico. NASA will lease tracking and data relay services from the Space Communications Co. for a number of Earth-orbiting spacecraft, including Shuttle, and commercial customer traffic will flow through the Advanced Westar portion of the payload. The system is the first such large-scale space undertaking to share service with both government and commercial users.

- TRW is building six TDRSS telecommunications satellites, the largest yet developed. TDRS #1 will be the first free-flying payload launched from Shuttle. It will be launched on STS #5 (the first operational flight), scheduled for 1982.

- For NASA's highly automated Earth Station at White Sands, one of the largest and most complex ever built, TRW has developed the software for the overall system and is integrating the hardware and software with the Earth Station and the satellites -- tying the space and ground segments together.

Inertial Upper Stage (IUS)

Under subcontract to Boeing, TRW produced the telemetry, tracking and command communications hardware, power converters and guidance system software for the Inertial Upper Stage expendable booster. The IUS will carry TDRS and other NASA payloads from the Shuttle's low-Earth orbits into higher Earth orbits.

Spacelab

The European Space Agency (ESA) is building Spacelab, the reflyable laboratory that will be placed in the cargo bay of the Shuttle Orbiter. Designed to fly on research and development missions, Spacelab is Europe's major contribution to the Space Transportation System. ERNO of Germany is the prime contractor. TRW provided management and technical assistance to ESA/ERNO on Spacelab, including software development, validation and test.

- more -

Control Center Implementation Contract (CCIC)

Under contract to the U.S. Air Force, TRW is conducting preliminary studies essential to planning, monitoring and verifying security for DoD Space Shuttle missions. These studies include implementation of DoD security requirements at NASA's launch and mission control centers.

Systems Analysis Programs

A variety of STS systems analysis programs have been developed at TRW's Houston Operations, adjacent to the NASA Space Center.

The ground controllers will use a TRW-developed processor to get an immediate position and trajectory check for both ascent and descent. The system draws upon TRW's extensive Apollo work on mission planning and trajectory development.

The Shuttle avionics project contributed to the verification of the onboard attitude control and navigation software for the STS, and performed software hazard analysis for critical onboard software functions. Shuttle will depend more on the proper operation of the onboard software than any other manned spacecraft or aircraft before it.

TRW's Advanced Information Management (AIM) system is used by NASA and its contractors in the configuration management of the software at the Shuttle crew training facility -- Shuttle Mission Simulator (SMS).

- more -

A real-time desk-top flight simulator developed by TRW is used by mission analysts to plan and verify deployment, separation, and retrieval of payloads.

TRW PAYLOADS TO FLY ON SHUTTLE*

In its role as a delivery system into space, Shuttle will carry a number of TRW payloads in the near future.

Materials Processing in Space (MPS)

Materials processing research in the zero-gravity space environment will expand our knowledge of both the science and technology of materials, and is expected to lead to production of high-value products in space that cannot be made on Earth. MPS experiments may also provide new knowledge that will improve ground-based processing of materials. Under contract to NASA Marshall, TRW is developing MPS Attached Shuttle/Spacelab payloads to assess the effect of the micro-gravity, environment of space on materials solidification, crystal growth, and fluids systems. For NASA Lewis, TRW is designing a facility to study the effects of zero-gravity on a number of combustion processes.

*See also page two -- Tracking and Data Relay Satellites

- more -

The Solidification Experiment System is scheduled to fly on a pallet in Shuttle Orbiter in mid-1984; the Fluids Experiment and the Vapor Crystal Growth Systems will fly on Spacelab 3; the Zero-Gravity Combustion Facility will fly on a mid-1980's Spacelab mission.

International Solar Polar Mission (ISPM)

ISPM is a joint US/European mission to investigate the Sun's poles and unexplored space around them. TRW is building the U.S. spacecraft for JPL, and Dornier of Germany is building the European spacecraft for the European Space Agency (ESA). The two are scheduled to be launched in 1985 on a trajectory to Jupiter. Boosted by the planet's tremendous gravitational field, they will boomerang back toward the Sun in mirror-image trajectories above and below the ecliptic to the north and south poles of the Sun. Each spacecraft will curve around the Sun to study both poles with different but complementary scientific instruments, obtaining a bird's-eye view of them for the first time in the history of planetary space exploration. They will also study interstellar space above the poles to determine what enters the solar system from far outside.

