

# Ground Systems Telemetry Data Flow Workbook GND TM 2102A

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Advanced Training Series

For Training Purposes Only  
Crew Training and Procedures Division  
Flight Training Branch

March 28, 1979

**NASA**

National Aeronautics and  
Space Administration

**Lyndon B. Johnson Space Center**  
Houston, Texas

ERRATA SHEET

GROUND SYSTEMS TELEMETRY DATA

FLOW WORKBOOK GUID TM 2102A

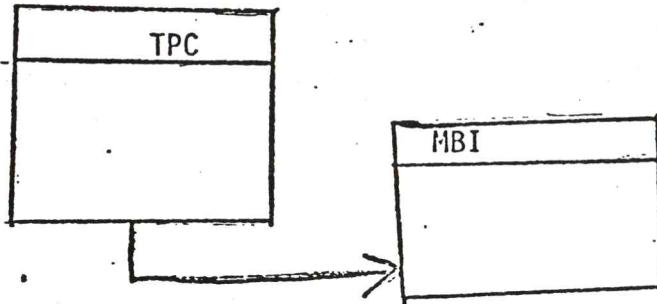
Page 3-1      Learning Material - should read "The drawings on pages 4-37, 4-38, 4-39, and 4-40 are your Learning Material."

Page 3-1      Instructions - should read "Turn to pages 4-37, 4-38, 4-39, and 4-40."

Page 4-1      Learning Material - should read "The drawings on pages 4-37, 4-38, 4-39, and 4-40 are your Learning Material."

Page 4-40      Consoles and Display Equipment - should read as follows:  
o MCC Consoles  
o Input Keyboards  
o Displays for TV, event lites, SCR's, and clocks

Page 4-40 and  
Page 4-55      Drawing should be as follows:



## REVISIONS

Revision A to the Preliminary Telemetry Data Flow Workbook (GND TLM 2102) contains the following changes.

### I. Additions

- Segment 3, Telemetry Data Flow
- Segment 4, Major Telemetry Subsystem Functions.

The Air Force STC (Satellite Test Center) Interface is incorporated.

### II. Deletions

- Segment 1, Orbiter Downlinks
- Segment 2, Orbiter Downlink Contents of GND TLM 2102 are combined into Segment 1 - Orbiter Telemetry Downlinks.

### III. General

- The segments are resequenced to provide a better lesson flow.
- Segment 5, Telemetry Data Rates and formats have been rewritten for better clarity.

If you have already taken GND TLM 2102, you will only need to take Segments 3 and 4 of this Revision A in order to receive credit for having taken the course.

## FOREWORD

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This training material is part of a series of lectures, handouts, and workbooks for instruction on Ground Systems.

This training package should be studied before attending any classroom session on this material or taking any lesson for which this is a prerequisite.

The Ground Systems lesson sequence chart shows where this lesson fits in the series. The prerequisites for each lesson, and the optimum presentation order. The lesson sequence charts are located in the Shuttle Training Program Catalog.

This material is for training purposes only; it should not be used as a source of operational data.

This workbook is part of the advanced training series with data for specific examples taken from the STS-Flight. This should not detract from its training value for later STS Flights.

The last two pages of this workbook are two forms:

(1.) "Lesson Critique Sheet"

(2.) "Training Report"

- (1) The "Lesson Critique Sheet" is used to obtain your comments on this workbook. Please fill it out and mail to the instructor when you have completed this workbook. (It need not be placed in an envelope nor be signed.)
- (2) The "Training Report" applies to FOD personnel ONLY. It provides the information to enter this training in your training record. To receive credit when you have completed this workbook, please complete the "Training Report" and mail to CG3.

## HOW TO USE THIS WORKBOOK:

This book is organized into segments. You should proceed through the segments in the order in which they are presented. Within the segment, however, you control your own progress. You should begin each segment by reading the objective and the learning material. The learning material is set apart in a box. This is the central information to be learned. Supporting data following the learning material is provided as additional information to aid you in learning. If you are already quite familiar with the material presented in the learning material, skip right to the exercise items. For other segments with which you are somewhat familiar, you may want to read the objective, learning material, and some of the supporting data, then go on to the exercise. If the material is totally new to you, most of the supporting data should be very helpful.

Before going on, you should always make certain that you understand the correct answers to each of the exercise items. The feedback explains the correct response and is particularly helpful for items you missed. Exercise items are usually on the right-hand page, and exercise feedback on the left-hand page, so that you can fold the page over to compare your answer with the correct answer.

All the acronyms and abbreviations used in this lesson are discussed wherever first used. A list of definitions is provided in Appendix A.

A content bibliography outline is often provided at the end of the lesson for those persons who may desire more detailed data on a specific topic.

This workbook is provided for your use. You may make notes or write comments anywhere you like. You may retain the text for later reference.

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## LESSON INTRODUCTION

The major emphasis of this lesson is focused on the following areas:

- Transmitting data from the space shuttle vehicle to a typical GSTDN (Ground Spacecraft Tracking and Data Network) stations and to the IOS (Indian Ocean Station)
- Processing this data at the GSTDN station
- Transferring this data to MCC
- Processing and distributing this data at MCC.

This lesson begins at the telemetry generation inputs internal to the orbiter and proceeds through/from the GSTDN site to MCC, describing major telemetry subsystems and their functions. So that, given a failure in any one of these subsystems, you will know how telemetry data are affected.

This lesson has been developed to portray the telemetry capability for early Shuttle Transportation System (STS) flights. This configuration should hold true until TDRSS (Tracking and Data Relay Satellite System) is incorporated. Later editions of this workbook will discuss the payload interfaces, the TDRSS and other STS and GSTDN elements which represent the additional capabilities.

We will begin this lesson by first introducing the types, contents, and characteristics of the telemetry downlink between the orbiter and the GSTDN stations. This is followed by an end-to-end data flow and a functional description of all major subsystems involved in acquiring and processing telemetry data from the orbiter.

## SEGMENT 1

### ORBITER TELEMETRY DOWNLINKS

#### OBJECTIVE:

Be able to state the 3 basic Space Shuttle telemetry data links downlinked by the orbiter S-band systems and identify their contents.

#### INTRODUCTION:

Data links to and from the orbiter are the means by which flight controllers "command and control" the Space Shuttle and obtain data regarding the performance of the Shuttle, its payloads and the payload's scientific data. By monitoring Space Shuttle systems data, flight controllers can identify degradation trends and system failures and thus recommend corrective actions. This segment discusses the 3 basic telemetry data downlinks for early STS flights.

LEARNING MATERIAL:

The 3 Space Shuttle telemetry data links downlinked and their contents by the two orbiter S-Band systems are:

a. Operational Downlink (OD):

- (1) Operational Instrumentation (OI)
- (2) GPC "downlist" data
- (3) Digital Air-Ground (A/G) voice channel(s)
- (4) Payload "housekeeping" data

b. FM Wideband Downlink (FM)

Selection of one at a time of the following:

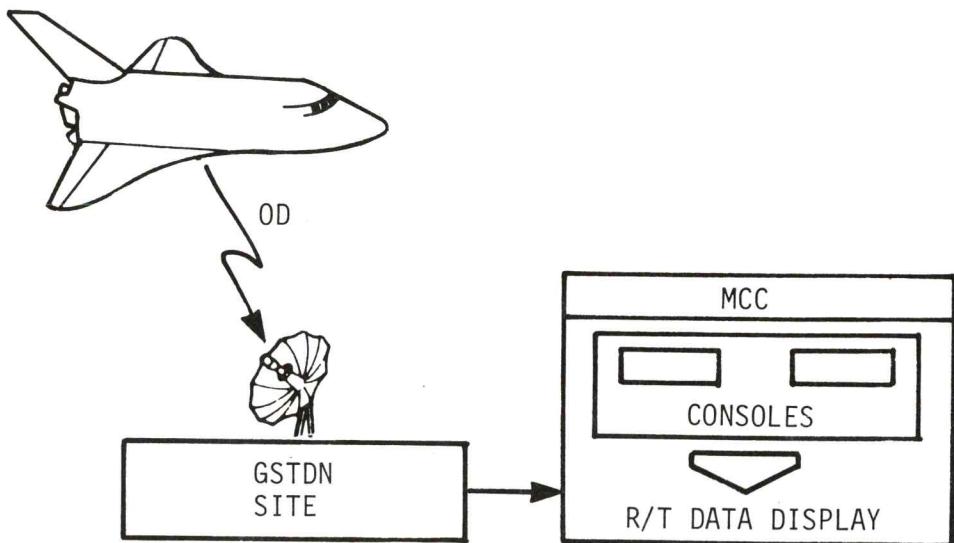
- (1) On-board orbiter recorder dumps
- (2) R/T SSME (Space Shuttle Main Engine) data
- (3) R/T TV (video)
- (4) R/T payload data

c. Development Flight Instrumentation (DFI)

- (1) PCM telemetry
- (2) 15 subcarrier channels (analog) flutter measurements

SUPPORTING DATA:

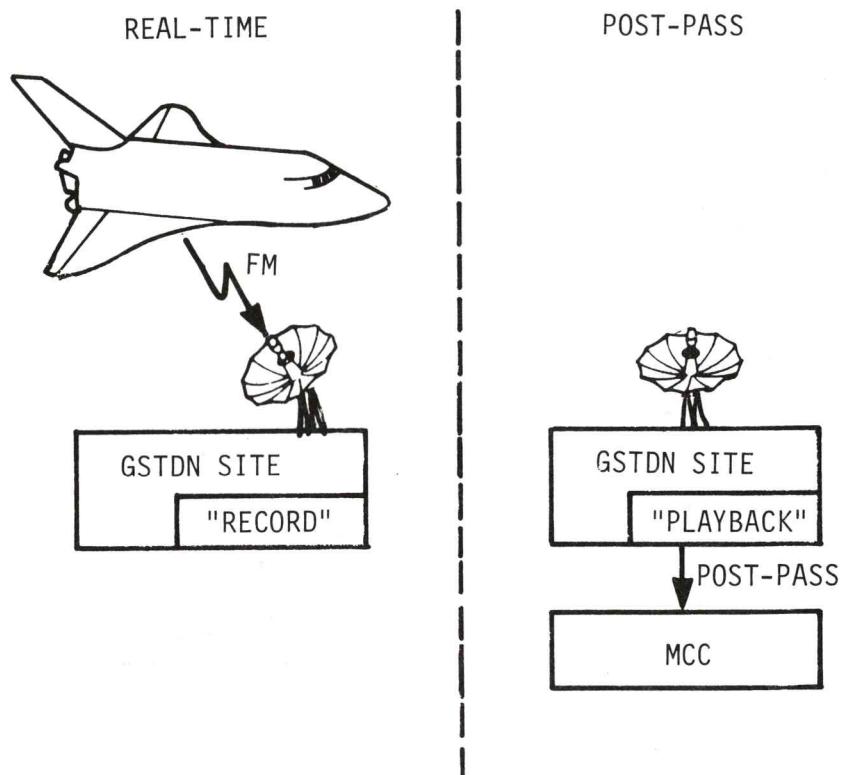
OPERATIONAL DOWNLINK



a. Operational Downlink (OD). Of the 3 data links, the OD is termed "operational" because it is the prime (and only) link providing orbiter-to-MCC telemetry for use in R/T (real time) control and monitoring. The operational downlink contains the following types of data:

- (1) OI (Operational Instrumentation). OI data contains Space Transportation System (STS) parameter measurements such as temperatures, pressures, voltages, and flow rates. These parameter measurements are collected by OI sensors.
- (2) GPC "Downlist". Flight critical data inputs from the orbiter's guidance, navigation and control (GN & C), solid rocket boosters (SRB's), and the Engine Interface Unit (EIU) along with the computed data from the General Process Computers (GPC's) comprises the data stream referred to as the GPC downlist.
- (3) Air-to-Ground (A/G) Digital Voice Channels. As part of the OD, either 1 or 2 digitized voice channels is contained within the OD downlink.
- (4) Payload Housekeeping Data. This data will include status and timing data on the Payload experiments.

### FM WIDEBAND DOWNLINK

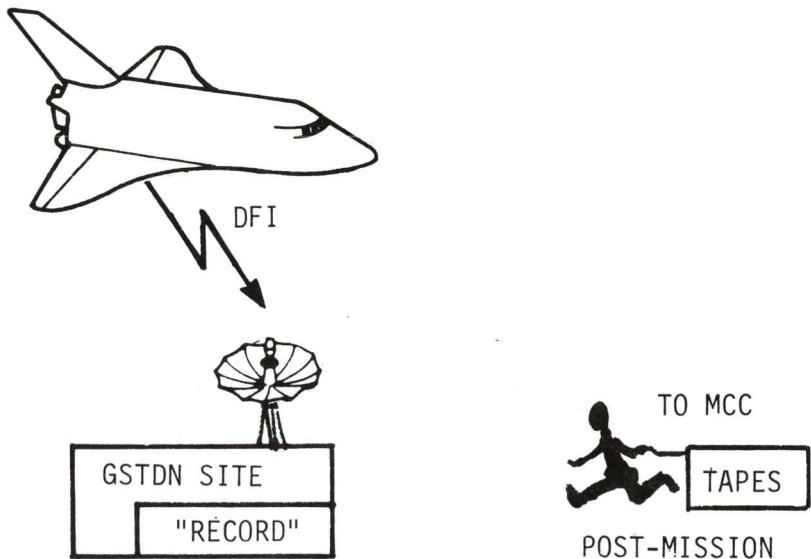


b. FM Wideband Downlink (FM). This data provides for (one at a time) either on-board recorder dumps, R/T main engine data, R/T TV, or R/T payload data (if any).

#### NOTE:

Current requirements call for recorder dumps to be played back to MCC post-pass.

## DEVELOPMENT FLIGHT INSTRUMENTATION DOWNLINK



- c. Developmental Flight Instrumentation (DFI) . This link is a result of a unique development flight instrumentation package supplying additional engineering telemetry. This link will be received and recorded at the GSTDN sites for transfer to MCC post mission.

PRACTICE:

I. State the names of the 3 basic telemetry data link downlinks by the Orbiter S-Band systems.

1. \_\_\_\_\_

2. \_\_\_\_\_

3. \_\_\_\_\_

PRACTICE FEEDBACK:

I. State the name of the three basic telemetry data streams downlinked by the Orbiter S-Band system.

1. Operational Downlink (OD)
2. FM Wideband Downlink (FM)
3. Development Flight Instrumentation (DFI)

PRACTICE:

Match the appropriate downlink title with the correct functional description of its associated data content.

Downlink Title:

Functional Description:

DEVELOPMENT FLIGHT INSTRUMENTATION (DFI)

on-board orbiter recorder dumps  
R/T SSME data  
R/T TV (video)  
R/T payload data

OPERATIONAL DOWNLINK (OD)

PCM telemetry  
15 subcarrier channels (analog)  
flutter measurements

FM WIDEBAND DOWNLINK (FM)

Operational Instrumentation (OI)  
GPC "downlist" data  
Digital Air-Ground (A/G) voice  
channel(s)  
Payload "housekeeping" data

PRACTICE FEEDBACK:

Match the appropriate downlink title with the correct functional description of its associated data content.

Downlink Title:

Functional Description:

DEVELOPMENT FLIGHT INSTRUMENTATION (DFI)

on-board orbiter recorder dumps  
R/T SSME data  
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OPERATIONAL DOWNLINK (OD)

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flutter measurements

FM WIDEBAND DOWNLINK (FM)

Operational Instrumentation (OI)  
GPC "downlist" data  
Digital Air-Ground (A/G) voice  
channel(s)  
Payload "housekeeping" data

## SEGMENT 2

### ORBITER DOWNLINKS MODULATION METHODS

#### OBJECTIVE:

Be able to identify the S-Band modulation method that the 3 Space Shuttle data links utilize.

#### INTRODUCTION:

It is important that you know which modulation method the OD, FM, and DFI utilizes. This segment lists these modulation methods.

#### LEARNING MATERIAL:

<u>Downlink/S-Band Equipment</u>	<u>Modulation Scheme</u>
1) OD (Operational Downlink)	PM (Phase Modulation)
2) FM Wide Band Downlink	FM (Frequency Modulation)
3) DFI Downlink	FM (Frequency Modulation)

#### SUPPORTING DATA:

The orbiter's OD utilizes phase modulation (PM) and both the wideband FM link and the DFI link utilize frequency modulation (FM). This is reflected at each GSTDN site where receivers are selected to operate in either the "PM or FM Mode" in support of detecting and demodulating specific downlink carriers.

#### NOTE:

For specific orbiter modulation characteristics, refer to the Interface Control Document (ICD) ICD 2-OD004, "JSC/GSFC Space Shuttle RF Communication and Tracking Document."

PRACTICE:

Match the S-Band modulation method with the appropriate Orbiter downlink.

