TRW NO. 28042-H007-RO-00

MISSION CONTROL COMMUNICATIONS INTERFACE REQUIREMENTS STUDY SPACE TRANSPORTATION SYSTEM

FINAL SUMMARY REPORT

VOLUME I OF FINAL STUDY REPORT

NAS9-14709

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

23 MARCH 1976

TRW
SYSTEMS GROUP

ONE SPACE PARK • REDONDO BEACH, CALIFORNIA 90278

28042-H007-RO-00
Volume I

FINAL REPORT
FOR
MISSION CONTROL COMMUNICATIONS INTERFACE REQUIREMENTS STUDY, SPACE TRANSPORTATION SYSTEM

FINAL SUMMARY REPORT

NAS9-14709 — 23 March 1976

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

Prepared by

TRW DEFENSE AND SPACE SYSTEMS GROUP

One Space Park
Redondo Beach, California

and

1110 NASA Road One
Houston, Texas

Approved: C Weitzman
C. Weitzman
Study Manager,
TRW Defense and Space
Systems Group
Redondo Beach, California
(213) 536-3328

Approved: C A Beers
C. A. Beers
Contracting Officer
Representative
Flight Control Division (CF)
(713) 483-4555

FOREWORD

This report summarizes the results of the Mission Control Communications Interface Requirements Study, Space Transportation System, performed by TRW Defense and Space Systems under Contract NAS9-14709 for NASA, Lyndon B. Johnson Space Center. This document represents one section (Volume I) of the Final Study Report. The complete set of seven documents that comprise the STUDY PLAN and the FINAL REPORT of the Study, plus the four key Study Briefing documents, are listed below:

- TRW No. 28042-H001-RO-00, Study Plan
- *TRW No. 28042-H007-RO-00, Volume I - Final Summary Report
- TRW No. 28042-H002-RO-00, Volume II-1 - Study Task 1 - 2.0 Total Communications Analysis
- TRW No. 28042-H003-RO-00, Volume II-2 - Study Task 2 - 2.0 Assessment of Applicable Communications Processing Techniques
- TRW No. 28042-H004-RO-00, Volume II-3 - Study Task 3 - 3.0 Assessment of Information Flow Technology
- TRW No. 28042-H005-RO-00, Volume II-4 - Study Task 4 - 4.0 Development of Detailed Requirements to Implement Ground Systems Capabilities
- Volume II-5 - Study Task 5 - 5.0 Identification of Applicable Standards and Conventions (DELETED)
- TRW No. 28042-H006-RO-00, Volume II-6 - Study Task 6 - 6.0 Communications Interfaces for Data Bases
- Study Orientation Briefing, TRW Document, dated 26 June 1975
- First Quarterly Progress Report, TRW Document, dated 15 October 1975
- Second Quarterly Progress Review, TRW Document, dated 6 January 1976
- Executive Summary Briefing, TRW Document, presented to NASA, Lyndon B. Johnson Space Center (25 March 1976) and revised for presentation to NASA Headquarters, Office of Space Flight (6 April 1976)

*This document.

CONTENTS

FIGURES

1.0 STUDY DESCRIPTION AND BACKGROUND

1.1 STUDY OBJECTIVES

The two major objectives of this study were to: 1) develop communications traffic models required by the STS Operator to satisfy the operational requirements and concepts; and 2) develop detailed requirements for the ground system required for flight control of the STS and interface with Payload Operations Control Centers.

1.2 STUDY GUIDELINES

The Study guidelines, originally given in Section 7 of the NASA Statement of Work, have been modified during the course of the Study. The list of revised Study guidelines is shown in Figure 1.

1.3 STUDY SCHEDULE AND APPROACH

This has been a 10-month study, started in June 1975, with the work organized into two basic phases of activity:

<u>PHASE 1</u> Analysis of Communications Requirements

<u>PHASE 2</u> Synthesis of STS Flight Operations Facility Interface Requirements

The communications requirements analysis was performed initially using 1974 Space Shuttle Payload (SSPD) data. Based on a NASA request, this analysis was later repeated in the Study using new, 1975 SSPD data. To accommodate this additional activity, TRW was requested by NASA to delete from the Study the task of identifying standard operating procedures and conventions that apply to operations to simplify the common interface between users, assure systems compatibility, and minimize operations cost.

The Study was supported by NASA documentation, pre-formatted inputs on data bases and other communications elements from the various NASA Centers, and review comments by members of the Study Advisory Team and the Communications and Data Systems Integration (CADSI) Functional Requirements Subpanel, see Figure 2.

The Milestone Schedule shown in Figure 3 was closely adhered to in accomplishing the Study.

1. MCC/JSC will provide "Mission Support" for all NASA missions during prelaunch, ascent, and reentry and landing. ("Mission Support" includes Go/No-Go for launch; trajectory, event, systems, and crew status; ground contribution to abort decision and management; range safety; and landing site readiness).
2. In addition, MCC/JSC will provide "Mission Support" for all DOD flights through 1982.
3. For on-orbit operations during all periods when the STS has operational interfaces with payloads, "Mission Support" will be jointly provided by MCC/JSC and the responsible payload operations center. ("Mission Support" includes all functions (tasks) done in support of the on-orbit operations.)
4. For on-orbit payload operations during periods when the STS has no operational interface with the payload, "Mission Support" will be provided by the responsible Payload Operations Center, unless specifically requested to be done by MCC/JSC by the responsible payload project officer.
5. Automated earth orbit payloads will be controlled from GSFC.
6. Planetary payloads will be controlled from JPL.
7. Spacelab payloads will be controlled from JSC.
8. For on-orbit operations which require the IUS (Interim Upper Stage), "Mission Support" will be provided jointly by MCC/JSC and the responsible Payload Operations Center until payload separation from the IUS. DOD and NASA will, from start of program, independently plan and operate their respective upper stage missions. MCC will interface with DOD on flight control through the handover phase to DOD.
9. Required voice, data, command, and tracking channels will be provided to all operations areas, but will be coordinated by MCC/JSC so long as the STS has an operational interface.
10. Mission support must be responsible for assistance to the flight crew for problem resolution and activity planning but need not be instantly responsive, i.e., may resort to "on-call" support ("On-call" means having expertise and systems available but not dedicated to mission support.)
11. Automation (computerized tools) may be employed if needed to meet mission requirements or if consistent with reducing operations costs.
12. Mission support shall be provided in a manner which satisfies the requirement at the minimum costs.
13. Mission support shall be "interactive", i.e., able to effect mission changes which maximize the mission value.
14. Major control centers shall provide host facilities for PI's (Primary Investigators) or will provide appropriate operational interfaces with PI's remotely located with respect to the control center.
15. Simplicity of all interfaces and minimization of the number of POC's shall be considered as criteria in assessing interfaces and costs.
16. "Flight Planning", which is normally done prior to the flight, shall be a joint responsibility of the STS/Payloads Operations Program Office and the responsible payload developer. ("Flight Planning" includes all work required to define the nominal flight profile and timeline).
17. Detailed Orbiter "Flight Planning" which is the generation of detailed procedures and timelines for nominal and contingency execution of the flight activities is the responsibility of MCC/JSC. MCC/JSC is also responsible for integration of the total flight plan definition of all STS operations and identification of time periods and resources available to the payloads. The payload developer specifies the detailed flight plan and procedures for the operation of the payload.
18. A semi-automated "Mission Data Base" shall be assumed. ("Mission Data Base" is a reservoir of all data needed to plan or execute a mission. It includes system specification values, models, operating constraints, schedules, etc.)
19. The traffic rate will be based on a reduced 572 Flight Shuttle Traffic Model with one flight per month for first two years, (4-5 Spacelab and 4-5 upper stage flights per year). This rate will gradually increase to the peak level established in the "Yardley" flight model, dated 2 October 1974.
20. The Communications Traffic Model for STS Payloads related traffic shall be based on the representative flight types and payloads (Payload Mission Control Study).
21. The STS Flight Operations will coordinate, the overall communications system configuration, and necessary alterations thereto for the STS/Payloads joint operation flight phase.