Earth Radiation Budget Experiment (ERBE)

For NASA Langley, TRW is developing instruments for the Earth Radiation Budget Experiment. The instruments will

- more -

measure radiation from the Sun and determine the portion reflected from the Earth and its atmosphere and that absorbed and re-emitted. Those measurements can help improve techniques for predicting long-term climatic trends. The instruments will fly on a NASA Earth Radiation Budget Satellite and two NOAA weather satellites.

Halogen Occultation Experiment (HALOE)

The Halogen Occultation Experiment being developed for NASA Langley will measure the concentration of important trace pollutants that might be depleting Earth's ozone layer. HALOE will determine their concentration in the upper atmosphere by correlating their effects on solar radiation with the absorption of that radiation by gas filters in the instrument. During occultation, the optics look at the Sun's rays as they course through and are altered by atmospheric gases. HALOE instruments will be orbited on the Earth Radiation Budget Satellite.

Monitoring of Air Pollution from Satellites (MAPS)

This instrument is part of NASA Langley's program for Monitoring of Air Pollution from Satellites. A very sensitive detector uses infrared gas correlation spectroscopy to measure trace atmospheric pollutants. A MAPS instrument to measure carbon monoxide will fly on the Shuttle during Orbital Flight Test 2 (OFT-2), the first Shuttle flight to carry scientific experiments. Carbon monoxide pollution has been measured over several areas of the world by a MAPS instrument flown in an aircraft.

Waves in Space Plasmas (WISP)

TRW is designing concepts for instrumentation and experiments to study a broad range of phenomena taking place in the Earth's magnetosphere, ionosphere and atmosphere. WISP promises an extremely wide contribution to basic science by studying phenomena as diverse as magnetospheric instabilities and energy transport, the dynamics of ionospheric current systems, plasma wave emissions from antennas, atmospheric motions and waves, communication characteristics from ULF to UHF, and safety of man in space. The design is being performed under contract to NASA Marshall and the effort is supported by a team that includes sixteen scientists from three countries. Controlled by a WISP scientist on Shuttle/Spacelab, powerful radio transmitters will beam plasma waves, ranging from the audio range to television frequencies, into the space plasma surrounding the Earth. WISP will ride into orbit aboard Spacelab 6.

High Voltage Drainage Experiment (HVDE)

For NASA Langley, TRW is building an instrument for flight on the Long Duration Exposure Facility (LDEF) to determine how spacecraft materials change under electrical stress in space. Materials such as Teflon, Kapton and solar cells will be electrically charged to as high as 1000 volts and exposed to the environment. Bombardment of the samples by the charged particles in space will change their physical and electrical

properties. Leakage currents will be monitored on board and post flight ground testing will determine other changes to the properties of the materials. The HVDE instrument will be carried on the LDEF-A, that will be put into orbit in 1984 and retrieved one year later by the Shuttle.

25 kW Power System

TRW is developing a design concept for the 25 kW space Power System under a study contract with NASA's Marshall Space Flight Center. The Power System is a free-flying module that will be carried into space by Shuttle. It will be designed to operate in any of three modes: a sortie mode -- attached to Shuttle and from which Shuttle can disengage, as a free flyer, or in an on-orbit storage mode. It will provide more power for longer periods to Shuttle payloads and experiments than can be provided by the Orbiter's onboard fuel cells and will extend the Orbiter's capabilities and staying time in orbit. Electrical power will be generated by two large rectangular solar array wings, each 120 feet long by 12 feet wide.

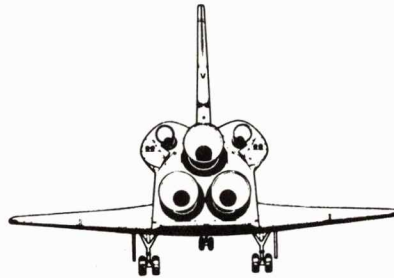
Project POSTAR

In a cooperative effort with the Boy Scouts of America and NASA, TRW has purchased a "Getaway Special" ticket on a future Shuttle flight and donated it to the Exploring Division of the Boy Scouts of America. A national competition called Project POSTAR is being conducted to stimulate interest of young people in the space program and science careers.

Explorer Posts will submit proposed experiments to fly on a Shuttle Orbiter on a space-available basis. Finalists in the competition will be selected by a panel of NASA and TRW scientists, headed by former astronaut James Lovell. The Explorer flight is currently targeted for mid-1985.

#

April 1981



TRW

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