DOWNLINK

- Operational Downlink
- Wideband FM Downlink
- DFI Downlink

MODULATION

FM

PM

PRACTICE FEEDBACK:

Match the S-Band modulation method with the appropriate Orbiter downlink.

DLINK

- Operational Downlink
- Wideband FM Downlink
- DFI Downlink

MODULATION



## SEGMENT 3

### TELEMETRY DATA FLOW

#### OBJECTIVE:

Trace the flow of telemetry data from the Orbiter to MCC on the end-to-end Orbiter-to-MCC data flow drawing.

#### INTRODUCTION:

This segment is based on four data flow functional drawings that contain the major telemetry subsystems (along with A/G voice, ranging, command and TV) onboard the Orbiter; at a typical GSTDN site; at the IOS (Indian Ocean Station) and the Air Force STC (Satellite Test Center) at Sunnyvale, California; and at MCC. The IOS interface is included because the data flow through the IOS is different from the typical GSTDN ground station. This segment is designed to give you an overall picture of telemetry data flow before a detailed discussion of the major subsystem function is given.

#### LEARNING MATERIAL:

The drawings on Pages 4-39, 4-40, 4-41, and 4-42 are your learning material.

#### INSTRUCTIONS:

Turn to pages 4-39, 4-40, 4-41, and 4-42. You will find four foldout drawings entitled Space Shuttle-1 Orbiter-to-MCC Telemetry Data Flow. The drawings when detached from the workbook present a complete drawing of the telemetry data flow from the Orbiter to MCC. Trace the flow of telemetry data through the telemetry subsystems as the flow is discussed in the supporting data section. Disregard the groups of functions in the blocks at this time. They are discussed in Segment 4. The actual tracing of the telemetry data flow as we go through the supporting data discussion is your practice.

## SUPPORTING DATA:

### ORBITER

We discuss the flow of data for the three telemetry data downlinks separately completing the flow of the three downlink onboard the orbiter before proceeding to the GSTDN site and IOS/STC. Likewise, at the site, the flow is discussed separately, however at the site the three downlinks are combined and discussed together to/through the MCC.

#### Operational Downlink (OD) Data

The General Process Computer (GPC) receives OD telemetry formats from the MASS Memory and vehicle subsystem parameter data from Flight Critical Multiplexer/Demultiplexer (MDM's). From these inputs, the GPC builds the GPC downlist and transfers the downlist to the Pulse Code Modulation Master Unit (PCMM). The PCMMU also receives other vehicle subsystem data from Operational Instrumentation (OI) MDM's and builds the downlink telemetry data stream. The PCMMU outputs this data stream to the Network Signal Processor (NSP) where it is combined with A/G voice. (A detailed discussion on A/G Voice Data Flow is contained in A/G Voice Data Flow Workbook -GND A/G 2102A). This combined data is the OD and is routed to the S-Band Transponder for transmission to the ground and to the Operations (OPS) Recorder for recording and dumping.

#### FM Wideband Downlink Data:

The telemetry part of the FM wideband downlink contains the Main Engine data from the Engine Interface Unit (EIU's) or the recorded OD telemetry data plus voice from the Ops Recorders. The data from the EIU's and Ops recorder are input to the FM Signal Processor for selection and transfer either of OD telemetry recorder dumps or SSME data to the FM Transmitter. The FM transmitter outputs the data to the S-Band combiner where it is mixed with the DFI Data Signal for transmission to the ground.

#### Development Flight Instrumentation (DFI) Data:

DFI MDM's receive DFI vehicle parameter data and transfer this data to the DFI PCMMU where the DFI data downlink is built. The DFI PCMMU outputs the data stream to the Frequency Division Multiplexer (FDM's) and DFI WB Recorders. The DFI transmitter receives the data from the FDM, frequency modulates the data and transfers it to the S-Band combiner where it is mixed with the FM wideband data signal for transmission to the ground.

### GSTDN SITE

At the GSTDN site the S-Band equipment receives the two Orbiter S-Band signals consisting of the 3 downlinks and transfers the signal to the multi-coupler for distribution to the appropriate receivers.

### OD Downlink

The multi-coupler distributes the composite signal of telemetry and voice to the PM Receiver where it is demodulated and transferred to the Program Patch-Board. The signal is then switched to PCM Decommutator (DECOMM Number 1) and the WB recorders. PCM DECOMM Number 1 discards the A/G voice and transfers the telemetry data stream to the 642-B computer for processing and transmission to MCC via the GSFC Message Switch at GSFC.

### FM Wide Band

The multi-coupler distributes the FM wideband data downlink to the FM Receiver where it is transferred to the Program Patchboard for switching to the WB recorders and PCM DECOMM Numbers 3 and 4. From there the data is transferred to the 642-B computer for processing and transmission to MCC via the GSFC Message Switch at GSFC.

### DFI Data

The multi-coupler distributes the DFI data to the DFI Receiver where it is routed to the Demodulator Phase Shift Keyed (PSK) via the Program Patch Board. The PSK Demodulator separates the PSK subcarrier from the DFI data and transfers the data to PCM DECOM Number 2 where it is then routed to the 642-B computer for processing and transmission to MCC via the GSFC Message switch at GSFC.

R/T OD telemetry playbacks, Site Status Messages (SSM), and Data Link Summary Messages (DLSM) consisting of a summary of the orbiters R/T, OD, OD dump and DFI data downlinked during a pass are formatted and output by the 642-B computer in a standard communications NASCOM/4800 bit block. This is called a Blocked Data Format (BDF). The 642-B outputs this data onto three (3) 56 kbs lines to the GSFC Message Switch at Goddard Spaceflight Center (GSFC).

## INDIAN OCEAN STATION (IOS)/SATELLITE TEST CENTER (STC)

If the GSTDN site within the orbiter's line of sight is the IOS, the flow of data is as follows: At the Indian Ocean Station, (as at the typical GSTDN site), S-Band Equipment receives the orbiter S-Band data and transfers it to the multi-coupler for distribution to the appropriate receiver.

### OD Downlink

The multi-coupler distributes the composite signal of telemetry and voice to the GRARE receiver where the signal is transferred to the Data Routing Patch Panel (DRPP) for switching to the Defense Satellite System via the Defense Communication System/Satellite Control Facility Interface System (IOS/DSIS). The Satellite Test Center (STC/DSIS) at Sunnyvale, California receives and records the signal, then transfers the signal to the Delta Modulation System (DMS). In the DMS, the voice is separated from the telemetry data. The remaining telemetry data stream is reconstructed and transferred to the Adaptive Communication Line Controller (ACLC) for processing and transmitting to GSFC.

### FM Wideband Data

The multi-coupler transfers the wideband data link to the FM Receiver Number 1 where the data signal is demodulated and transferred to the DSIS for transmission to the STC. At the STC, the DSIS receives and records the data. If the data signal is OD dump telemetry data, the data stream is played back to MCC post-pass. The playback data are transferred from the DSIS to the ACLC where it is processed for transmission to MCC.

If the data signal is EIU data, the data are recorded but are not transmitted to MCC. The tapes are sent to MCC post mission.

### DFI Data

The multi-coupler distributes the DFI data to the FM Receiver Number 2 where it is routed to the DSIS. The IOS/DSIS transmits the data to the STC/DSIS where it is recorded. The data are not transmitted to JSC, but the tapes are sent to MCC post mission.

### Summary

During R/T, telemetry data along with trajectory data are formatted in a 4800 bit NASCOM blocked data format and are switched to MCC via the GSFC Message switch.

### MCC

At MCC, the Wide Band Data (WBD) switch receives the block of data and switches it to the Network Communication Interface-Common (NCIC) where the data are processed and distributed to the appropriate subsystems. Telemetry data only are routed to the Network Communications Interface-Unique (NCIU). There it is frame synced and transferred to the Telemetry Preprocessor Computer (TPC). Dump and R/T OD data are transferred from the NCIC to the Dump Data Processor for temporary storage.

The telemetry data stream that is transferred from the NCICU and routed to the TPC is processed into appropriate data sets. Selected Analog/Event Data are the input to the Analog Event Distribution (AED) Equipment for display on MCC Display and Console Equipment. The remaining data are then transferred to the Shuttle Data Processing complex (SDPC) via the Multi-Bus Interface (MBI). The SDPC performs various data computations and transfers this data to the Digital-to-Television Equipment (DTE) where the SDPC digital computer information is converted to video displays for displaying on MCC Display and Console Equipment.

The SDPC also drives Digital Display Drivers (DDD) indicators on up to 50 MCC consoles simultaneously. The SDPC receives MCC console keyboard requests for displays via the Display Select Computer Input Multiplexer (DSCIM).

## SEGMENT 4

### MAJOR TELEMETRY SUBSYSTEM FUNCTIONS

#### OBJECTIVE:

Be able to identify the major functions of the telemetry subsystems, given the telemetry data flow drawing and a list of the telemetry subsystem functions.

#### INTRODUCTION:

In segment 3, you traced the flow of telemetry data through the telemetry subsystems. In this segment, the major functions of these subsystems are discussed.

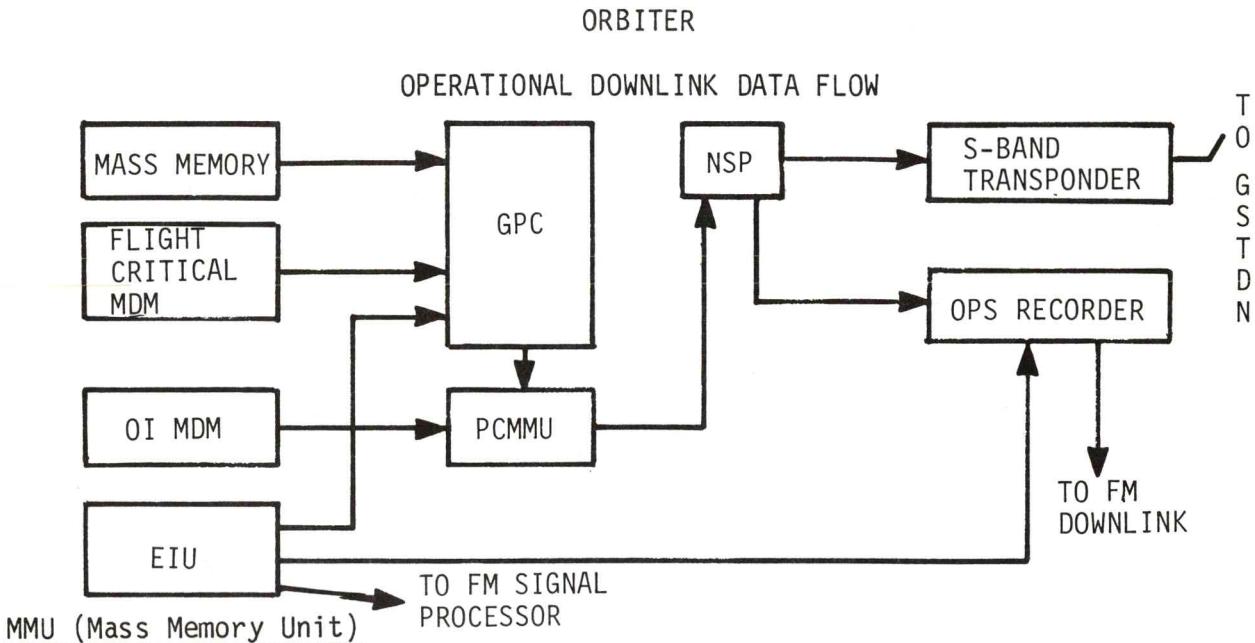
#### LEARNING MATERIAL:

The drawings on pages 4-39, 4-40, 4-41, and 4-42, are your learning material.

#### INSTRUCTIONS:

For this segment, you will use the same foldout drawings that you used for Segment 3. You are only expected to identify the highlighted blocks (the blocks with the groups of functions listed inside). You are not required to identify those blocks that are shaded or words inside blocks that are bracketed. These are included only to provide a comprehensive data flow with interfaces. Their function and contents are covered in other lessons. Also, you are not expected to memorize all the functions of each subsystem. You should, however, familiarize yourself with the functions so that given a group of functions, you can match them to the appropriate subsystem.

SUPPORTING DATA:



The orbiter mass memory unit is a digital tape storage unit providing a large storage medium for bulk data, GPC application programs, display format, and other orbiter data. It has both read and write capability and provides storage for display formats, computer reconfiguration, diagnostics, pre-flight checkout routines and PCMMU downlink formats. Whenever a new OD telemetry format is required, it is read from the Mass Memory into the PCMMU by the GPC for utilization.

Flight Critical Multiplexer/Demultiplexer (MDMS)

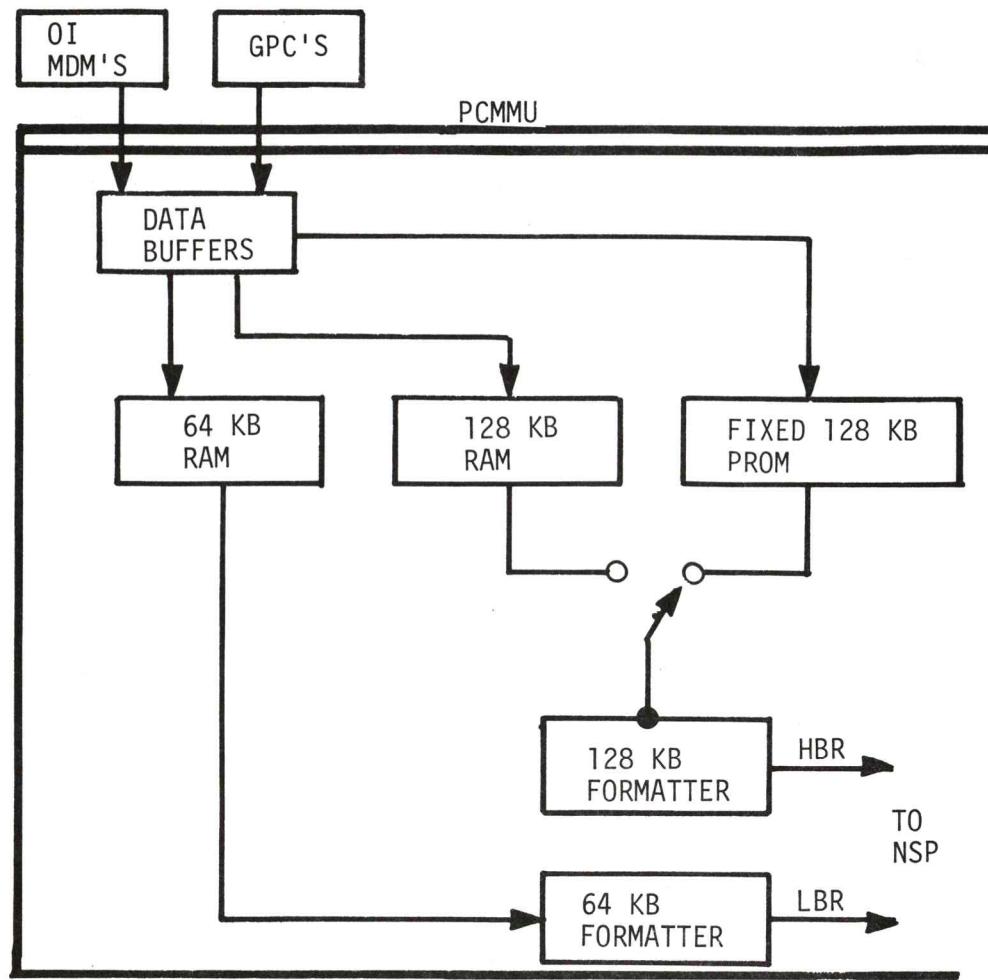
This set of MDM's are used to accept and encode data from flight critical systems to the GPC. MDM's are devices capable of compiling analog, discrete, and serial digital signals from vehicle subsystems on command from the GPC's. In this case critical flight control system measurements from the orbiter guidance, navigation and control system and solid rocket boosters are sampled and sent to the GPC for processing and subsequent downlinking.

Operational Instrumentation Multiplexer/Demultiplexers (OI MDM's)

This set of MDM's accepts and encodes data from OI vehicle subsystems to the PCMMU.

Engine Interface Unit (EIU)

The EIU accepts main engine controller data and distributes the data to the GPC's, the Ops recorders and the FM data system. It provides the means for data transfer between the Main Engine Controller and the orbiter interfaces. This data transfer interface includes control data from the orbiter to the engines and status data from the engines to the orbiter.



#### General Process Computer (GPC)

There are 5 GPC's onboard the orbiter which provide the capability for complete on-board data processing. The GPC's perform programmed application computational services and then prepare the data for telemetry transmission by means of a downlist. A GPC downlist is comprised of a table of values compiled within a GPC and sent to the PCMMU GPC data buffers called Toggle buffers.