Figure 1. Study Guidelines

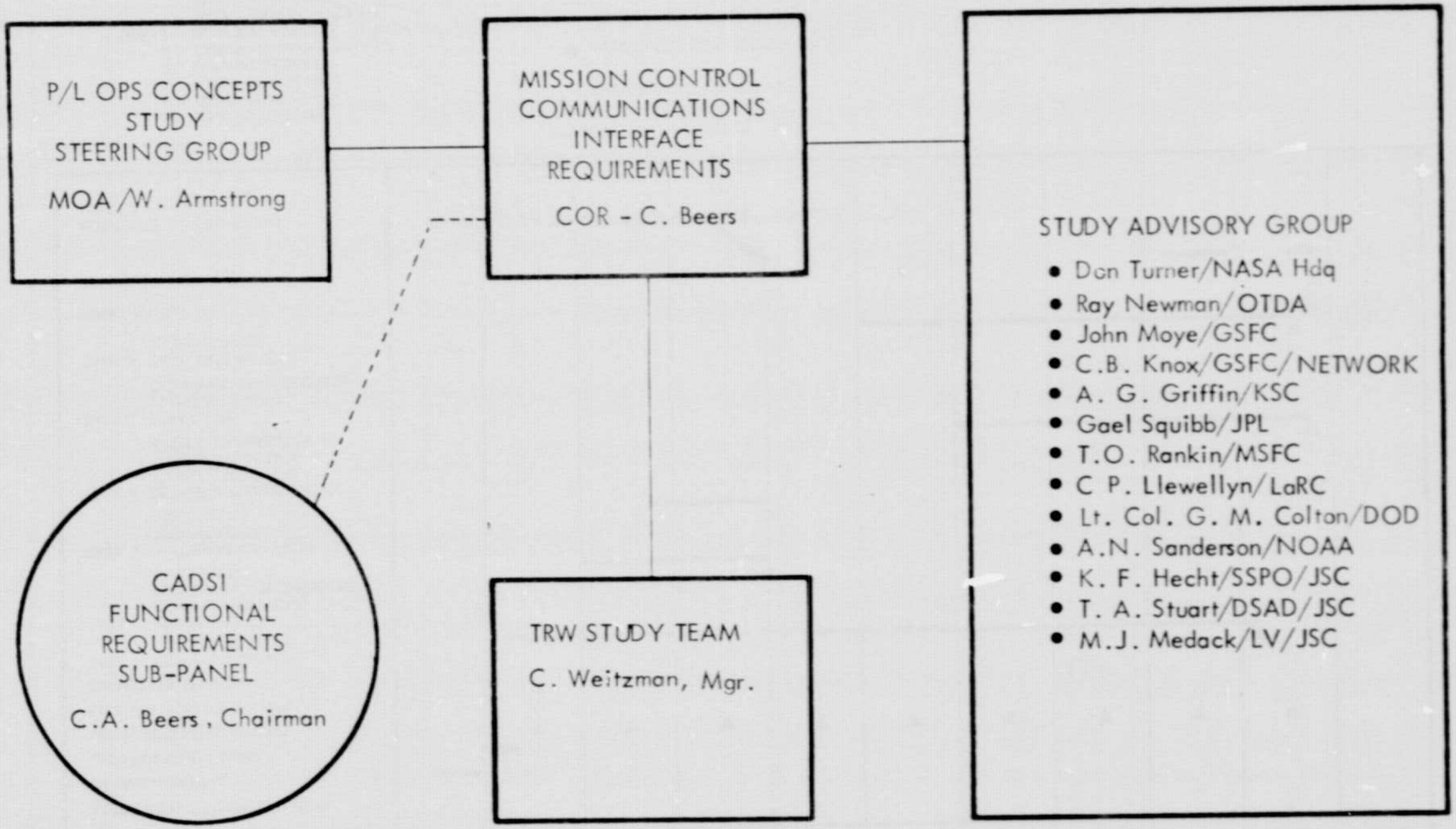
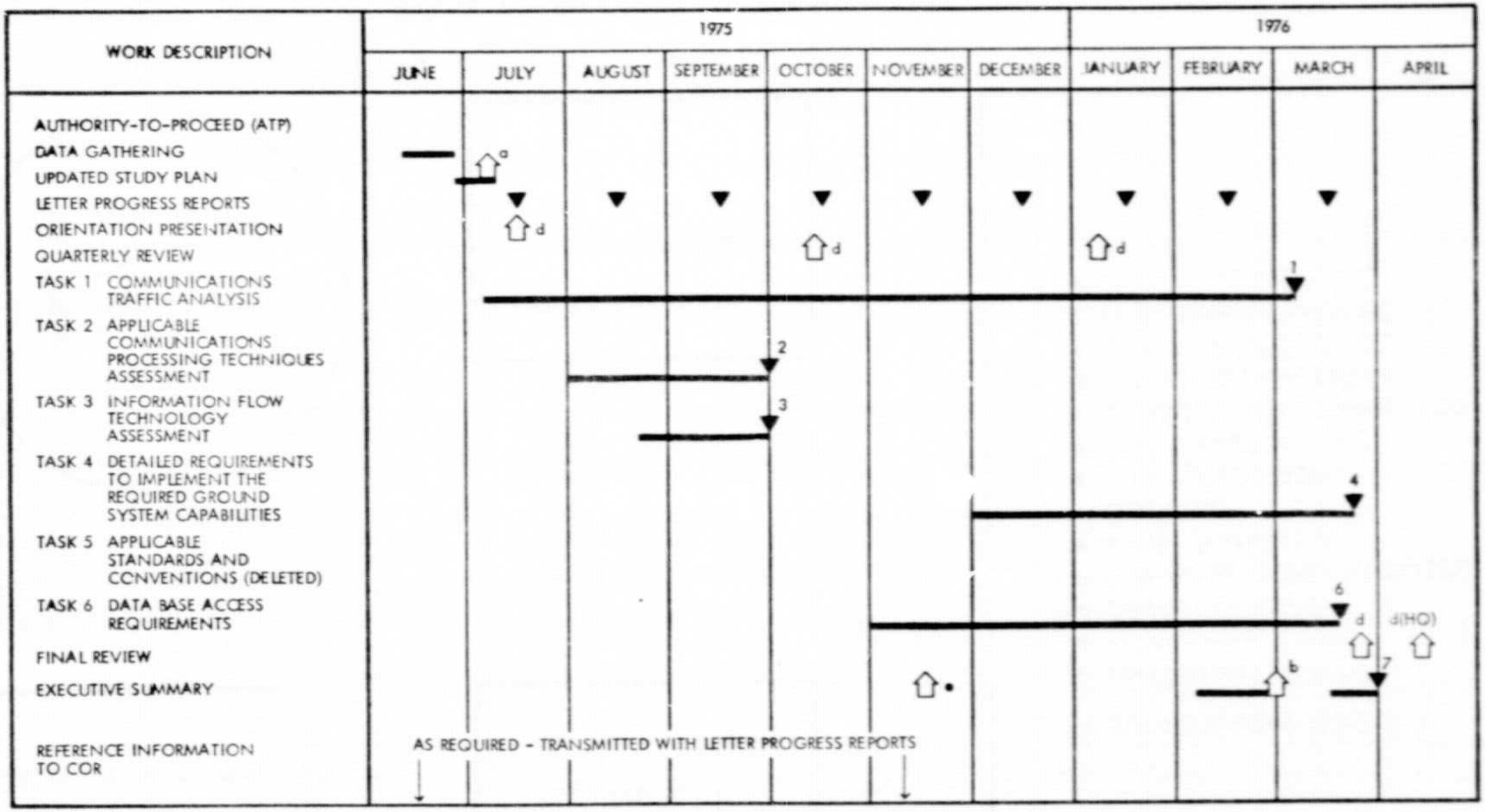


Figure 2. NASA Overview and Study Direction



LEGEND: NOTES

- a FINALIZED PLAN
- b DRAFT REVIEW
- c NASA COMMENTS
- d FORMAL BRIEFING
- e CONTENT AND FORMAT
- 1 THRU 7 NUMBERS ASSOCIATED WITH TASK OUTPUTS REFER TO STUDY PRODUCTS (TASK 5 HAS BEEN DELETED)

SYMBOLS (PER NHB 2330.1)

- ⇧ CONTROLLED MILESTONE
- ▼ SCHEDULED COMPLETION DATE

Figure 3. Major Milestone Schedule

1.4 TASK DESCRIPTION

A communications traffic analysis was performed wherein the total traffic into and out of the STS Flight Operator Facility was identified and modeled based on a Modified Payload Traffic Model as shown in Figure 4. The traffic included total flow to and from Payload Operations Centers, launch and landing sites, and other related facilities and organizations. The total network with all major elements is shown in Figure 5. A composite functional flow diagram including communications links to and from STS Flight Operations is shown in Figure 6. In addition to telemetry and command data flow, communications interface requirements were determined for distributed Mission Data Bases. Mission data base locations were correlated with STS Flight Operations functions and Users, in order to minimize cost, response time and other critical parameters.

The projected total annual data base traffic growth using the Flight Model shown in Figure 4 is summarized in Figure 7.