The GPC downlist is controlled by the computer memory configuration with one operational downlist format defined for each memory configuration except for the GPC System Management Program. The downlist is then transmitted to the PCMMU where the data is incorporated with OI data into the OD.

#### Pulse Code Modulation Master Unit (PCMMU)

The PCMMU is the heart of the OD telemetry system. The PCMMU contains three format memories as follows:

- a. 128 Kbs Fixed Program Read Only Memory (PROM)
- b. 128 Kbs Updateable RAM (Random Access Memory) Software
- c. 64 Kbs Updateable RAM Software.

The 128 Kbs fixed format is hardwired for each mission and cannot be altered during the flight. The standard fixed format is used primarily during launch and entry phases, but also serves as a backup format should the PCMMU lose its updateable format memory.

The 128 Kbs and 64 Kbs updateable software formats are stored in the mass memory and are read into the PCMMU by a GPC as required.

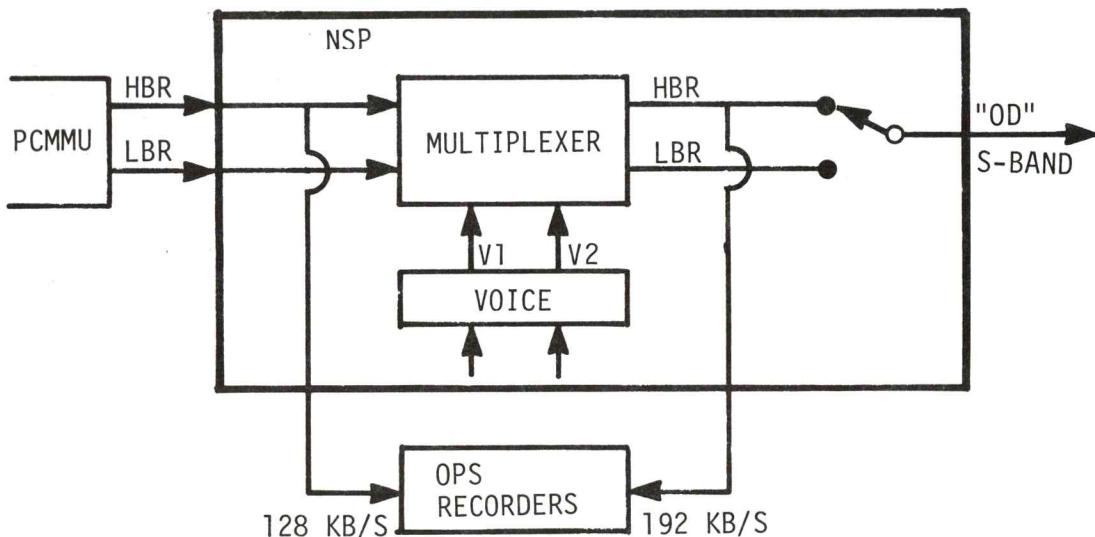
The PCMMU continuously outputs both a HBR and LBR OI telemetry data format to the NSP.

#### Network Signal Processor (NSP)

The NSP receives the formatted telemetry data streams from the PCMMU in addition to voice channels from the orbiter voice subsystems. The NSP digitizes the voice channels and interleaves the PCMMU data with selected voice channels as follows:

- a. 128 Kbs + (2) 32 Kbs voice channels = 192 Kbs
- b. 64 Kbs + (1) 32 Kbs voice channels = 96 Kbs

The NSP is where the OD time division multiplexer downlink rate is selected - HBR at 192 Kbs or LBR at 96 Kbs, reference the figure below.



The NSP also outputs to the Ops recorder either the 192 Kbs HBR TDM OD data or the 128 Kbs HBR telemetry for recording.

#### Operational (OPS) Recorders

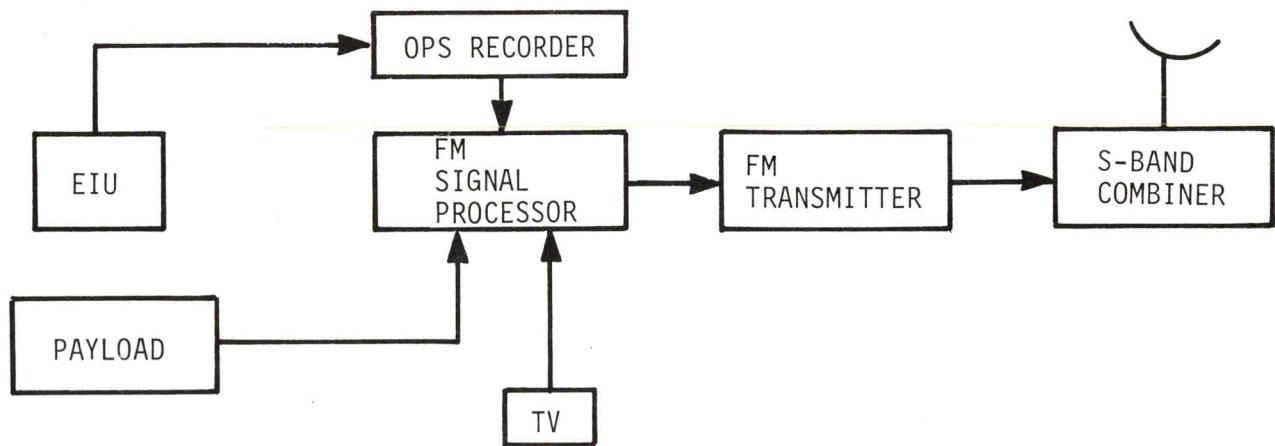
The Ops recorders are used for serial recording and dumping of on-board systems data and digitized voice. There are 2 Ops recorders onboard. They are normally operated in a serial digital mode except that Ops recorder Number 1 records EIU data in parallel during launch.

The recording mode is controllable by the Crew and MCC. The serial mode allows approximately 4 hours of data to be recorded on each recorder, so as to provide the greatest quantity of OI data for in-flight and post-flight data analysis.

#### S-Band Transponder

The S-Band transponder is the primary unit which modulates and transmits to the ground receiving stations on S-Band RF carrier the voice and telemetry data received from the NSP. The S-Band portion of the RF spectrum operates in the 2200 megahertz frequency range.

## FM WIDEBAND DATA FLOW



### FM Signal Processor

The FM signal processor receives main engine data from the Ops recorders. The signal processor outputs one at a time either:

- 3 channels of main engine data at 60 Kbs each
- R/T television from TV cameras onboard
- Ops recorder dumps - one channel of main engine data at 50 Kbs and 128 Kbs and/or 192 Kbs OD PCM telemetry data.

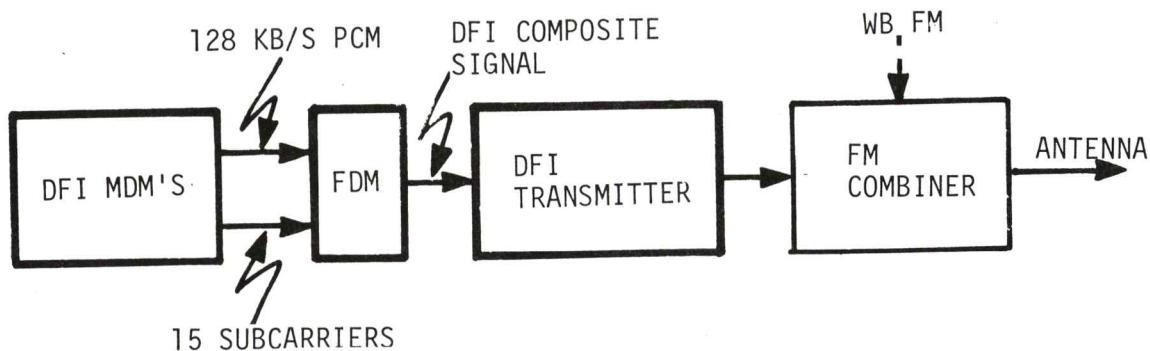
### FM Transmitter

The FM transmitter frequency modulates the data signal received from the FM signal processor for transmission to the GSTDN sites. The FM transmitters operate on the S-Band frequency of 2250 Mhz.

### S-Band Combiner

The S-Band combiner is simply a device which allows the two orbiter FM transmitters, the FM transmitter, and the DFI transmitter to share the same antenna. In short, it provides for two FM downlink transmission simultaneously.

### DFI DATA FLOW



We will now discuss the data flow for the 3rd and last data link (DFI). Recall that the DFI link is a unique STS development flight instrumentation package supplying additional engineering telemetry for early STS flights only. The DFI link is used to transmit R/T 128 Kbs DFI PCM data (just like the OD link except with different telemetry measurement and different telemetry formats). In addition to the 128 Kbs PCM data there are 15 FM subcarriers, that also get frequency multiplexed at the frequency division multiplexer (FDM). The multiplexed composite signal out of the Frequency Division Multiplexer is then used to frequency modulate the FM carrier (22<sub>05</sub> MHz) in the DFI FM transmitter before being radiated from the antenna.

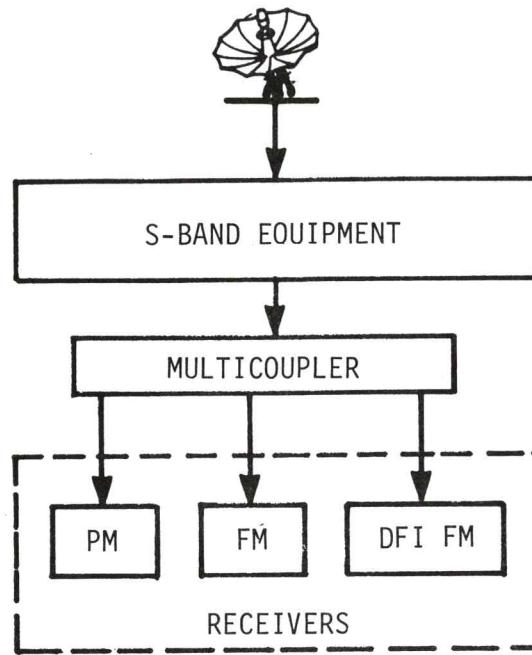
This data is used for post-flight analysis and is not sent back to MCC until the flight is over. Since DFI is not used during the flight and since the MDM's, the DFI PCMMU, DFI recorders, and transmitters functionally perform in a similar manner to the OD PM system, we will not repeat the functions here but rely on the learning material. Refer back to the lower left of the orbiter diagram and locate the DFI MDM's. Familiarize yourself with the statements. After completing the DFI flow we have completed the on-board orbiter discussion of the OD, FM Wideband, and the DFI links as they are radiated to the ground. We will now address the acquisition, reception, and processing of these 3 links by the GSTDN stations.

### GSTDN SITE



The Ground Spaceflight Tracking and Data Network (GSTDN) is comprised of a number of communication earth stations, located around the world. This discussion talks about the data flow through a typical station that has locked onto the 3 data links as the orbiter passes over. Also included is the IOS site because it is different from a typical S-Band site.

## GSTDN SITE

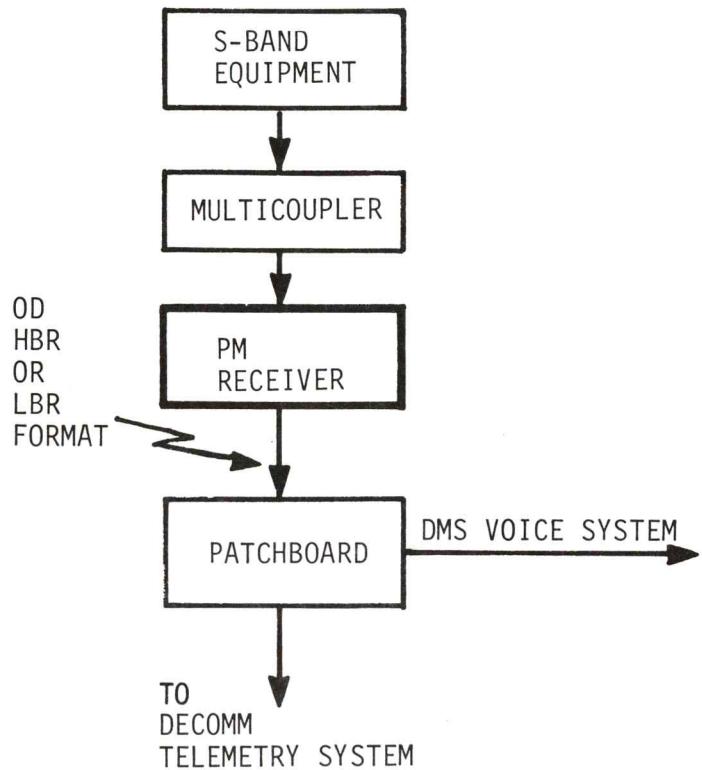


### S-Band Equipment

Looking at the "front-end" of the GSTDN station, the antenna, their associated servo drive systems, acquisition tracking systems, feed system that is the connecting link between the physical antenna structure and the S-Band receivers and the associated amplifiers; deliver the received signals to the multicoupler for distribution. The S-Band equipment provides the necessary subsystems to "acquire, amplify, and convert the orbiter S-Band signals" for proper distribution to the PM and FM receivers.

### Multi-Coupler

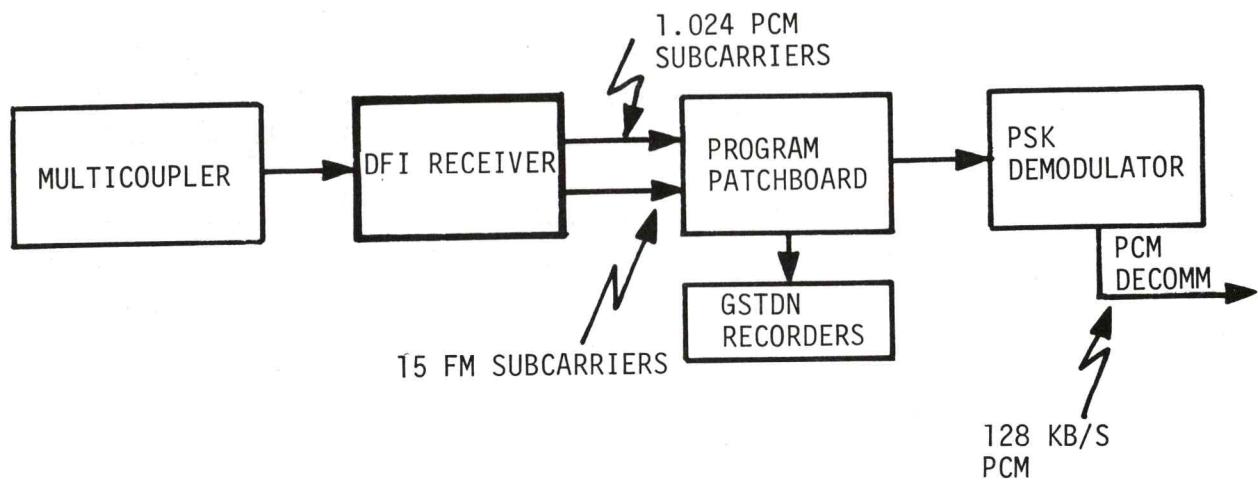
The multi-coupler allows the S-Band signals to be made available to receiving carrier detection and demodulation equipment for each of the 3 orbiter downlinks.



### PM Receiver

The PM receiver demodulates the combined received PM sum signals into the baseband signals, i.e. it removes the modulation and reconstructs the information that was being modulated in the S-Band Transponder. The baseband signal (the OD TDM telemetry and voice signals) is then transferred to both voice and telemetry systems for individual voice and telemetry processing. At this point in the system it is back in the form of the OD HBR 192 Kbs or LBR 96 Kbs format. Specifically the PM receiver:

- detects the carrier frequency and removes the modulation
- transfers the HBR or LBR link to a program patchboard where it is made available to the DMS voice, and telemetry to the PCM decomms and recorders.

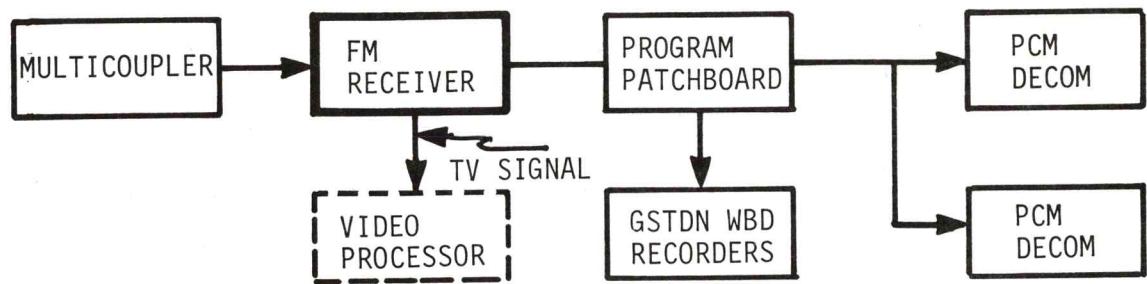


### DFI Receiver

The DFI FM receiver acquires the FM carrier, detects the 128 Kbs PCM phase shift keyed (PSK) subcarrier and transfers it to the PSK demodulator for subsequent demodulation. Likewise, the DFI receiver detects the 15 FM subcarriers and makes them available for subsequent demodulation. (NOTE: currently there is no requirement for the FM subcarriers to be processed, just the 128 Kbs PCM PSK for data quality monitoring purposes).

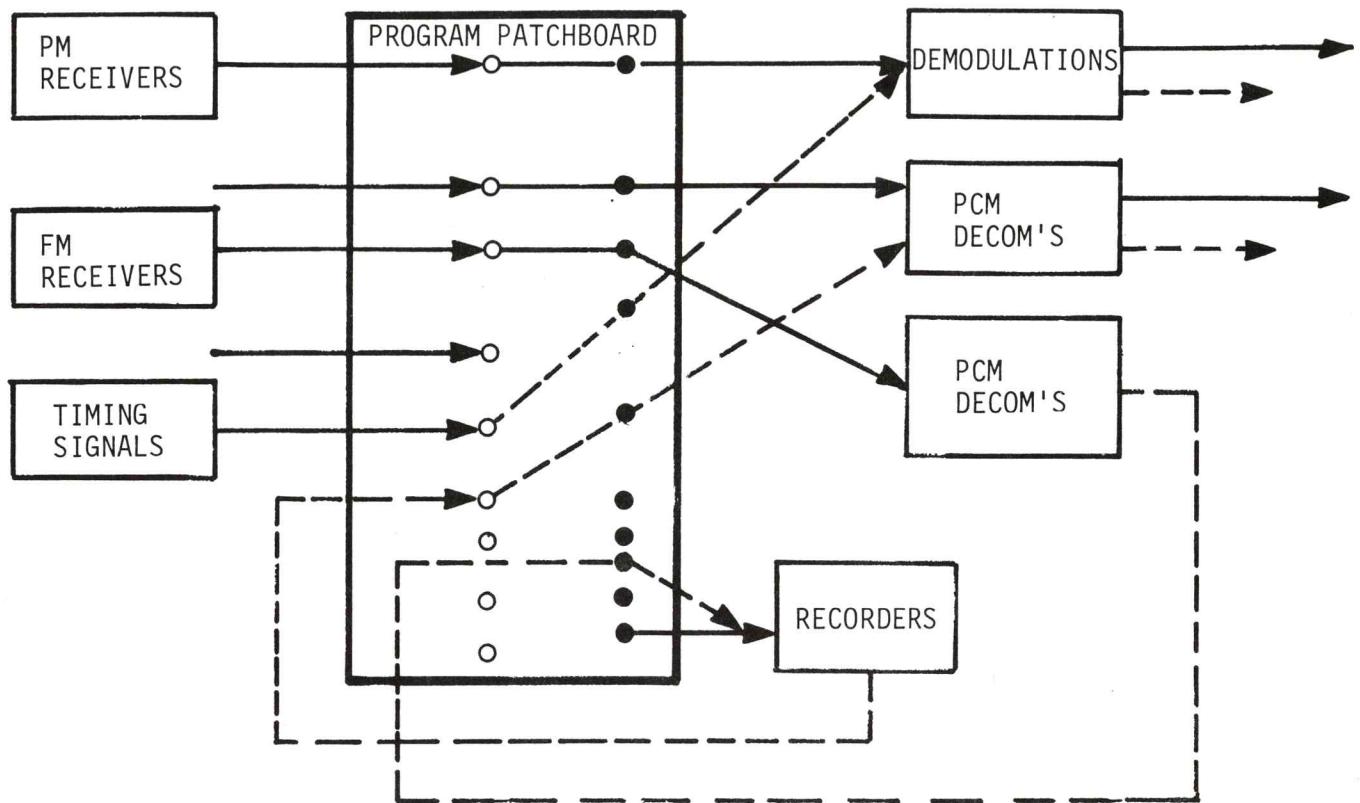
### PSK Demodulator

The Phase Shift Keyed (PSK) Demodulator receives the 1.024 subcarrier from the DFI receiver and removes the subcarrier to obtain the 128 Kbs PCM DFI signal.



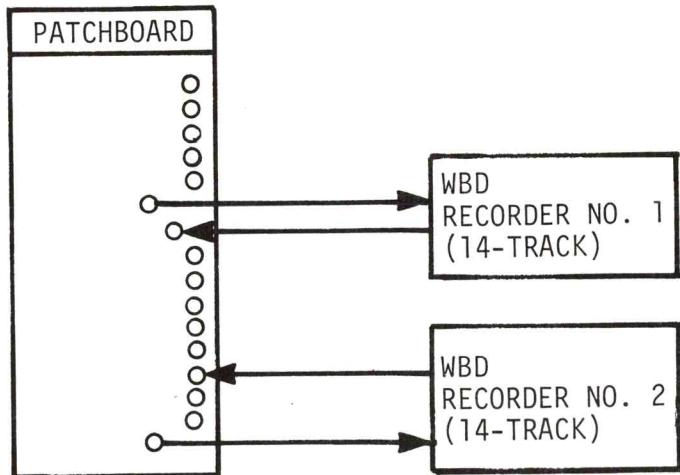
### FM Receiver

The FM receiver recovers the carrier modulating signal and demodulates the wideband data (WBD) channel. Recall that this link carries (one at a time) either main engine data, TV, Payload (P/L), or on-board OD recorder dumps.



### Program Patch Board

The program patch board provides for GSTDN subsystem signals to be routed to various selected devices. Functionally it does not alter the signals but provides a means of cross-patching various input signals to GSTDN subsystems.



### WBD Recorders

The wide band data (WBD) recorders are 14 channel (track) magnetic tape recorders used to record and playback various GSTDN data including the OD, DFI, and WBD FM received links. In addition various timing, reference, and command listing signals are recorded.

## PCM DECOMM's

### NOTE:

We will now discuss the roles of the 4 PCM (Decommutators) Decomm's at each GSTDN site. For the Space Shuttle program each decomm is utilized in a slightly different manner. However, the process performed is essentially executed in the same fashion for each decomm. The PCM Decomm's are stored program devices which utilize computer techniques to accomplish real-time processing of serial PCM data formats under the control of an internally stored program. The system automatically goes into a "search" mode and begins searching for frame sync (synchronization) patterns. After valid "checks" are accomplished the system "locks" up on the incoming frame patterns and is considered "in step" with the on-board telemetry scheme. It should be noted that any of the 4 Decomms can be programmed for either of the 4 following utilized functions but for simplicity we have assigned Decomm's Nos. 1-4 in a "typical" assignment configuration.

### PCM DECOMM No. 1

This decomm is shown as being assigned to the PM receiver (i.e., the OD link). In this capacity the PCM Decomm is programmed to process the incoming OD TDM format, either the HBR 192 Kbs or the LBR 96 Kbs format. Processing in this case means essentially 4 simultaneous functions:

- a. Validating OD frame sync
- b. Discarding (stripping) of A/G voice bits
- c. Transferring OD frame telemetry words and bits used to build the site status message word to the 642-B computer.

### PCM DECOMM No. 2

PCM Decomm No. 2 in the data flow diagram is shown as being assigned as the DFI Decomm. In this capacity, the decomm is programmed to perform frame sync lock-up and validation and provide DFI link status to the 642-B. Recall that DFI PCM data does not get processed for transfer to the 642-B and MCC. So, in this case it's a matter of validating the data and telling MCC the status of it. Remember that the DFI PCM is recorded on one of the 14 tracks of the WBD recorders at GSTDN. This tape is delivered post-flight.

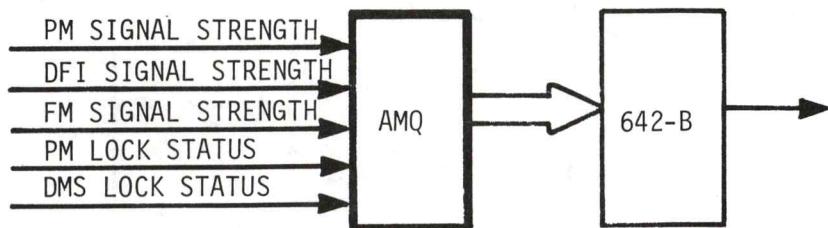
In summary then, the PCM Decomm assigned to the DFI link (in this case PCM Decomm No. 2) does "DFI minor frame validation and transfers the DFI link status to the 642-B."

#### PCM DECOMM No. 3 and No. 4

PCM Decomm No. 3 and No. 4 are shown as being assigned to the FM receiver (WBD FM link) to handle the onboard recorder OD dump data mode. Recall that for Space Shuttle, the WBD FM downlink can be used for OPS recorder OD dumps (i.e., using the FM link to playback the OD (OI and GPC) data recorded on the OPS recorder). During a real-time pass, if the OPS recorder has been commanded to stop recording and go into a "dump mode", the GSTDN site will be set up on 2 Decomms (in this example Decomms Nos. 3 & 4) to handle "forward and reverse" data blocks (i.e., "OD dump data" can be 128 Kb/s or 192 Kb/s and the downlinked data could contain interleaved blocks of backward data.) So to accommodate this possibility one decomm is set up to sync (lock-on) and frame validate forward blocks while the other is set up to sync and frame validate reverse (backward) blocks. In addition to frame validation the decomms send status bits to the 642-B to indicate bit rate, direction of dump data (forward or backwards) ratio of the dump (e.g., 1:1, 5:1, or 8:1) and the number of valid OD dump frames processed since the last message and since AOS (acquisition of signal). Meanwhile, the dump data itself (PCM telemetry) is being recorded from the FM receiver onto one of the GSTDN WBD tape recorded tracks. Post pass this OD dump data can be played back via the PCM No. 1 to MCC just like R/T OD. In other words, the 2 decomms (PCM Nos. 3 & 4) are used to validate and construct status words to MCC during the R/T pass. In summary, PCM decomm No. 3 is used for "forward dump data minor frame validation and transfers status, timing, and format ID (identification) to the 642-B." PCM decomm No. 4 is used for "reverse dump data minor frame validation and transfers status, timing, and format ID to the 642-B."

#### NOTE:

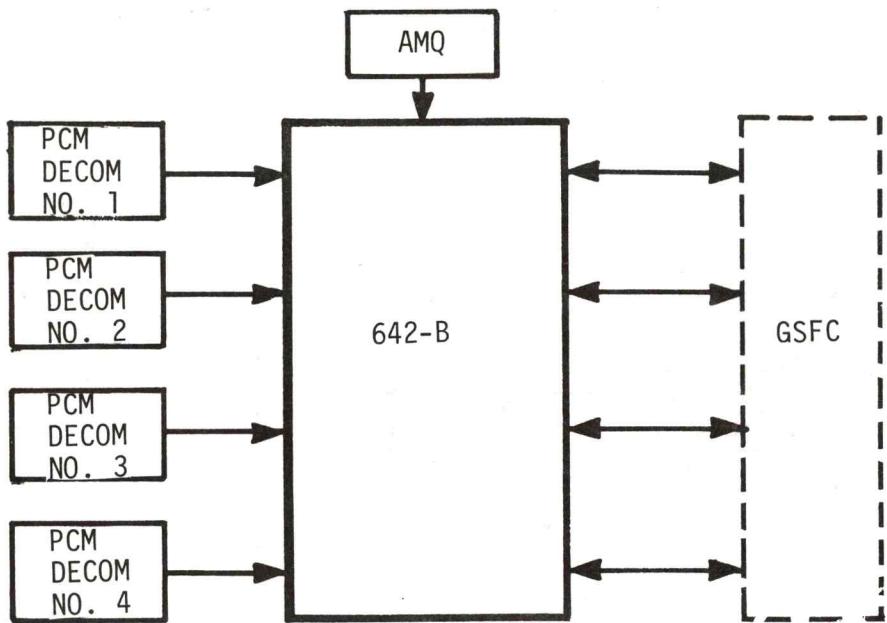
The previous discussion on PCM decomms Nos. 3 and 4 was only one example of a configuration. Both decomms might be set up to handle forward or reverse, one at 192 Kbs and the other at 128 Kbs. The configuration of these decomms is a function of what the on-board recording scheme was for that portion of the tape being "dumped". For more information on the on-board recorders you are referred to "Instrumentation INST 2102."



### AMQ

The analog to Digital (A/D) Multiplexer Quantitizer (AMQ) is simply a device which receives signal strength from the PM, DFI, and FM receivers and the "lock status" from the PM receiver and the DMS\* and converts these signals into digital words used by the 642-B system for the Site Status Message.

\*Delta Modulation System (DMS) is part of the Air/Ground Voice system. It is discussed in the A/G Voice Workbook GND A/G 2102A.



### 642-B Computer System

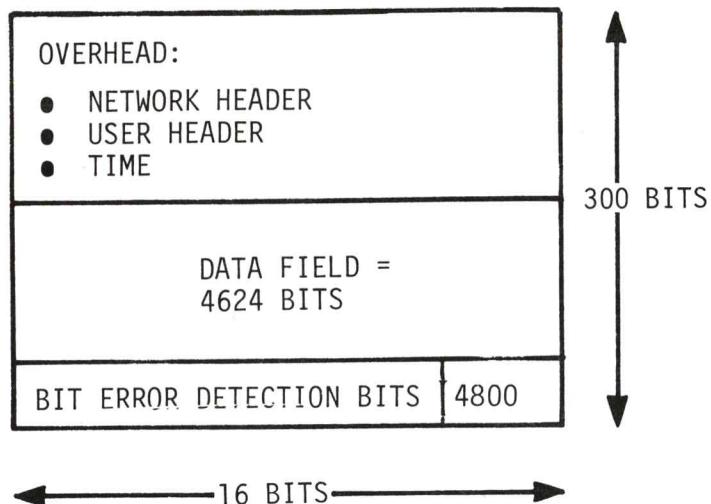
The Univac 642-B computer system is essentially the telemetry communications processor between the "front door" and the "back door" of the GSTDN site. It handles the 4 PCM decomm outputs and the AMQ to accomplish during real-time passes, the following:

- a. OD telemetry transmission to MCC
- b. DFI link status to MCC
- c. FM link status to MCC
- d. Site status to MCC.

} all constructed into a Site Status Message (SSM) once per second.  
NOTE: for SSM definition, refer to JSC-11534 JSC/GSFC Communication ICD.

Post-Pass it can process R/T and OD dump telemetry playback. In addition to the real-time and post-pass telemetry it also constructs a "Data Link Summary Message" (DLSM). A DLSM provides a summary of the orbiter R/T OD, OD dump, and DFI data downlinked during a pass. It amounts to a data and message accounting scheme vs. actual data measurement values. Such things as vehicle ID, flight no., message count, GSTDN site ID, Data type, time of receipt, number of valid frames, number of dropouts, etc. are contained in this message. MCC requests generation of this message post-pass and it can be generated within 5 minutes of (LOS) Loss of Signal by each GSTDN site.

All of the above products output by the 642-B systems i.e., R/T OD TM, playbacks, site status messages, and post-pass DLSM's are formatted and output by the 642-B in a standard NASA Communications NASCOM/4800 bit blocks. This is called a "Blocked Data Format" (BDF).

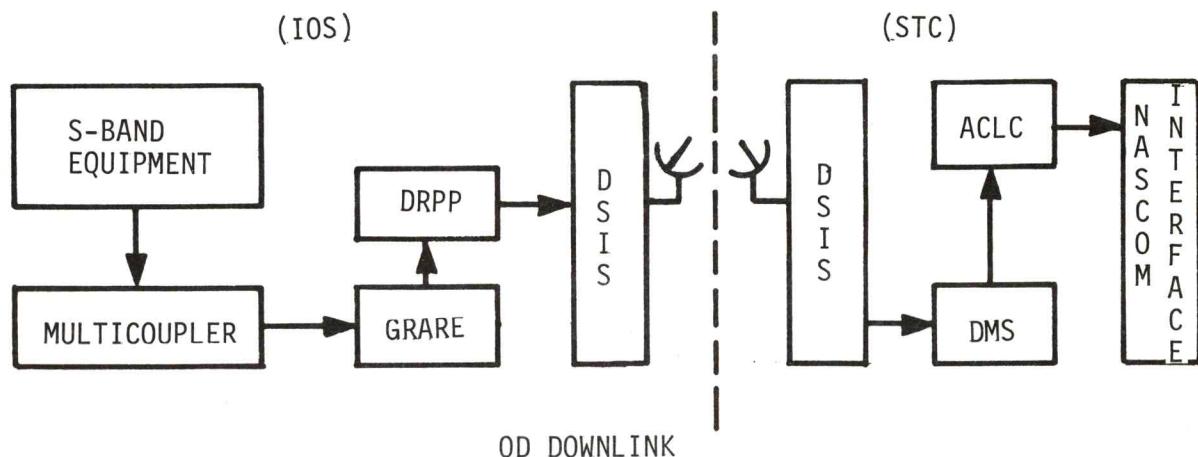


The 642-B then outputs this data by multiplexing the 4800 bit blocks onto three (3) 56 Kbs lines connected to the Goddard Space Flight Center (GSFC) switching center i.e., GSFC Message Switch on your diagram. (NOTE: the communications equipment between the 642-B and GSFC is not shown for simplicity but it is there and consists of standard communications transmit and receive equipment).