Point-to-point communications facilities were subsequently identified in terms of development status and future availability, to support the projected needs of communications traffic to and from STS Flight Operations. The various services and capabilities are summarized in Figure 8. A survey was also made of future low-cost "mobile" ground stations, and new communications procedures and technology such as Dynamic Channel Sharing and Satellite Packet Broadcasting. In addition, a more in-depth assessment was made of communications processing requirements and techniques applicable to baseline plans for NASA use in the STS timeframe. These communications processing requirements and techniques are applicable for the nodes connected to STS Flight Operations, as shown in Figure 4. Major node processing requirements surveyed consisted of data recording, data quality checking, data content logging, malfunction detection, etc. The recommended assignment for these major communications processing requirements are summarized in Figure 9.

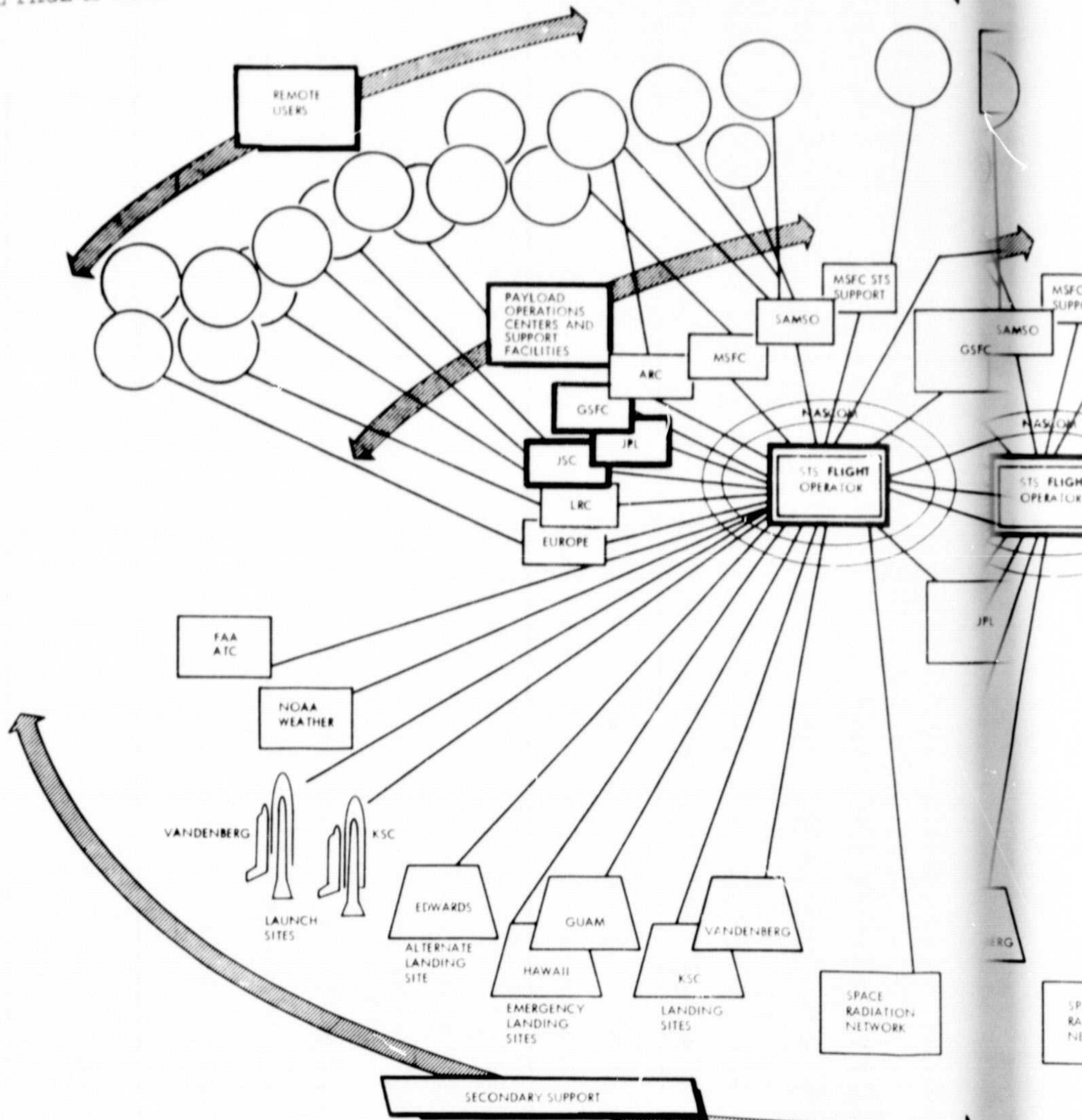
Based on the traffic analysis, communications processing assignments and projected communications services and capabilities, detailed STS Flight Operations, Ground Communications systems performance and requirements were developed, Figure 10.

	PAYLOAD FLIGHT TYPE	REPRESENTATIVE PAYLOADS	DEVELOPMENT CENTER	CALENDAR YEAR												TOTAL
				80	81	82	83	84	85	86	87	88	89	90	91	
SPACELAB	A	M + P (OP)	LARC	-	1	1	1	2	3	3	4	4	4	5	5	33
	A	M + P (OP)	GSFC	-	1	1	1	2	2	2	2	2	2	2	2	19
	B	M + P (MD)	MSFC	1	1	1	2	3	3	4	5	5	6	7	8	46
	C	P (AS)	MSFC	-	-	1	1	2	3	5	6	6	5	6	6	41
	C	P (Stellar)	ARC	-	-	-	1	1	1	1	1	1	1	1	1	9
	D	P (SO)	GSFC	1	1	1	2	3	4	4	4	4	4	4	5	37
LOW EARTH ORBIT	E	LEO Delivery	GSFC	-	1	1	1	-	1	1	1	-	1	-	1	8
	F	LEO Delivery and Retrieval	GSFC	-	-	-	2	2	3	4	3	3	3	4	3	27
	G	LEO Revisit without EVA	GSFC	-	-	-	-	1	1	-	-	1	-	1	-	4
	H	LEO Revisit with EVA	GSFC	-	-	-	1	1	-	1	1	1	1	-	1	7
	I	Multi-Cargo LEO-Delivery	GSFC	-	-	-	1	1	2	2	2	2	[illegible]	[illegible]	1	14
	J_1	SL (LS)	JSC	-	-	1	1	1	1	1	1	1	1	1	1	10
	J_2	Multi-Cargo (MD)	TBD	-	1	1	1	1	1	1	1	1	1	1	1	11
UPPER STAGE	K	IUS Multi-Satellite	GSFC	-	1	2	3	1	-	-	-	-	-	-	-	7
	L	IUS Planetary	JPL	-	1	2	2	2	-	-	-	-	-	-	-	7
	M	Tug Multi-Satellite	GSFC	-	-	-	-	3	5	7	7	10	12	13	11	68
	N	Tug Planetary	ARC	-	-	-	-	-	4	5	6	2	3	1	2	23
SUBTOTALS		30 Day Flights (General Dynamics) Type J_1 and (PLMC Study) Spacelab (36 of 226 or 20%, Task b, p. 2-64)		-	-	1	1	1	2	3	3	4	5	5	5	30
SUBTOTALS		7 Day Flights		2	8	11	19	25	32	38	41	39	41	42	43	341
			TOTALS	2	8	12	20	26	34	41	44	43	46	47	48	371

ABBREVIATIONS:

AP - Atmospheric and Space Physics
AS - Astronomy
EVA - Extravehicular Activity
IUS - Interim Upper Stage
LEO - Low Earth Orbit
LS - Life Sciences
M - Module
MD - Multi-Discipline
OP - Earth and Ocean Physics
P - Pallet
SO - Solar Physics
SL - Spacelab

Figure 4. Flights Per Year - Modified Payload Traffic Model


REMOTE USERS
PAYLOAD OPERATIONS CENTERS AND SUPPORT FACILITIES
ARC
MSFC
SAMSO
MSFC STS SUPPORT
GSFC
JPL
JSC
LRC
EUROPE
NASCOM
STS FLIGHT OPERATOR
FAA ATC
NOAA WEATHER
VANDENBERG
KSC
LAUNCH SITES
EDWARDS
ALTERNATE LANDING SITE
GUAM
HAWAII
EMERGENCY LANDING SITES
VANDENBERG
KSC
LANDING SITES
SPACE RADIATION NETWORK
SECONDARY SUPPORT