In summary, the 642-B computer system:

- Processes and outputs R/T P/B, and dump OD telemetry data to MCC
- Builds and outputs SSM to MCC
- Builds, stores, and outputs DLSM to MCC (on demand)

## INDIAN OCEAN STATION (IOS)/SATELLITE TEST CENTER (STC)



### S-Band Equipment

Same as previously discussed at GSTDN site.

### Multi-coupler

Same as previously discussed at GSTDN site.

### GRARE (Ground Receiving and Routing Equipment)

The GRARE receiver demodulates the incoming PM signal into the baseband signal. The baseband signal of telemetry and voice is transmitted to the GRARE output device. This equipment replaces the PM receiver that is at the GSTDN site.

### DRPP (Date Routing Patch Panel)

The DRPP output is simply a device that routes the PM baseband signal to the DSIS. This equipment is similar to the Program Patch Board at the GSTDN site.

### DSIS

The DSIS transmits digital voice, telemetry and ranging via the Defense Communication Satellite system to the STC at Sunnyvale, California.

### STC/DSIS

The DSIS at Sunnyvale receives the digital voice data, telemetry and ranging data from the Defense Communication Satellite System, records the data and transmits the incoming data to the appropriate output devices.

### Delta Modulation System (DMS)

The function of the DMS in processing downlink telemetry and voice data is to extract the voice signal from the composite signal, and to reassemble voice and telemetry data in their proper order. The telemetry data is reassembled to provide serial bit-stream outputs.

### Adaptive Communication Line Controller (ACLC)

The ACLC builds telemetry data in a 4800 bit Nascom blocked data format for transmission to MCC via GSFC. In the ACLC, the data is buffered in and packed first-in/first-out into data blocks of 4624 bits. The ACLC adds a header, a time tag and block allocated to a polynominal error protection remainder. The total of the above becomes a 4800 bit NASCOM blocked-data format message for transmission to NASA.

### STC/NASCOM Interface:

The NASCOM interface between the STC and GSFC consists of a 56 Kbps data line from GSFC to the STC and a 224 Kbps line from the STC to GSFC for command and telemetry processing. In addition, tracking, teletype information and two voice data lines are utilized.

The NASA Communication Network (NASCOM) consists of several systems of diversely routed, full period communications channels leased from various domestic and foreign common carriers on a worldwide basis. These channels consist of leased landlines, submarine cables, and communications satellites.

### Summary

The major subsystem functions for the DFI and FM wideband data flow have been discussed previously. They are essentially the same as discussed in the GSTDN site subsystem section.

PAUSE AND REFLECT:

This segment is getting rather lengthy so let's stop a second to reflect on where we've been. We have essentially, up to this point, discussed the functions of the major systems of the OD, DFI, and FM telemetry links on the orbiter, at a typical GSTDN orbital support station, and at the IOS.

The data transmission of a GSTDN station to MCC is via the GSFC. The means of data transmission between GSTDN and GSFC is the 3 56 Kbs circuits. The effective bandwidth therefore, represents  $3 \times 56 = 168$  Kb/s to transmit 4800 bit BDF words from each station. If 1 of the 56 Kb/s lines were to fail for any reason then the remaining 2 56 Kb/s line could still be used to transmit 4800 bits at a time (at a lower bandwidth) in the LBR mode.

NOTE:

There are some exceptions to the 3 56 Kbs line configuration from the sites to GSFC e.g., the Buckhorn entry support station uses one 168 Kbs line and some launch support sites will have one 224 Kbs circuit, however the majority of the orbital support GSTDN sites will use 3 56 Kbs lines. The NASCOM interface between STC and GSFC consists of a 56 Kbps data line from GSFC to STC and a 224 Kbps line from STC to GSFC.

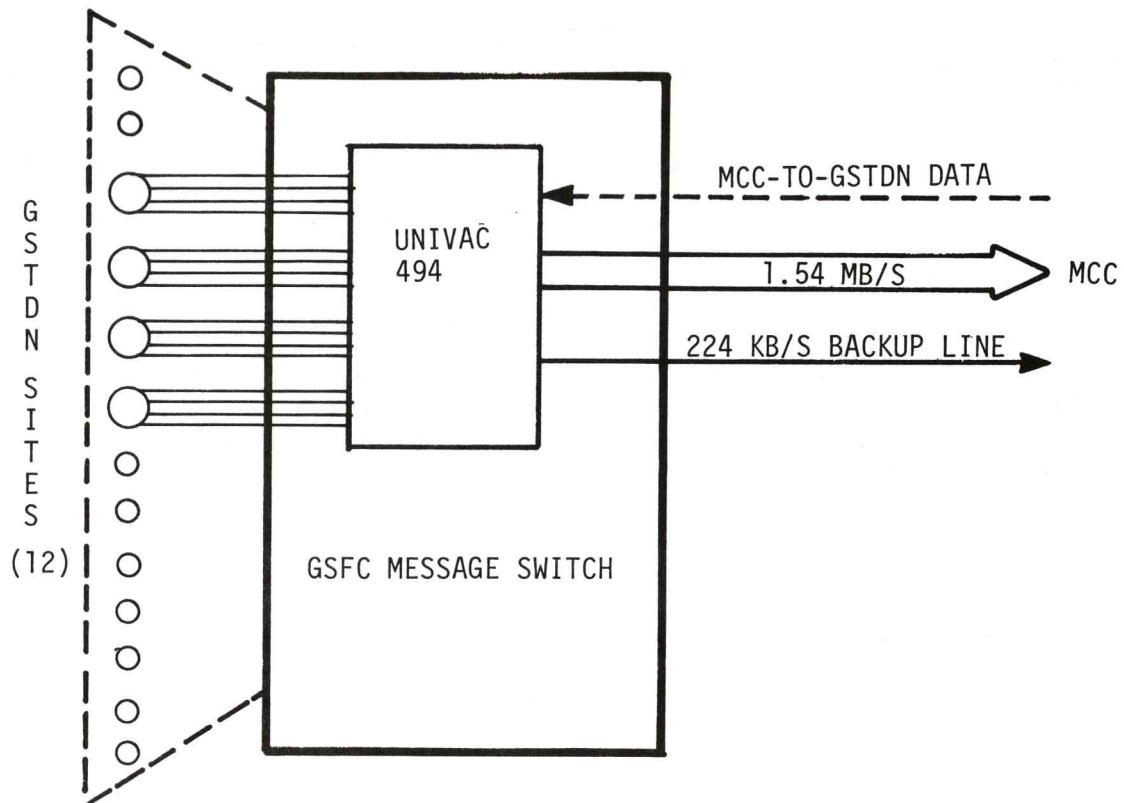
The most likely utilization of these circuits will be:

- OD and SSM's during site AOS (acquisition of signal) to MCC
- OD Playback or recorder dumps, or DLSM, post-pass.

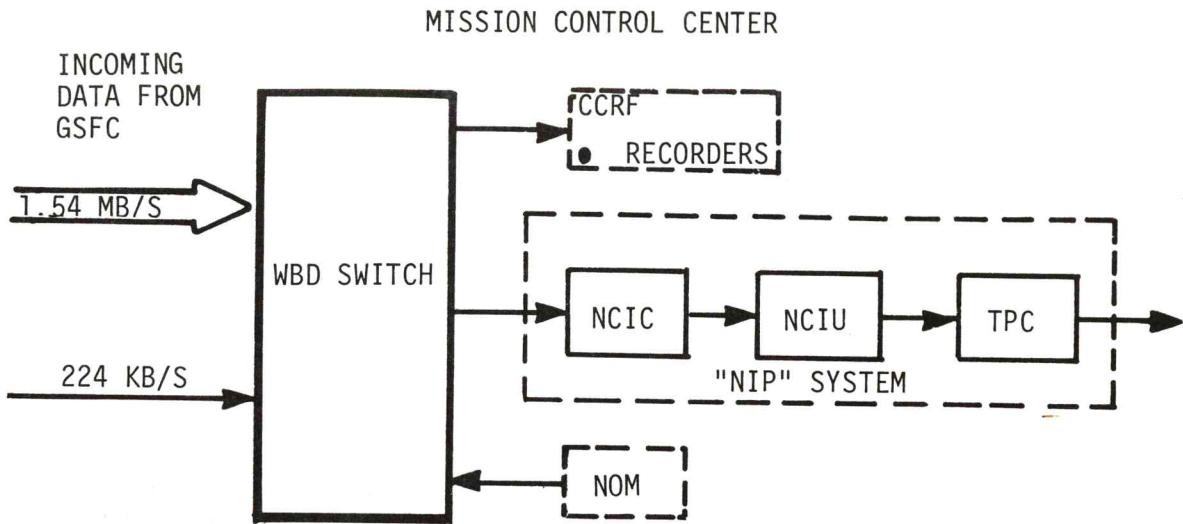
Let us now continue on with the data flow to and through GSFC to MCC.

### GSFC Message Switch (494)

The GSFC Message Switch has a Univac 494 computer as the heart of the system which allows up to (12) 56 Kbs incoming circuits (lines), representing 4 sites at a time, to be processed.



The 494 computer is programmed to accept the data lines from 4 sites simultaneously. As it receives BDF data in 4800 bit blocks it checks, identifies, accounts, and multiplexes the data onto a 1.54 megabit/second (Mb/s) data line to MCC. Data from the switching center to JSC MCC is also in the block data format (BDF) earlier described. A 224 Kb/s secondary (back-up) data link is provided and can accommodate data up to one GSTDN site at a time.



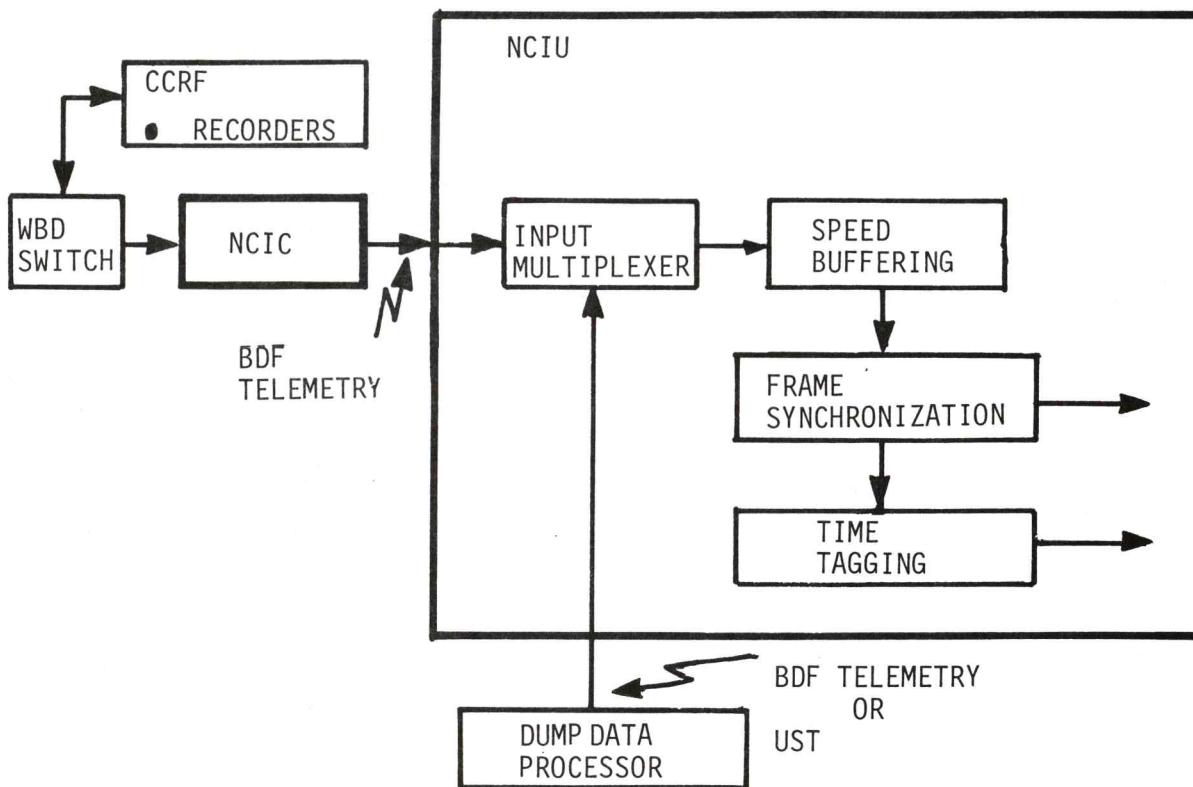
### WBD Switch

The Wide Band Data (WBD) Switch (also referred to as the WBD Transfer Switch) "controls, switches, and routes WBD circuits to and from MCC". This equipment provides not only switching and routing of circuits but it provides access for testing, monitoring, and restoration of up to 24 full duplex WBD circuits entering and leaving the MCC.

### Network Communication Interface - Common (NCIC)

Before addressing the NCIC specifically let us pause and introduce a new term, the Network Input Processor (NIP) system which is used to denote and encompass a number of subsystems that are discussed herein. The NIP is really comprised of the Network Communication Interface Common (NCIC), Network Communication Interface Unique (NCIU), and the Telemetry Preprocessor Computer (TPC). We will not discuss the NIP to any extent except to point out that collectively it serves to perform a generalized communications interface and routing function, and a generalized decommutation service for orbiter and associated payload data (if any). Prior to routing telemetry data, processing is performed to compensate for idiosyncrasies in Orbiter generated downlink data, permitting more conventional decommutation techniques to be utilized for subsequent processing of telemetry data by other MCC elements.

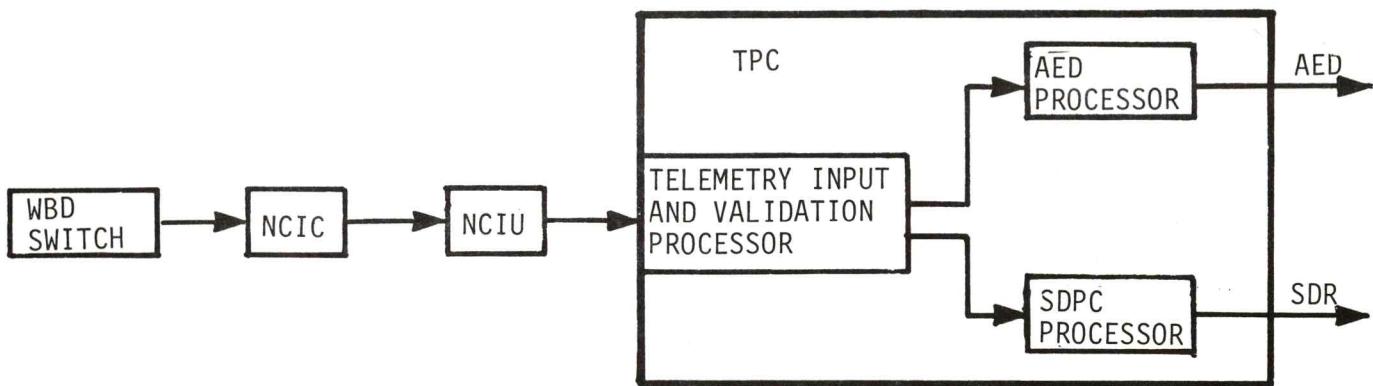
OK, let's get back to the NCIC and see how it serves to support the functions just discussed. The NCIC provides input interface with the WBD links and performs management type functions including block data format (BDF) synchronization, polynomial code checking, header processing, selective message handling, and communications error statusing. In summary it performs "message processing and routing of all incoming NASCOM 4800 bit block data formatted messages, message accounting and error statusing".