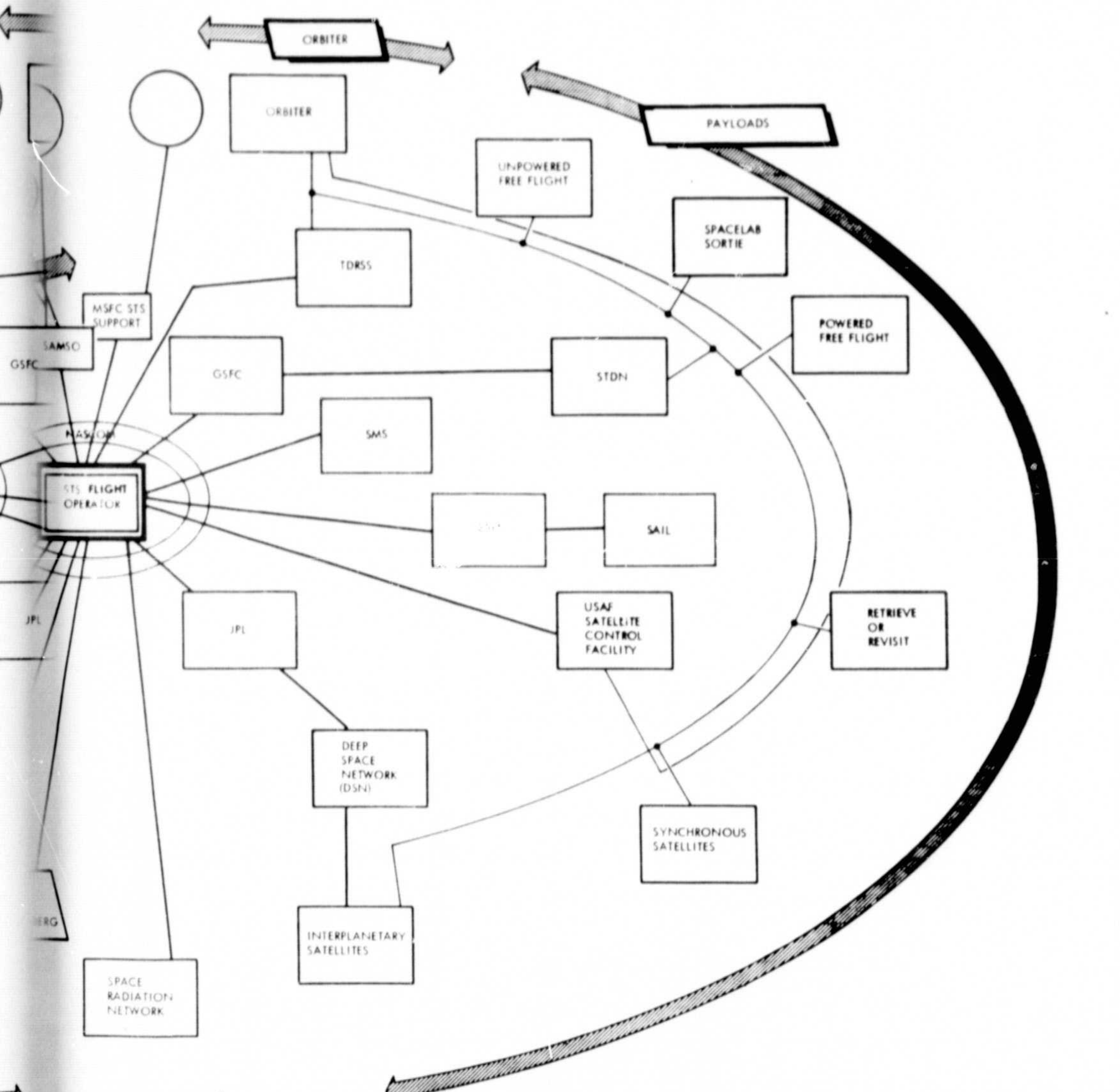
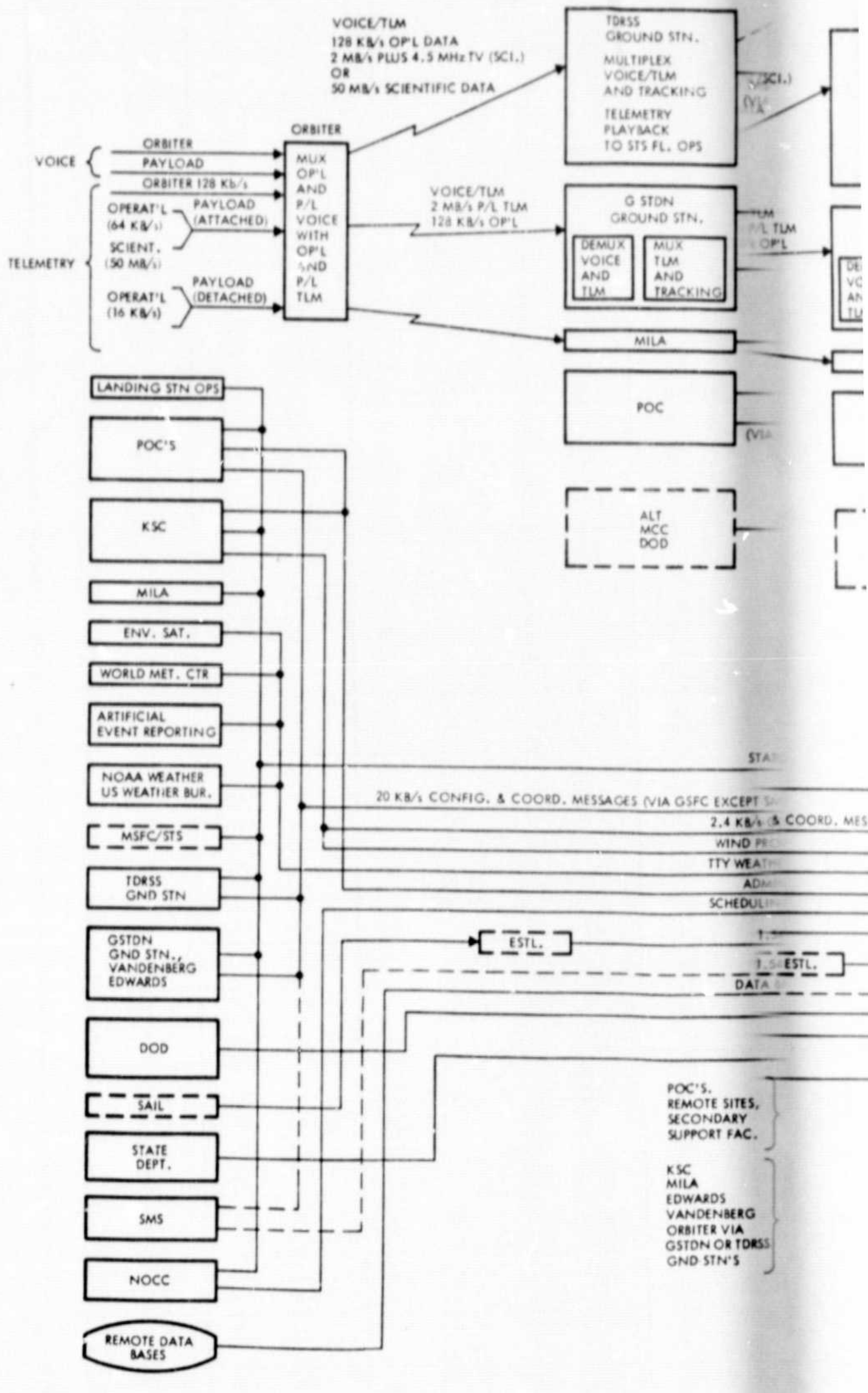