#### Network Communications Interface - Unique (NCIU)

Up to now we have discussed how 4800 bit blocks in BDF is handled from the output of the GSTDN site until it gets into the MCC. It is now time to see what action and process takes place with the data frames themselves once the data is received at the MCC. The NCIU will handle a single telemetry data stream. The data may be in either a BDF from an NCIC or an unblocked serial telemetry (UST) format. The NCIU performs frame synchronization and transfer of telemetry data to the TPC on a minor frame basis. The telemetry frame synchronizer initially searches the data on a bit-by-bit basis for the telemetry frame sync word. Once initial sync has been obtained, it goes into a "check" mode where the frame synchronizer counts the number of bits or words to the end of the data frame and then looks for the sync word at the expected location. After several consecutive in tolerance sync patterns have been detected, the frame synchronizer advances to the "lock mode". The NCIU, in this sense, is "building the minor frame" from the BDF data. Additional functions performed by the NCIU include network speed buffering to compensate for varying network rates e.g., 224 Kb/s and 1.54 Mb/s, and generation of ground receipt time (GRT) delta time components for the TPC, for BDF telemetry, the NCIU determines a delta bit count by counting the number of bits between the first data bit of the block and the first bit of the airground (A/G) sync pattern. The TPC will then calculate a delta time between GRT and on-board vehicle clocks.

In summary, the NCIU performs "A/G frame sync detection, minor frame building, and GRT delta time ( $\Delta T$ ) detection for a single telemetry stream."



The TPC is essentially a 32-bit minicomputer with the capability of directly addressing up to 1 megabyte of core memory. The telemetry preprocessing function includes breaking the data stream down into its appropriate data sets and performing decommutation scheme in order to display the data and process it further. Also included are input/validation processing, analog/event distribution (AED) processing, and Shuttle Data Processing Complex (SDPC) processing.

a. Input/validation Processing. This task validates all minor downlink frames received by the TPC from the NCIU. In addition, the downlinked data is separated into its principle parts (i.e., OI and subcoms) as a function of downlink/downlist characteristics, which are defined premission by format identification (ID's). All valid frames from the downlinked data set are moved to appropriate storage areas for use by the output processors. When sufficient data is received to describe a "data cycle", the status and statistics pertaining to the data cycle are posted, and the data released for use by TPC processor/-function. This processing includes:

- (1) Minor frame validation.
  - A/G status word check
  - Frame count validation
  - OD format ID verification.
- (2) Subcom (subcommutation) validation.
  - GPC subcom (sync, count, and ID).
- (3) Data cycle validation.
- (4) Time Processing.
  - Calculates and adjusts GRT time.

(5) Format processing.

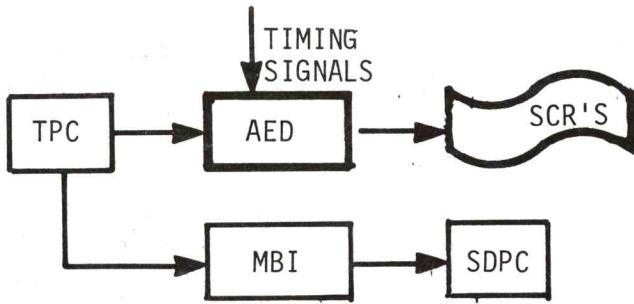
- Format verification
- Detects format changes.

b. AED Output Processing. The Analog/Event Distribution (AED) processor interfaces directly with the AED by formatting and transmitting analog, event, and timing for the driving of the displays on analog and event recording devices.

c. SDPC Output Processing. The SDP processing includes the output of 3 basic types of messages to the SDPC: 1) real-time data message used to transmit all vehicle telemetry with its associated status; 2) a summary message which provides a tape index of all telemetry data processed by the TPC; and 3) a configuration status message.

In summary, the TPC provides for:

- Master frame validation/decomm (OI)
- GPC subcom decommutation
- Time calculations
- Sample rate reduction
- Logging
- Status summary
- Outputs preprocessed telemetry data to the AED and the SDPC.



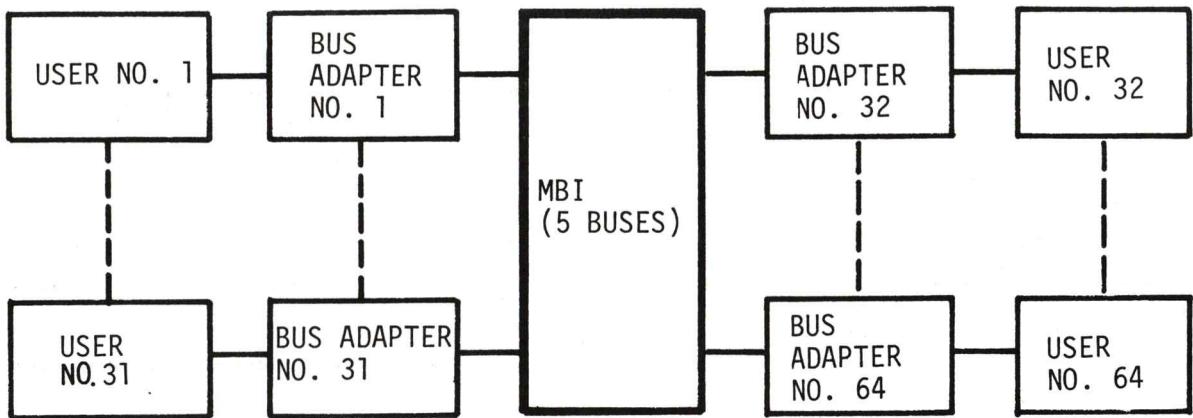
### AED (Analog/Event Distribution) Equipment

The AED receives analog and bilevel event data from the TPC and distributes this data to analog and event strip chart recorders (SCR's) located throughout the MCC. It can drive a maximum of 200 analog pens and 400 event pens simultaneously. In addition to telemetry data, it accepts timing signals from the MCC timing equipment for displaying GMT and various other spacecraft and ground time reference signals.

In summary, the AED "Converts and distributes analog event, and time data to analog and event strip chart recorders". (SCR's)

#### NOTE:

The AED is also referred to as the AES (Analog Event System).

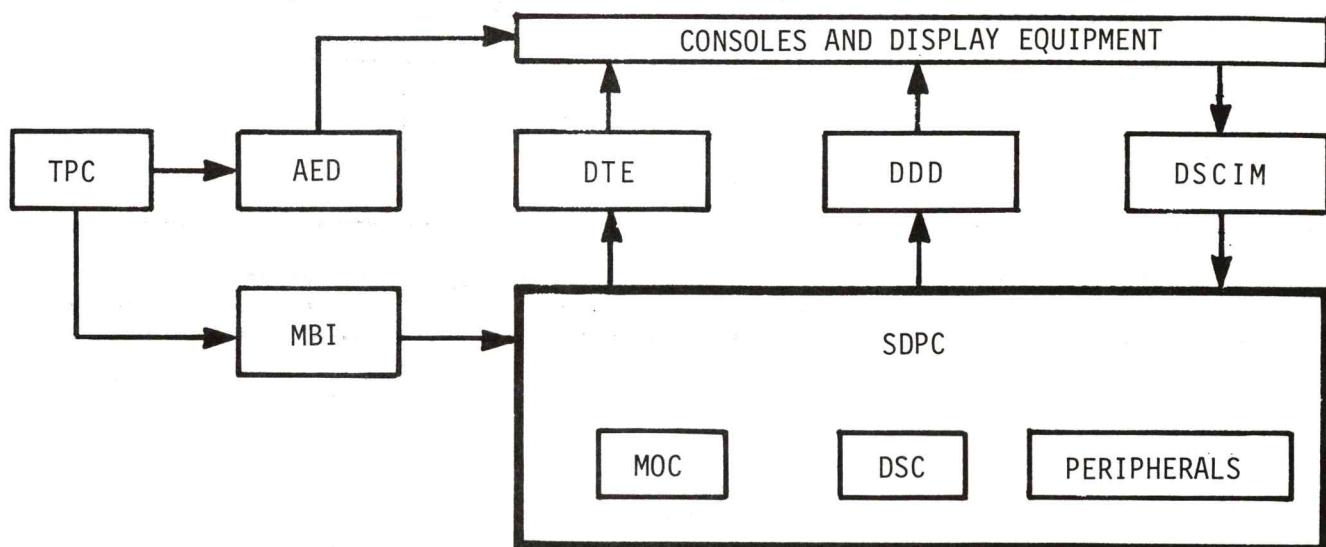


#### MBI (Multiple Bus Interface)

The MBI subsystem consists of two redundant standalone units (MBI-A and MBI-B) which have 64 interface adapters and 5 data buses each. They provide data link communications between 64 possible users. This link has the capability to establish message source and destination, operate transmission and reception equipment, detect and recover errors, supervise data exchange, and perform functions related to such communication. The MBI provides a common data bus enabling multiple paths that can be established dynamically on a demand basis between the users.

Users include the SDPC, NIP (TPC or NCIC's, NCIU's) and Network Output Multiplexer (NOM). The NOM is a "command" device not covered here.

In summary, the MBI provides a "data bus system for multiple paths between elements of the NIP, NOM, and the SDPC."



### SDPC (Shuttle Data Processing Complex)

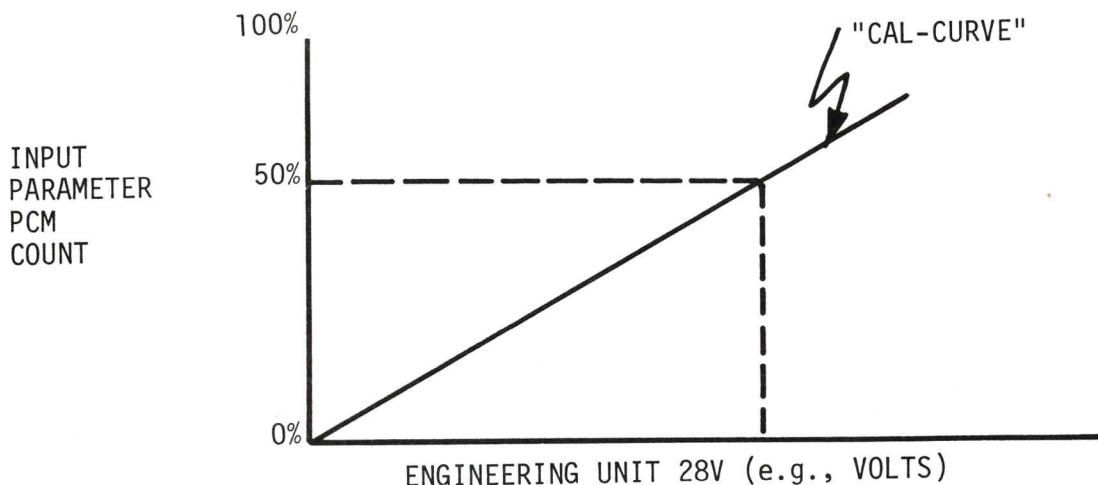
The SDPC is the computational element (IBM-370 computers) which, contains the application programs which validates, calibrates, performs special computation, performs real-time (R/T) display functions, performs data retention, and performs data tracking and management functions for telemetry data.

#### NOTE:

Within the SDPC there are several IBM 370 computers. Whichever 2 computers are selected for the on-line support discussed herein, they are assigned as a "mission operations computer" (MOC) and as a "dynamic standby computer" (DSC). You will most likely hear the words MOC and DSC referred to more often than the "SDPC" since the SDPC houses a number of computers and their associated peripherals. However, since we are really talking about the collective role the SDPC performs as a support element, we will continue to refer to it here as the SDPC. Keep in mind that operationally speaking the MOC/DSC is the term most usually used.

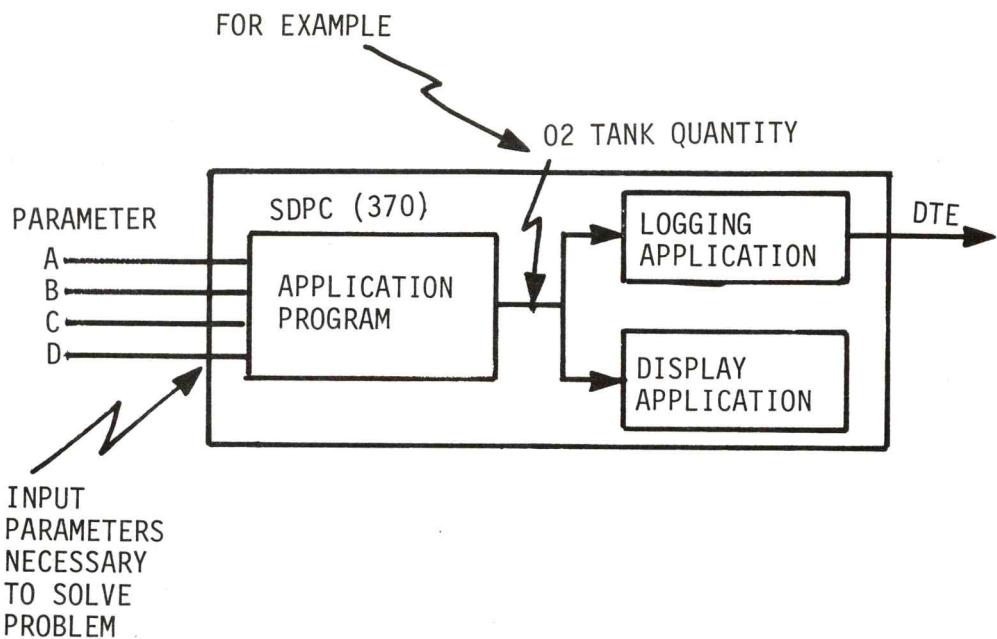
In general, the SDPC performs the following functions:

- a. Data Validation. Each valid input frame is "unpacked" using a set of constants for each format number. Data is validated prior to processing and indications of out-of-sync condition (if any) displayed.
- b. Calibration and Engineering Unit (EU) Conversion. This process involves the interpolation of PCM input "counts" e.g. a per cent full scale with a "calibration curve".

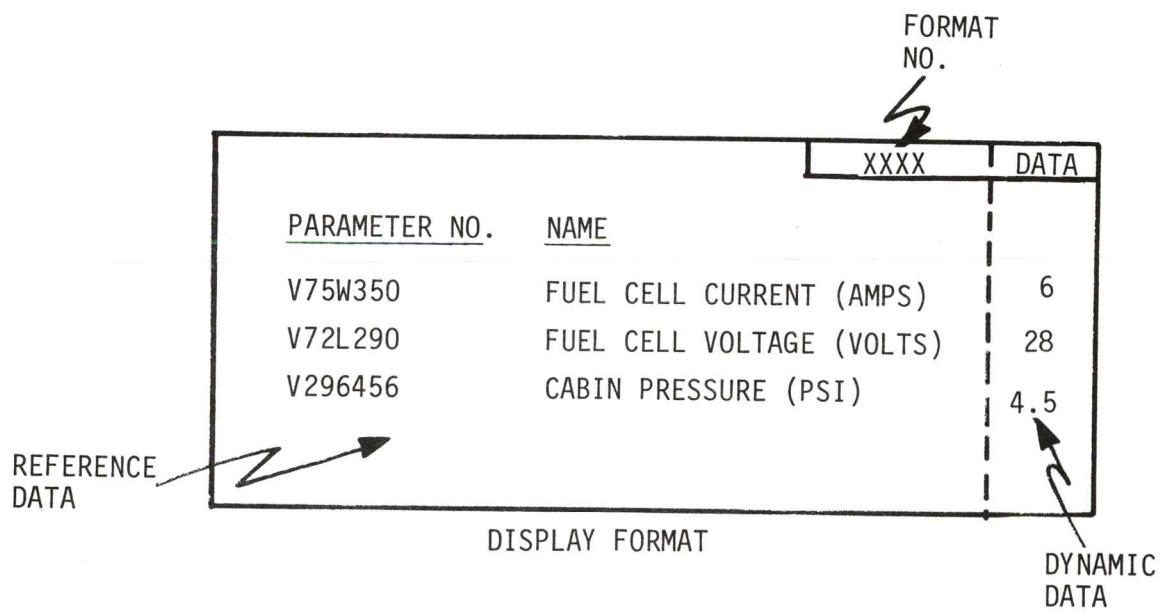


The above example shows that for a particular parameter PCM count of 50% full scale would equal an engineering unit (EU) value of 28 volts. Each orbiter parameter will have at least one calibration curve stored in the SDPC.

- c. Limit Sensing. This application provides for the ability for appropriate MCC personnel to establish "limits" on a parameter and have the SDPC "watchdog and alert" if the parameter exceeds the specified limit. For example limits could be set for cabin pressure where X = lower limit and Y = high limit. If either of these limits are exceeded then the SDPC might be programmed to lite lights, ring a buzzer, flash a symbol on a display, etc.
- d. R/T (Real/Time) Computation and Analysis. This function is used to compute and analyze logical solutions from a variety of inputs whereby a combination of more than one parameter is required to solve a problem. Some examples of problems to be solved are:
  - (1) Recorder per cent tape calculations
  - (2) Fuel cell power
  - (3) Orbiter power
  - (4)  $O_2$  flow rates
  - (5)  $O_2$  tank quantity

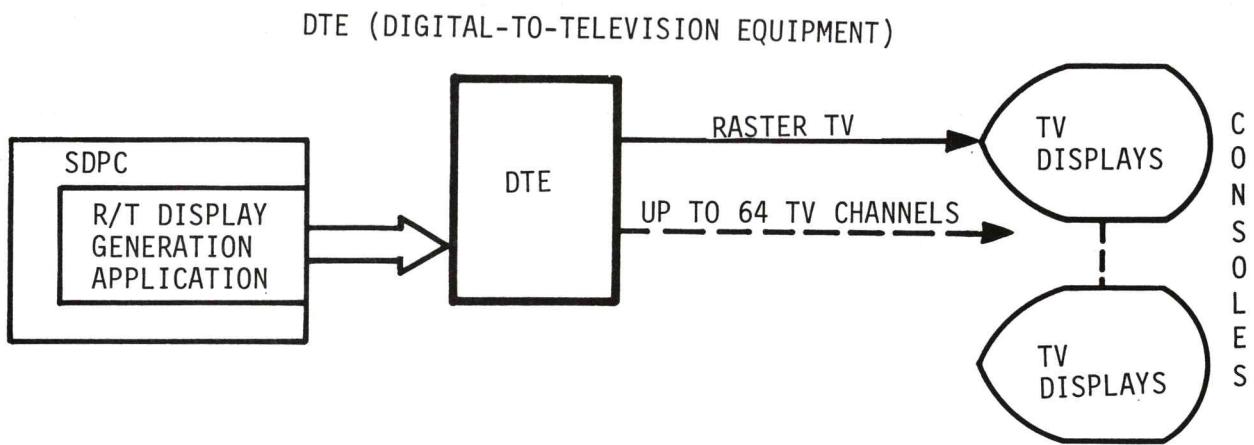


e. R/T Display Generation. This application provides for the data assembly, formatting, updating, and driving of telemetry data displays. Data displays include the Digital-to-Television Equipment (DTE) displays and the Digital Display Driver (DDD's) displays. The DTE channel driven by the SDPC contain data arranged (formatted) in a pre-arranged format determined pre-flight. The DTE channels carry formatted data destined for display via the television monitors. The SDPC is where the requested formats are assembled and output in digital words which contain both the background (or reference data) and the dynamic data. A simplified example:



Data displayed over the DTE channels is called up by "formats" from flight operations consoles via special keyboards (discussed in the "user tools" lesson). Each format called up utilizes one of the DTE channels. The Digital Display Driver (DDD's) driven by the SDPC contain event driver logic which illuminates event indicators on flight operations console. (The DDD's will be discussed shortly.)

In summary, the SDPC "performs TM calibration, TM limit sensing, TM EU conversion, R/T TM computation and analysis, and performs R/T TM data presentation to DTE and DDD's."

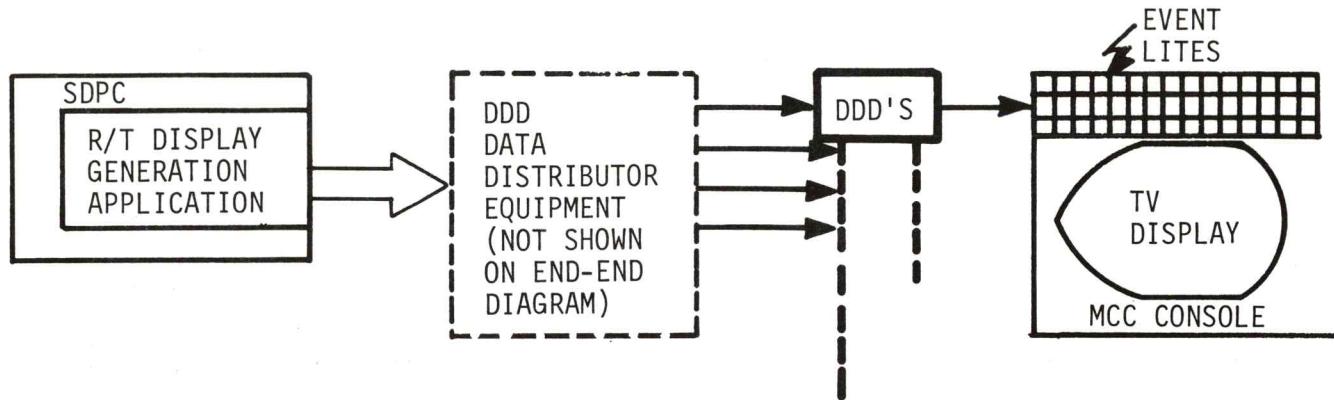


#### DTE (Digital-to-Television Equipment)

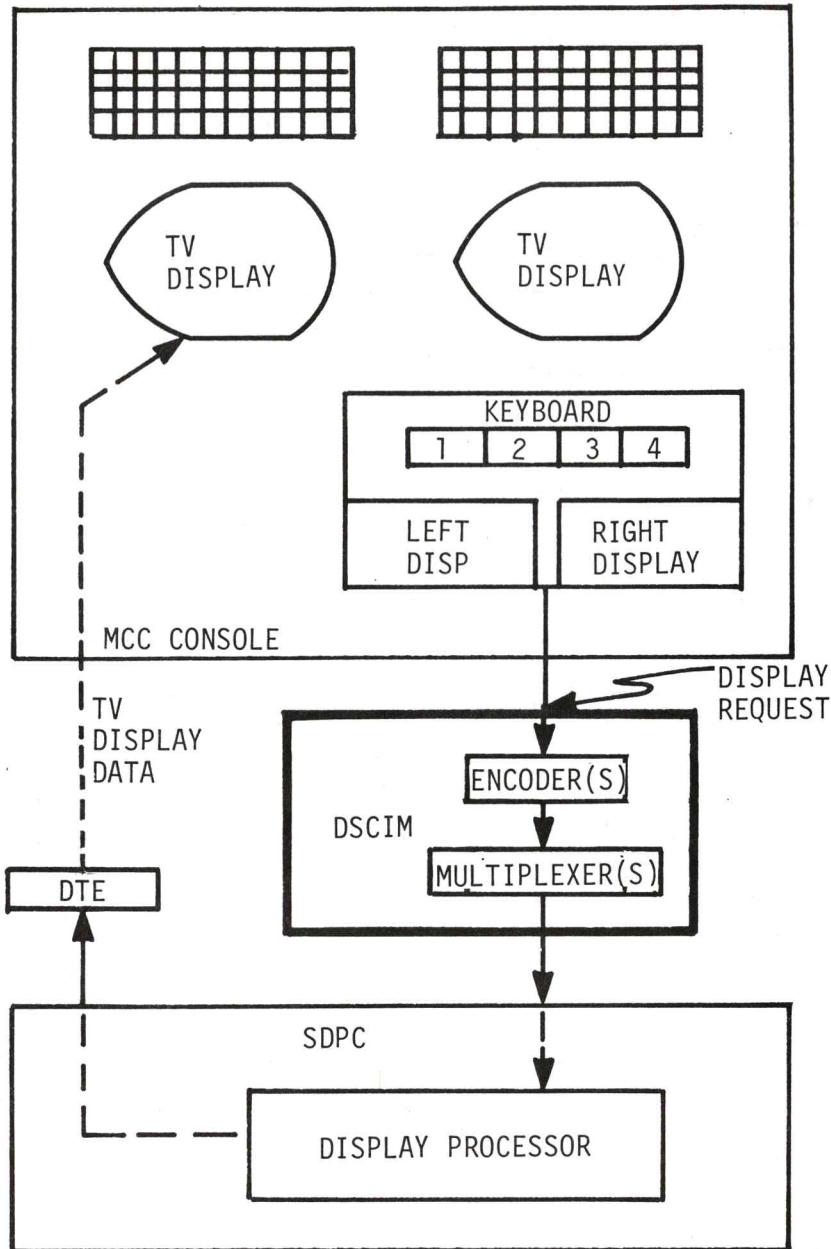
The DTE provides the capability to convert the SDPC digital computer information into dynamic raster type video displays containing both alphanumeric and graphic information. It continually refreshes the last information received from the SDPC until the display is either deselected by the user or updated by the SDPC. For flight operations purposes there are 64 television channels available, however for early STS flights a maximum of 38 channels will be allocated to STS telemetry driven displays. (Trajectory, command, and other uses take up the others.)

In summary, the DTE "converts SDPC computer language into dynamic TV video displays".

## DIGITAL DISPLAY DRIVERS (DDD's)



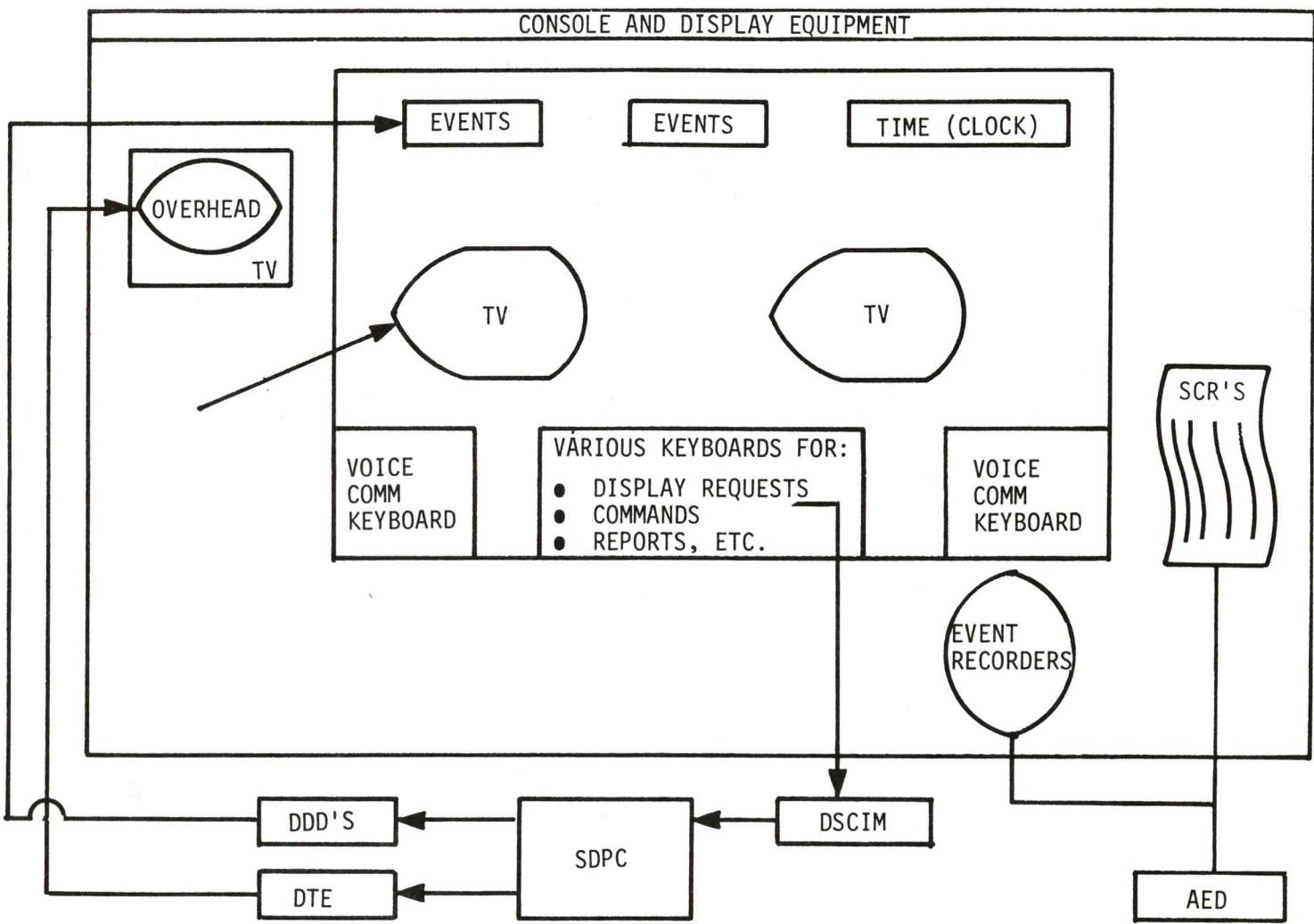
The DDD channels are driven by the SDPC to drive up to 5300 indicators simultaneously on up to 50 consoles at an update rate of once/second. Not all of these are telemetry driven indicators but a good portion are. These include latching and non-latching event and limit lights.



#### DSCIM (Display Select Computer Input Multiplexer)

The DSCIM is used to accept console keyboard inputs requesting display information from the SDPC. It detects, formats, and multiplexes large numbers of data request entries from the console users to the SDPC. Each keyboard request is encoded into information relative to console ID, data desired, where to display it, etc. The SDPC then acts upon the input information and completes the necessary steps to provide the requested display data back to the requester (user).

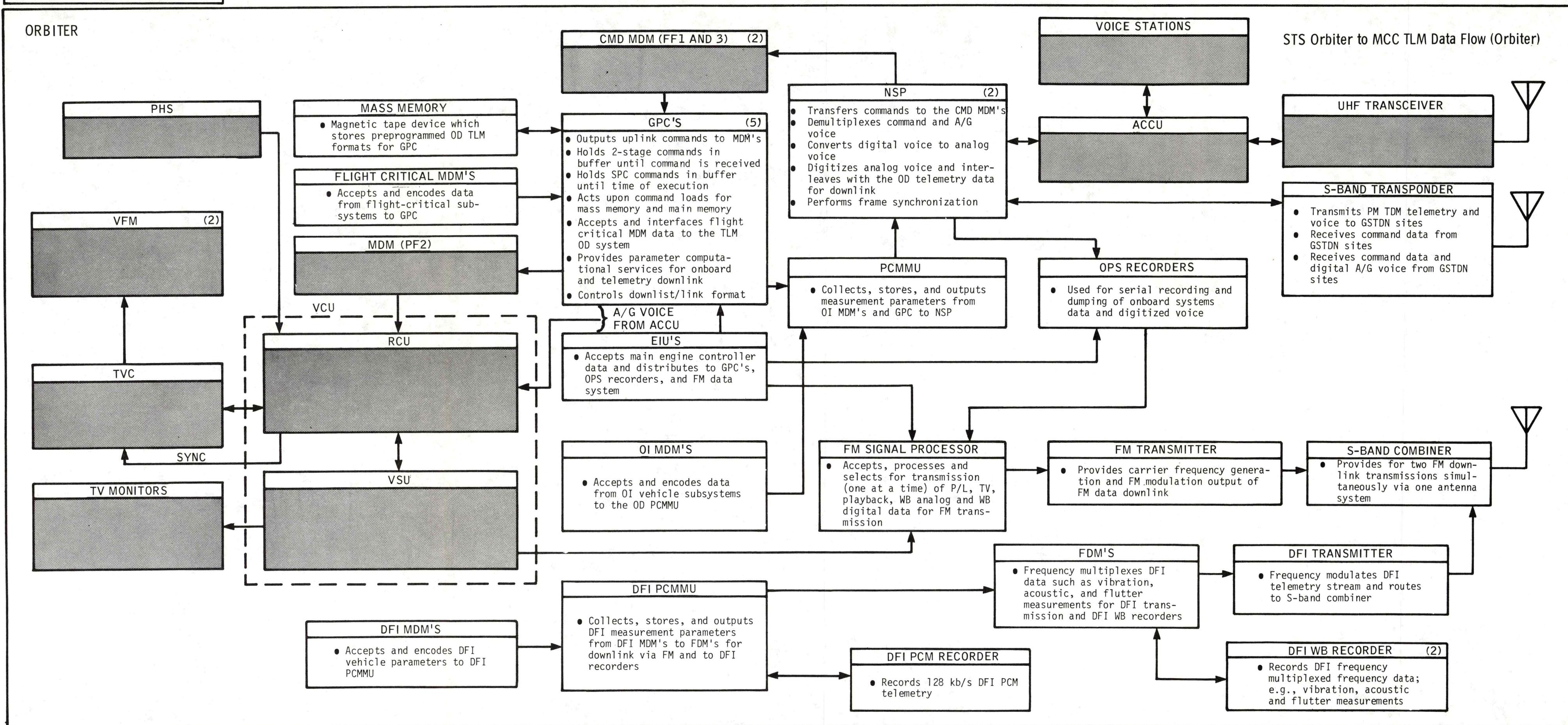
In summary, the DSCIM "detects, formats, and multiplexes display request from console keyboards to the SDPC".