Figure 5. STS Flight Operations Interfaces



FOLDOUT FRAME

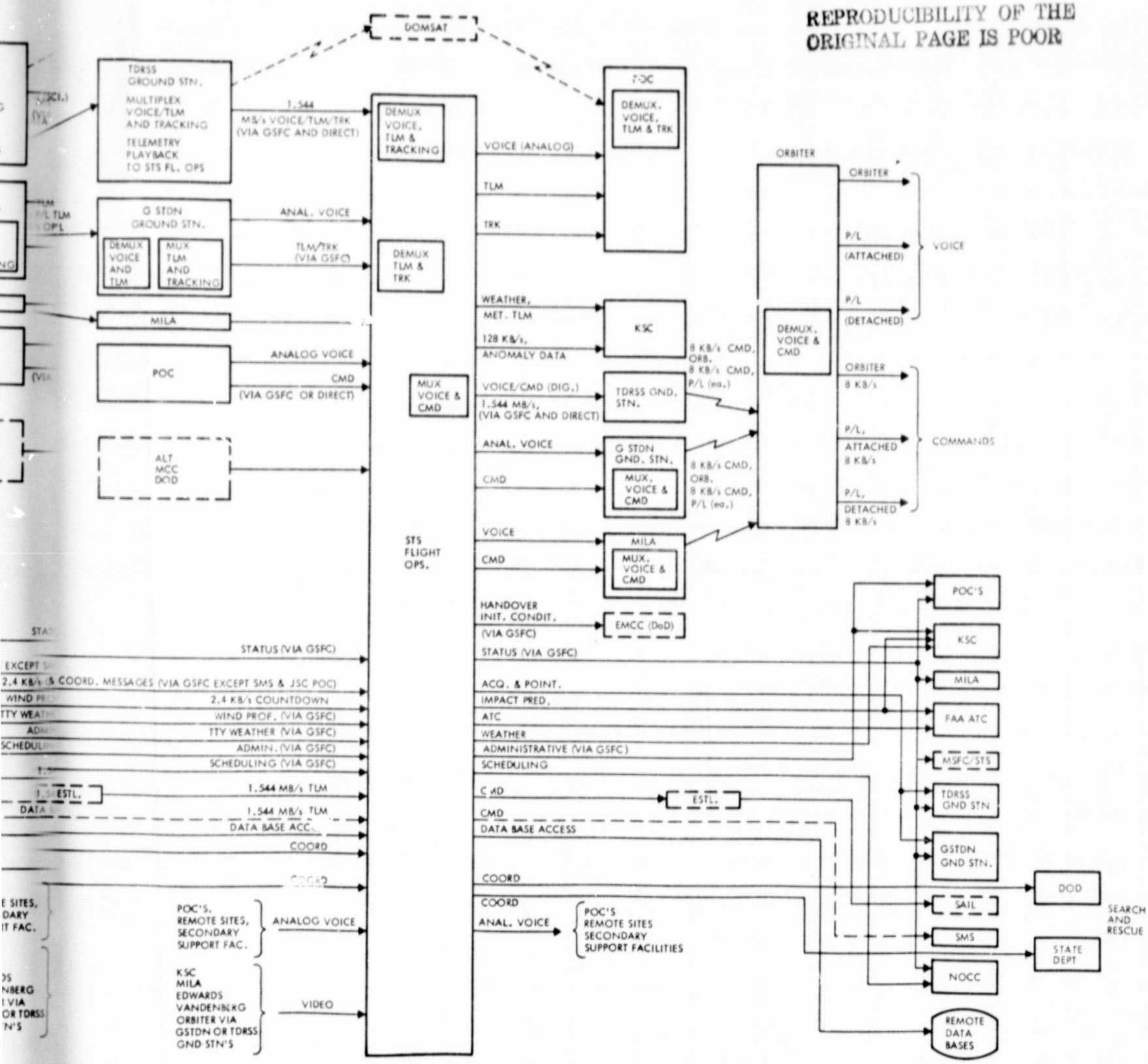


Figure 6. Composite Functional Flow Diagram, Communications Links to/from STS Flight Operations

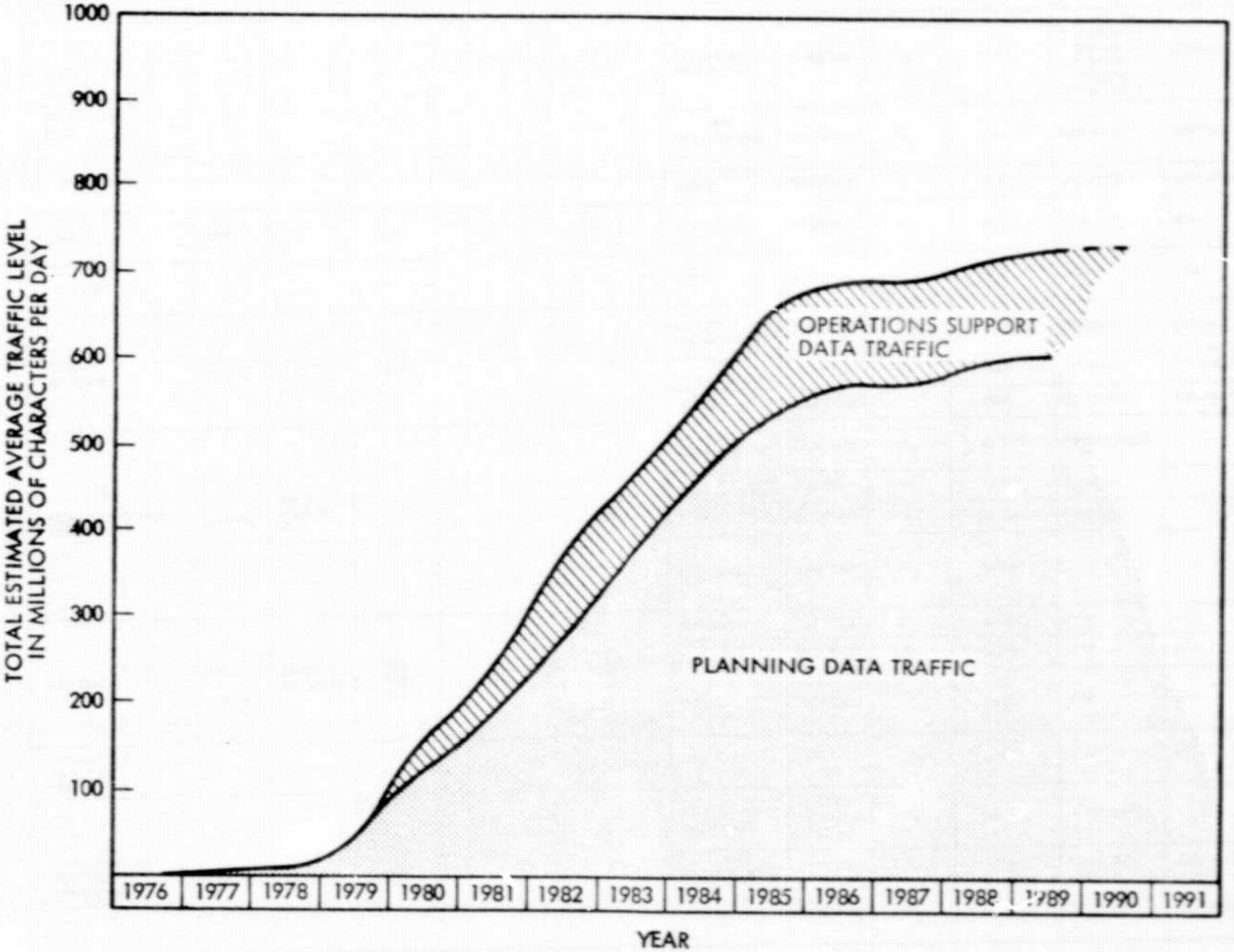


Figure 7. Annual Daily Traffic Growth Between STS Flight Operations and Mission Data Bases in Support of Planning and Operations Functions

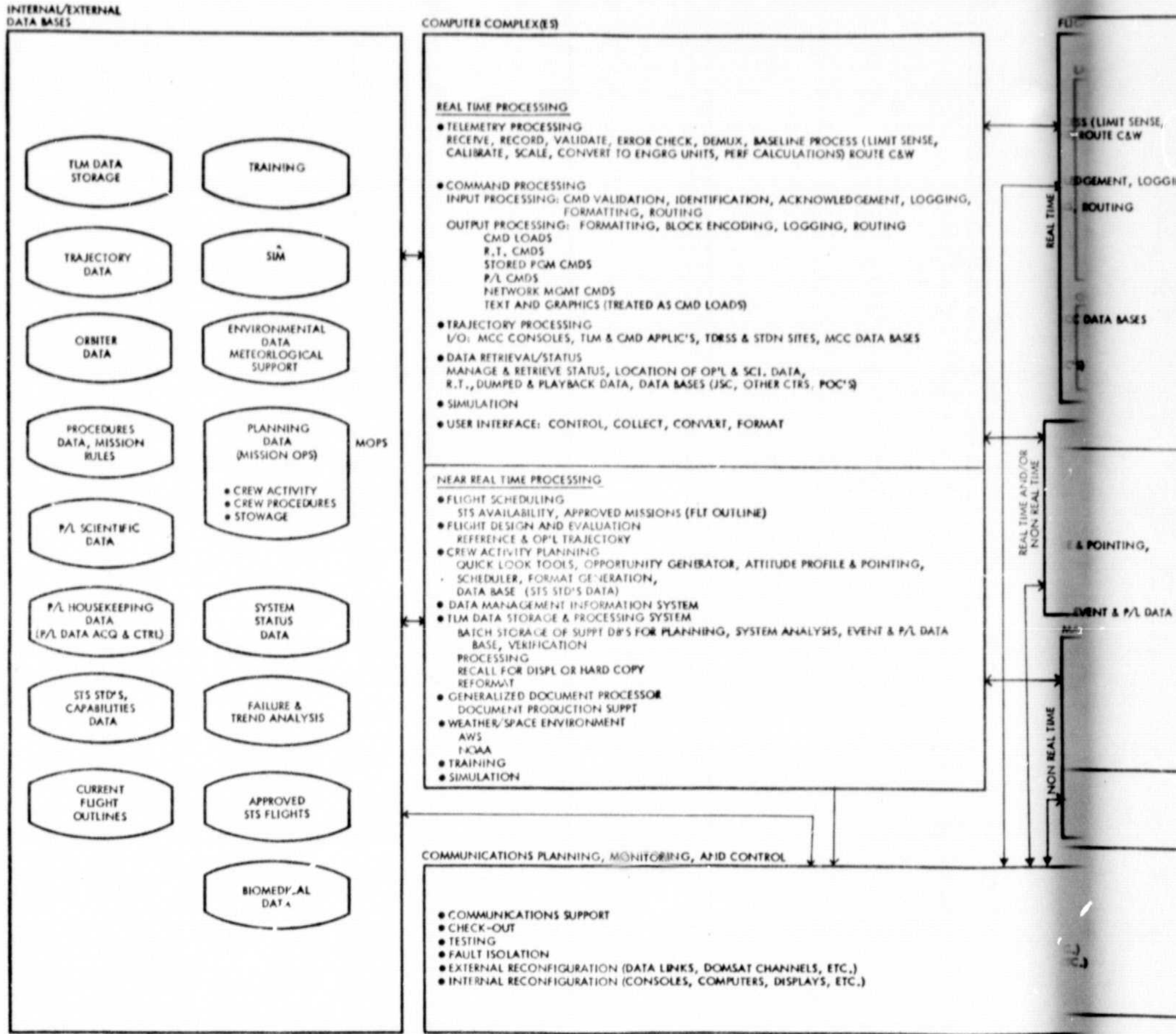
OWNING ORGANIZATION	SATELLITE NAME	PRIMARY COVERAGE AREA	FIRST LAUNCH	NUMBER OF TRANSPONDERS	TRANSPONDERS BANDWIDTH (MHz)	TYPE OF SERVICE	TYPE OF LINK	ESTIMATED BER	CIRCUIT AVAILABILITY	COST NY TO LA	TERMINAL CHARGES	REMARKS
AMERICAN SATELLITE CORPORATION	ASC	U. S.	1977 (EST)	12		VOICE	SATELLITE	10^7	99.9%	$1090/MO.	$120/MO.	PRESENTLY USING LEASED TRANSPONDERS ABOARD WESTAR I
						DATA TO 9600 B/s	SATELLITE	10^6	99.9%	$1118/MO.	$120/MO.	12 TRANSPONDER AND 6 SATELLITES BUILT BY HUGHES
						HIGH SPEED TO 1.3 MB/s	SATELLITE	10^6	99.9%	NEGOTIABLE	-	
CML SATELLITE CORPORATION *						N/A	N/A	N/A	N/A	N/A	N/A	NOT YET OPERATIONAL
INTELSAT	INTELSAT IV, IVA V	GLOBAL/ SPOT	1971 1975 1979	12 20 27	36 36 84	VOICE	SATELLITE	-	99.6%	N/A	N/A	INTELSAT IV-A OPERATIONAL LATE 1975
						DATA TO 9600 B/s	SATELLITE	10^7	99.6%	N/A	N/A	
						WIDEBAND	SATELLITE	10^7	99.6%	N/A	N/A	
RCA GLOBAL COMMUNICATION	SATCOM	U. S. AND PUERTO RICO	1975	24	34	SUB-SPEED	SATELLITE	10^7	99.4%	-	-	RCA GLOBAL OPERATIONAL, EARLY 1976
						VOICE	SATELLITE	-	99.4%	$1120/MO.	-	
						DATA TO 9600 B/s	SATELLITE	10^7	99.4%	$1560/MO.	-	
						WIDEBAND TO 60 MB/s	SATELLITE	10^8	99.5%	NEGOTIABLE	-	
WESTERN UNION	WESTAR	U. S. AND PUERTO RICO	1974	12	36	VOICE	SATELLITE	-	100%	$1000/MO.	$120/MO.	
						DATA TO 9600 B/s	SATELLITE	10^7	100%	$1038/MO.	$130/MO.	
						WIDEBAND TO 48 KB/s	SATELLITE	10^7	100%	$8100/MO.	$900/MO.	
NASCOM	-	-	-			ALL	ALL	N/A	N/A	N/A	N/A	DEPENDENT ON CIR-CUIT AVAILABILITY
TDRSS	TDRS	U. S.	1980	3		ALL	SATELLITE	10^5	N/A	N/A	N/A	NOT YET OPERATIONAL
AT&T LONG LINES	-	-	-			VOICE	LANDLINE	-	N/A	89¢ MILE	$126.20/MO.	
						DATA TO 9600 B/s	LANDLINE	10^7	N/A	89¢ MILE	$166.20	C2 CONDITIONED LINES
						WIDEBAND TO 50 KB/s	LANDLINE	10^7	N/A	$15.77/MI. - 1-250 MI. $11.04/MI. - 250-500 MI. $ 7.88/MI. - 50 MI. ON	$950/MO.	AT&T DATA SETS
COMSAT GENERAL	COMSTAR 1	U. S. AND PUERTO RICO	1976	24	34		SATELLITE	N/A	N/A			

* COMSAT GENERAL, AETNA AND IBM

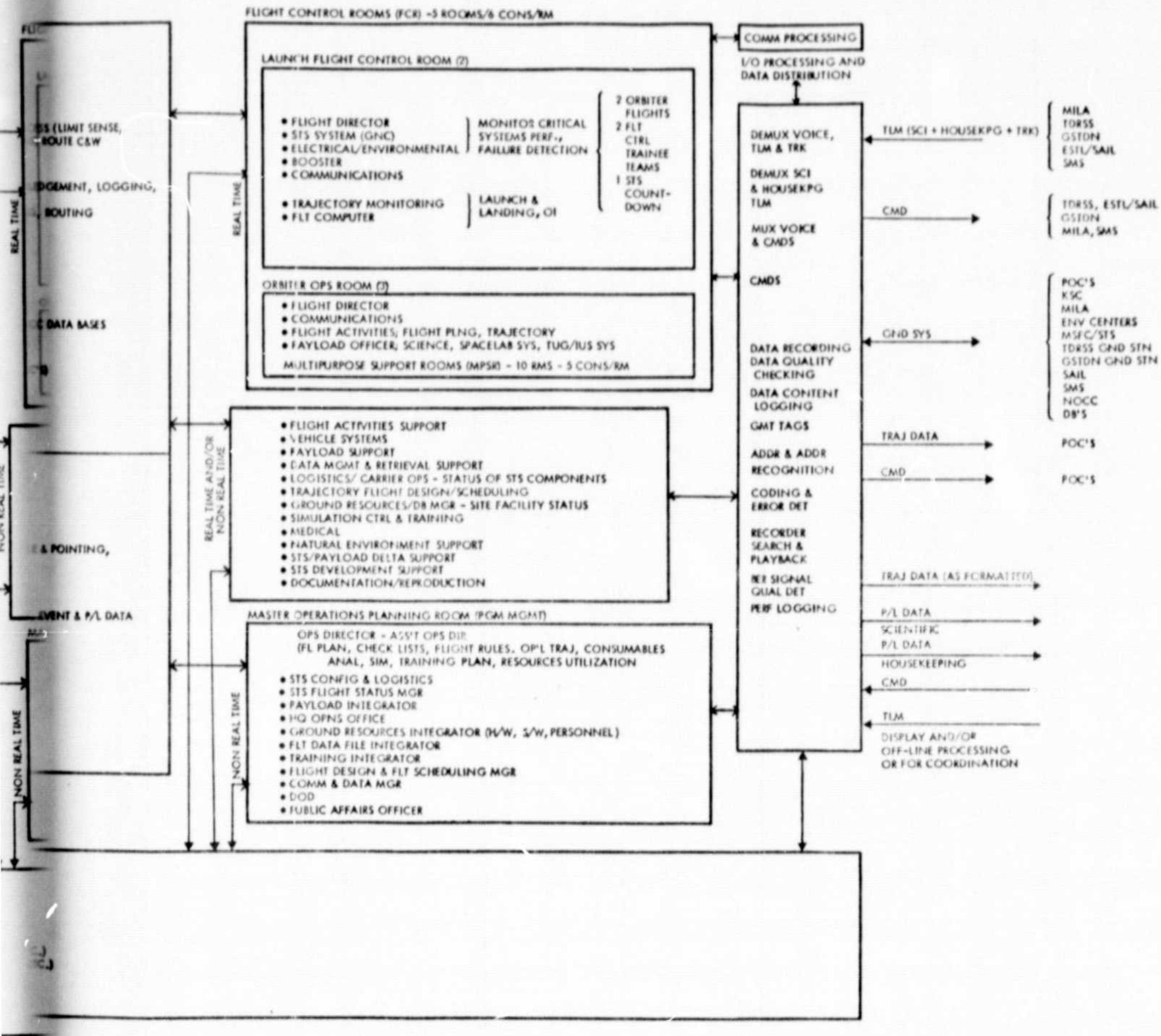
Figure 8. Common Carrier, NASCOM and TDRSS Performance Characteristics

Major Node Processing Requirements \ Communications Nodes	TDRSS Ground Station	STDN Ground Stations	GSFC/NET (NASCOM)	DOMSAT Ground Stations	POC'S	STS Flight Operations
Data Recording	X	X			X	X
Data Quality Checks	X	X	X	X	X	X
Data Content Logging		X			X	X
GMT Tags on Data/Voice/Video	X	X			X	X
MUX/DEMUX with/from Digital Voice		X			X	X
Blocking for Point-to-Point Transmission			X			
Addressing and Address Recognition	X	X	X		X	X
Coding and Error Detection for Retransmission		X	X		X	X
Recorder Search and Playback	X	X			X	X
Processing of CMD Instructions	X	X			X	X
Check Quality and Configuration Test	X	X	X	X	X	X
Malfunction Detection and Auto Line Switch			X			
BER Signal Quality Determination/ Performance Logging			X		X	X
FM with Other Voice Circuits and/or TTY, FAX, etc., on T1 Circuit			X			X
Voice Quality Tests and Logging		X	X		X	X
Image Enhancement					X	X
Voice and Image Synchronization					X	X
Video Frame Rate Conversions (if required)					X	X
Encryption					X	X

Figure 9. Application Recommendations for Major Communications Processing Requirements



FOLDOUT FRAME



FOLDOUT FRAME 2

Figure 10. STS Flight Operations Facility Performance Requirements

Channel Type \ Remote Facility		TDRSS GND STN	GSTDN REMOTE SITES	KSC	VAFB	MILA	JSC POC	GSFC POC	JPL POC	MSFC/STS	EDWARDS AFB	NOCC	ENV. SUPPORT	ESTL/SAIL	SMS
DOMSAT CHANNEL (≤ 50 Mb/s)		1					2								
WIDEBAND CHANNEL (T1 ≤ 1.544 Mb/s)	FDX	1												1	1
	HDX	1	1				2	1						1	
HIGH BANDWIDTH CHANNEL (56 Kb/s)	FDX	1	1	2	2	2	2	5			1				1
	HDX	1	2				1								
MEDIUM BANDWIDTH CHANNEL (9.6 Kb/s)	FDX	3	2	6	6	2			2	2		2		2	1
	HDX	2	2	2	2	3			4						
NARROW BANDWIDTH CHANNEL (1.2 Kb/s)	FDX								7				3	1	1
	HDX		1												1
VIDEO CHANNEL TO STS FLIGHT OPERATIONS		1	1	2	2	1					1			1	1
VIDEO CHANNEL FROM STS F.O.				1	1		2			1					
VOICE CHANNEL (ANALOG)		6	7	16	16	9	12	12	9	5	11	6	3	6	4

Figure 11. STS Flight Operations Interfaces, Channel Types, and Bandwidth Requirements (The quantitative values shown represent estimated number of full- and half-duplex channels required within each category, in the early 1980's.)

2.0 SUMMARY OF STUDY RESULTS

2.1 COMMUNICATIONS TRAFFIC MODELS REQUIRED BY STS FLIGHT OPERATIONS TO SATISFY OPERATIONAL REQUIREMENTS

The communications traffic models will impose the following requirements on the system:

DOMSAT Link TDRSS Ground Station to MCC-H

- Eighty-five percent of all payload telemetry is less than 1.544 Mb/s which can be accommodated with a single T-1 type circuit.
- The 15-percent delta can be accommodated in the early 1980's by a DOMSAT and kept to less than 50 Mb/s with minimal scheduling and configuration management.
- For overlapping flights, DOMSAT bandwidth requirements will increase to above 50 Mb/s starting in 1983.
- Due to the sporadic need for very large bandwidth telemetry links, it is recommended that transponders be leased on short term, demand basis from DOMSAT carriers, and used with NASA-owned, special purpose, low-cost portable ground station(s).
- It is estimated that a single transponder, 50 Mb/s DOMSAT channel will cost approximately $700,000 in 1982.
- Small ground stations have been developed for as little as $1 million. It is predicted that the cost of ground stations will continue to decrease in the future. However, the rate of decrease will probably be significantly less than that of satellite transponder channels.

T1 Channel, TDRSS Ground Station to MCC-H

- A single T1 channel will be adequate for traffic loads in the early 1980's.
- A single T1 channel will, however, not be adequate to handle operational traffic with overlapping flights starting in 1983 due to the wide bandwidth requirement for dumped data. (T1 bandwidth is 1.544 Mb/s while required bandwidth, excluding Payload Telemetry Data, is 2.432 Mb/s.
- The dumped data can either be transmitted over a second T1 channel, recorded at the TDRSS Ground Station for later transmission, or multiplexed with payload data on the DOMSAT link.
- The Backup T1 link connecting JSC to the TDRSS Ground Station via GSFC may be used for data base traffic between JSC and the mission Data Bases at GSFC. This will impose additional requirements on T1-link multiplexing, both at GSFC and JSC.

PRECEDING PAGE BLANK NOT FILMED

Additional T1 Channel Requirements

- The Operational data flow from Mission Data Bases to STS Flight Operations will more than double in the late 1980's. The planning data flow will increase at an even steeper rate (Figure 7). T1 links from STS Flight Operations to KSC and VAFB may be the most cost-effective method of linking STS Flight Operations and the two remote facilities in the mid to late 1980's.

2.2 SUMMARY OF REQUIREMENTS FOR THE GROUND SYSTEM REQUIRED FOR FLIGHT CONTROL OF THE STS AND INTERFACE WITH PAYLOAD CENTERS

A ground system configuration for STS Flight Operations was summarized in Figure 10. Based on this configuration, the following general requirements for the STS Flight Operations ground system were established:

- FCR, MPSR, and MOPR facilities should be used to support training and simulation activities. These activities should be scheduled on a noninterference basis with actual operations.
- High forward link data rates dictate the use of wideband data channels.
- For Status Processing, the checkout and reporting ground system function requires that each operational communication link be exercised.
- For Status Processing, the greatest majority of the actual link requirements are via the LSDL and the HSDL.
- Network management and fault isolation should be supported by the Communications Configuration Management function.
- System Administration and System Scheduling functions are required to interface with all external STS-associated facilities.
- Since the High Bandwidth Channels were "shared" between a large number of I/O functions (Return Link Telemetry, Forward Link Command Data and Ground Communications), a flexible multiplexing capability with standard message formats will be required in all the key network nodes including STS Flight Operations.
- The communications processing required is well within the state-of-the-art and may be handled by a number of dedicated communications processors.
- The man-machine interface and associated processing should be assigned sufficient intelligence (local processing capability) to off-load the real-time and near real-time processing facilities.

- It is envisioned that a distributed processing approach will maximize system availability and optimize system growth, with rapid reconfiguration capability. This can be achieved using a local network of low-cost task reassignable, mini- or midi-computers.

2.3 SUMMARY OF COMMUNICATIONS TECHNOLOGY AVAILABLE IN THE REQUIRED TIMEFRAME TO SATISFY THE REQUIREMENTS

- Some of the communications technology becoming available in the 1980's consists of low cost special-purpose mobile ground stations, satellite packet broadcasting and dynamic satellite channel sharing. These new technologies will force the network designer to perform tradeoffs between these and more conventional approaches to reducing communications costs (such as bandwidth compression, local buffering to handle peak loads, etc.).

- The availability of packet switching presents an alternate approach to data transmission and may, in some cases, be more cost effective than the use of full period leased point-to-point lines.

3.0 STUDY CONCLUSIONS

The following conclusions were arrived at in the Study:

- Projected communication services can be provided with existing technology.
- Study findings do not impact significnatly on MCC-H and POC projected planning.
- Further studies should be performed to determine traffic loads under varying rather than peak conditions as was done in this Study.
- Continued analysis for applications of new technology should be performed to reduce cost.
- A computer-interactive communications requirements analysis tool should be developed.

4.0 ISSUES REQUIRING ADDITIONAL STUDY

A tradeoff exists between demultiplexing the Ku-band return link at the TDRSS ground station and transmitting the wideband payload science data directly to the JSC-POC via a DOMSAT channel, or transmitting the entire Ku-band downlink from the TDRSS ground station to STS Flight Operations at JSC. In the latter case, it may be advantageous to multiplex the tracking data and the STS operational data at the TDRSS ground station, before transmission of the data over a T1 channel to STS Flight Operations. Also, demultiplexing would have to be performed by STS Flight Operations.

A compromise solution would entail the transmission of higher than 1 Mb/s scientific data from TDRSS ground station to JSC-POC via DOMSAT while using the T1 channel for tracking data. Less than 1 Mb/s scientific data would be multiplexed with tracking data at the TDRSS ground station for transmission over the T1 channel to STS Flight Operations. STS Flight Operations would then demultiplex the scientific and tracking data streams and forward the scientific data to the JSC-POC.

The mean instantaneous data rates and specific annual traffic pattern were not possible to determine based on information available at the time of the study. Detailed information would have been required regarding each flight, the types of payload(s) carried, the scheduled launch data and the length of each flight. Results from this task are, however, typical, and sufficient to indicate the relative traffic loads on the various network links.

A study should be undertaken to develop an automated system for sizing the network and projecting its utilization based on specific mission requirements, mean instantaneous data rates, specific launch dates, etc. The approach used in this study can, however, serve as a baseline in the development of such a tool.

In order to be able to support mission planning, scheduling and contingency operations, the automated system development should be started in 1976. Such a computer program system will require approximately 1 year for the development of design requirements, 2 years for implementation and testing, and finally a 4th year for documentation, training and modification, if required. This program should be available to NASA in the early 1980's.

In addition, since several new technologies resulting in lower and more reliable communications services are becoming available, such as dynamic channel sharing and packet broadcasting, it is recommended that a detailed study be performed to explore how these new techniques can be utilized in a distributed, NASA-wide communications system based on packet switching.

Finally, due to the decreasing cost of data transmission, a trade-off should be performed evaluating the cost of task-dedicated communications links versus "timesharing" communications channels between various functions and users at STS Flight Operations. The latter approach will require more complex communications processors with the ability to handle a variety of data rates and transfer data to a significant number of computers using different access methods.

APPENDIX

ACRONYMS AND ABBREVIATIONS

ACQ - Acquisition

ADDR - Address

AFB - Air Force Base

ALT - Alternate

AMPS - Atmospheric and Magnetospheric Plasmas in Space

AP - Atmospheric and Space Physics

ARC - Ames Research Center

AS - Astronomy

ASC - American Satellite Corporation

ASCII - American Standard Code for Information Exchange

ATC - Air Traffic Control

ATDM - Asynchronous Time-Division Multiplexing

ATL - Advanced Technology Laboratory

AWS - Air Weather Service

BER - Bit - Error - Rate

BESS - Biomedical Experiments Scientific Satellite

b/s - Bits per Second

CADSI - Communications and Data Systems Integration

CAIRS - Computer Assisted Interactive Resource Scheduling

CASH - Catalog of Available and Standardized Hardware

CCITT - International Telegraph and Telephone Consultative Committee

CIIS - Central Integrated Information System

CMD - Command

CN - Communications and Navigation

COMM - Communications

COMSAT - Communications Satellite Corporation

CONS - Consoles

CONUS - Continental U.S.

CRT - Cathode Ray Tube

CTO - Central Terminal Office

DAMA - Demand Assignment Multiple Access

D.B. - Data Base

DEMUX - Demultiplexing

DET - Detector

DMIS - Data Management Information System

DOD - Department of Defense

DOMSAT - Domestic Satellite

DSDP - Data Systems Development Plan

DSN - Deep Space Network

EIRP - Effective Isotropic Radiated Power

EOS - Earth Observations Satellite

ESTL - Electronic System Test Laboratory

ET - External Tank

EVA - Extravehicular Activity

FAA - Federal Aviation Administration

FCR - Flight Control Room

FFTO - Freeflyer Teleoperator

FM - Frequency Multiplexing

F.O. - Flight Operations

FOD - Flight Operations Directorate (at JSC)

FDX - Full Duplex

GDP - Generalized Documentation Processing

GHz - Gigahertz

GMT - Greenwich Mean Time

GN & C - Guidance, Navigation and Control

GSFC - Goddard Space Flight Center

GSTDN - Ground Spaceflight Tracking and Data Network

HEA - High Energy Astrophysics

HBR - High Bit Rate

HSDL - High Speed Data Link

HUGE - Hardware Utilization - Ground Equipment

HDX - Half Duplex

I/F - Interface

I/O - Input/Output

ICD - Interface Control Document

INTELSAT - International Telecommunications Satellite Consortium

ISL - Inter-Satellite Link

IUS - Interim Upper Stage

JPL - Jet Propulsion Laboratory

JSC - Lyndon B. Johnson Space Center

KBD - Keyboard

Kb/s - Kilobits per Second

KHz - Kilohertz

KSC - Kennedy Space Center

L/P - Line Printer

LaRC - Langley Research Center

LBR - Low Bit Rate

LEO - Low Earth Orbit

LPS - Launch Processing System

LeRC - Lewis Research Center

LS - Life Sciences

LSDL - Low Speed Data Link

MA - Multiple-Access

Mb/s - Megabits per Second

MCC - Mission Control Center

MD - Multi-Discipline

MDRS - Mission Data Reduction System

MGMT - Management

MHz - Megahertz

MMDB - Master Measurements Data Base

MOPR - Master Operations Planning Room

MOPS - Mission Operations Planning System

MPSR - Multi-Purpose Support Rooms

MSFC - Marshall Space Flight Center

MSFN - Manned Space Flight Network

MTBF - Mean Time Between Failures

MTTR - Mean Time to Repair

MUX - Multiplexing

N.R.T. - Near Real Time

NARC - National Association of Regulatory Commissioners

NASCOM - National Aeronautics and Space Administration Communications Netw

NOAA - National Oceanic & Atmospheric Administration

NOCC - Network Operations Control Center

NORAD - North American Air Defense Command

NPT - Network Planning Tool

NTSC - National Television Standard Code

OI - Operational Instrumentation

OP - Earth and Ocean Physics

P - Pallet

P/L - Payload

PGM - Program

PI - Principal Investigator

PLMC - Payload Mission Control

POC - Payload Operations Center

POCC - Payload Operations Control Center

PRACAS - Problem Reporting and Corrective Action System

PROC - Processor

R/T - Real Time

RADAS - Random Access Discrete Address System

RI - Rockwell International

SA - Single-Access

SAIL - Shuttle Avionics Integration Laboratory

SAMSO - Space and Missile System Organization

SCAMA - Switching, Conferencing, and Monitoring Arrangement

SCATS - Simulation Control and Training System

SCI - Science

SEOPS - Standard Earth Observations Package for Shuttle

SI - Science Instruments

SIM - Simulation

SIS - Shuttle Information Service

SL - Spacelab

SLAHTS - Stowage List and Hardware Tracking Systems

SMS - Shuttle Mission Simulator

SO - Solar Physics

SOCC - Spacecraft Operations Control Center

SP - Space Processing

SPADE - Single Channel per Carrier PCM Multiple Access Demand Assignment Equipment

SRB - Solid Rocket Booster

SSPD - Space Shuttle Payload Data

ST - Space Telescope

STDN - Spaceflight Tracking and Data Network

STP - Space Test Program (DOD Payloads)

STS - Space Transportation System

STS/FO - STS Flight Operations

TDM - Time Division Multiplexing

TDRSS - Tracking Data Relay Satellite System

TEKTR - Tektronix CRT

THRIFT - Telemetry History Reports in Formatted Tabulation

TLM - Telemetry

TRAIN - Training

TRK - Tracking

TT & C - Telemetry, Tracking and Control

UDS - Universal Documentation Systems

USAF - United States Air Force

VAFB - Vandenberg Air Force Base

WBDL - Wideband Data Link

WMC - World Meteorological Center

WS - White Sands