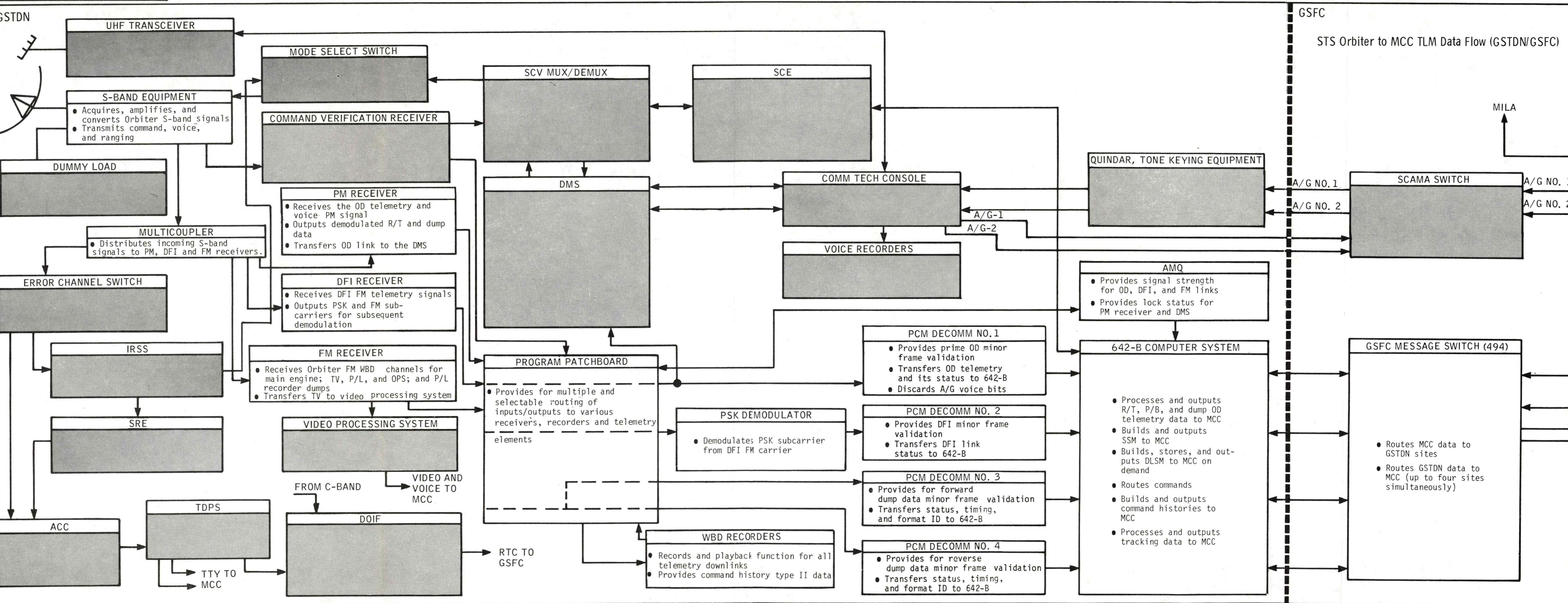
### Console and Display Equipment

The console and display equipment consists of essentially the elements used to ask for display information and those which display information. These consist of the consoles, CRT's (TV monitors), keyboards, indicators (e.g. clocks, event lites), and strip chart recorders (SCR's). In summary the Console and Display Equipment consists of "MCC consoles, input keyboards, displays for TV, event lights, SCR's and clocks".

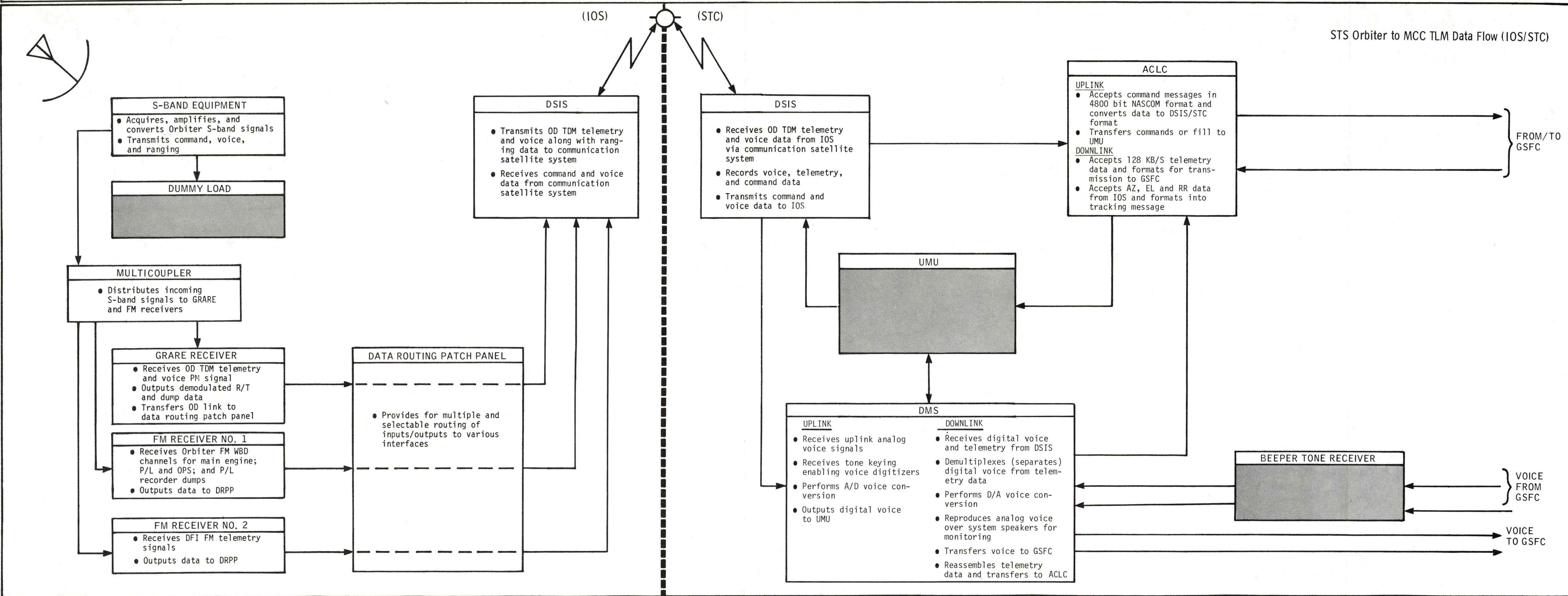
# Learning Material



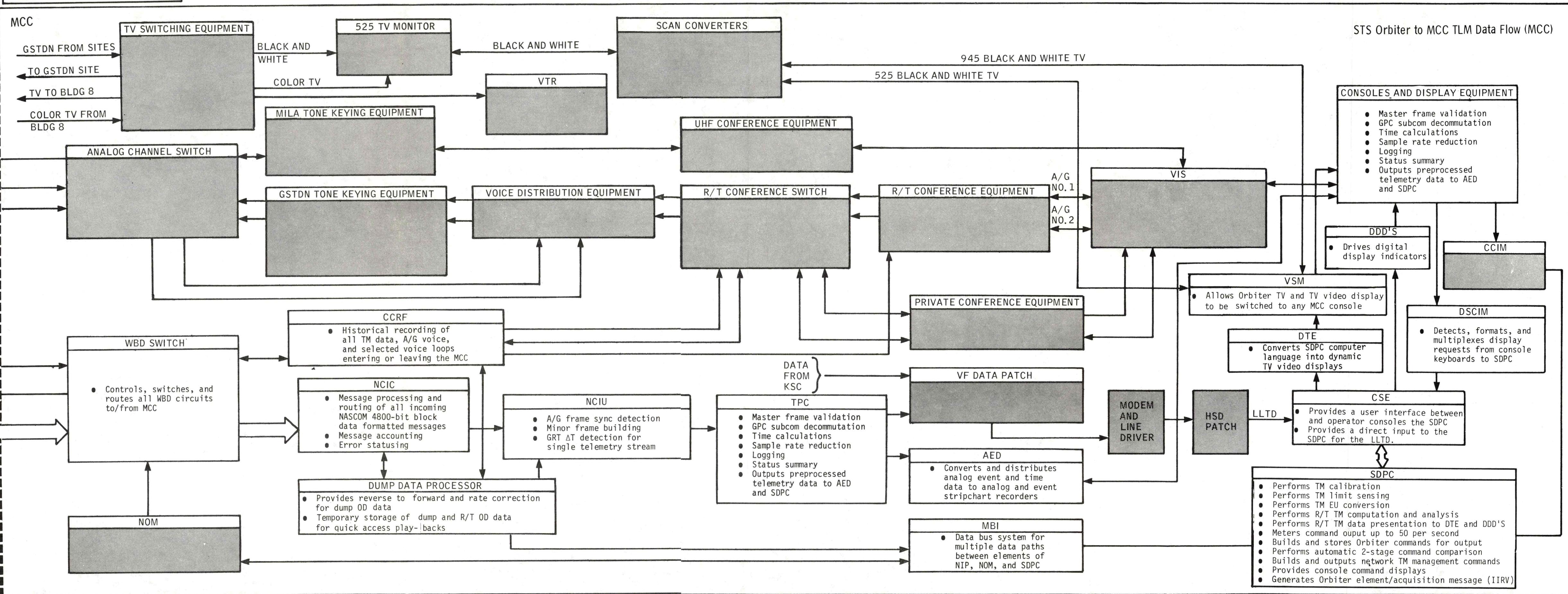
## Learning Material



## Learning Material



## Learning Material



PRACTICE:

Match the groups of functions listed below with the blank STS Orbiter-to-MCC Telemetry Data Flow diagram on the following page.

I. ORBITER

A.

- Digitizes analog voice and interleaves with the OD telemetry data for downlink
- Performs frame synchronization
- Demultiplexes command and A/G voice
- Transfers commands to the CMD MDM's.

B.

- Used for serial recording and dumping of on-board systems data and digitized voice.

C.

- Transmits PM TDM telemetry and voice to GSTDN sites.
- Receives command data from GSTDN sites
- Receives digital A/G voice from GSTDN sites.

D.

- Magnetic tape device which stores preprogrammed OD TLM formats for the GPC.

E.

- Accepts and encodes data from OI vehicle subsystems to the OD PCMMU.

F.

- Accepts and encodes data from flight critical subsystems to the GPC.

G.

- Accepts and interfaces flight critical MDM data to the telemetry OD system.
- Provides parameter computational services for on-board and telemetry downlink.
- Provides downlist/downlink format control
- Outputs uplink commands to MDM's
- Holds 2-stage commands in buffer until execute command received.
- Holds SPC commands in buffer until time of execution.
- Acts upon-command loads for mass memory and main memory.

H.

- Accepts main engine controller data and distributes to the GPC's, ops recorders, and the FM data system.

I.

- Collects, stores, and outputs measurement parameters from the OI MDM's and the GPC to the NSP for telemetry transmission.

J.

- Accepts and encodes DFI vehicle parameters to the DFI PCMMU.

K.

- Collects, stores, and outputs DFI measurement parameters from the DFI MDM's to the FDM's for downlink via FM and to the DFI recorders.

L.

- Frequency multiplexes DFI data such as vibration, acoustic, and flutter measurements for DFI transmission and DFI WB recorders.

M.

- Frequency modulates DFI telemetry stream and routes to the S-Band combiner.

N.

- Accepts, processes, and selects for transmission one at a time of TV, playback, WB analog, and WB digital data for FM transmission.

O.

- Provides carrier frequency generation and FM modulation output of FM data downlink.

P.

- Provides for two FM downlink transmissions simultaneously via one antenna system.

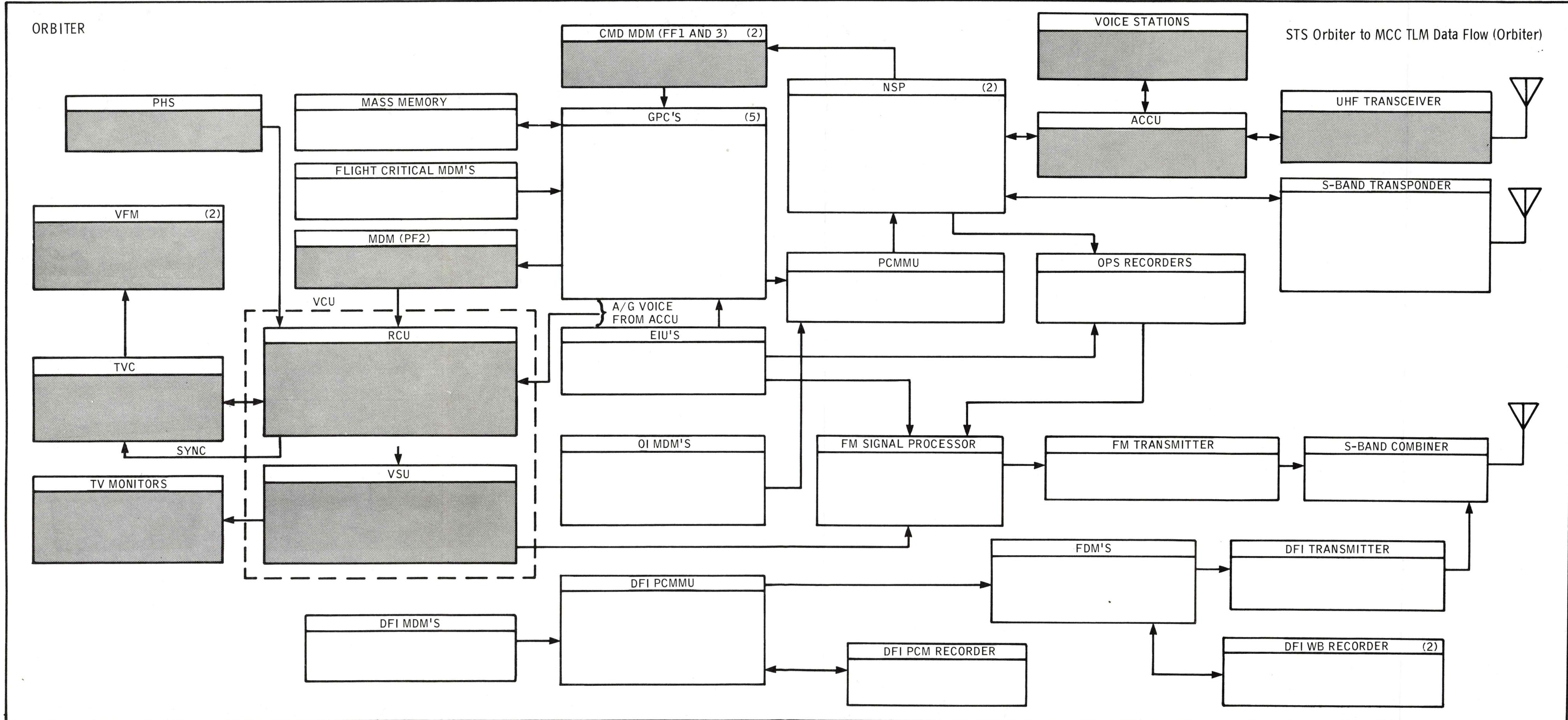
Q.

- Records 128 Kbs DFI PCM telemetry.

R.

- Records DFI frequency multiplexed frequency data e.g. vibration, acoustic, and flutter measurements.

## ORBITER



PRACTICE FEEDBACK:

Compare your answers with the orbiter telemetry data flow drawing in your Learning Material.

II. Match the groups of functions below with the blank STS Orbiter-to-MCC telemetry data flow drawing on the following page.

GSTDN/GSFC:

A.

- Processes and outputs R/T, P/B, and dump OD telemetry data to MCC
- Builds and outputs SSM to MCC
- Builds, stores, and outputs DLSM to MCC on demand.

B.

- Routes commands
- Builds and outputs command histories to MCC
- Processes and outputs tracking data to MCC.

C.

- Acquires, amplifies, and converts orbiter S-Band signals.
- (Transmits command, voice, and ranging.)

D.

- Distributes incoming S-Band signals to the PM and FM receivers.

E.

- Receives orbiter FM WBD channels for main engine; TV, P/L, and OPS and P/L recorder dumps

- Transfers TV to video processor.

F.

- Demodulates the PSK subcarrier from the DFI FM carrier.
- Prime OD minor frame validation
- Transfers OD telemetry and its status to the 642-B.
- Discards A/G voice bits

H.

- Forward dump data minor frame validation
- Transfers status, timing, and format ID to 642-B.

I.

- Receives the OD TDM telemetry and voice PM signal
- Outputs demodulated R/T and dump data
- Transfers OD LINK to the DMS.

J.

- Receives DFI FM telemetry signal
- Outputs PSK and FM subcarriers for subsequent demodulation.

K.

- Provides for multiple and selectable routing of inputs/outputs to various receivers, recorders, and telemetry elements.

L.

- Record and playback function for all telemetry downlinks
- Command history type II data.

M.

- DFI minor frame validation
- Transfers DFI link status to 642-B.

N.

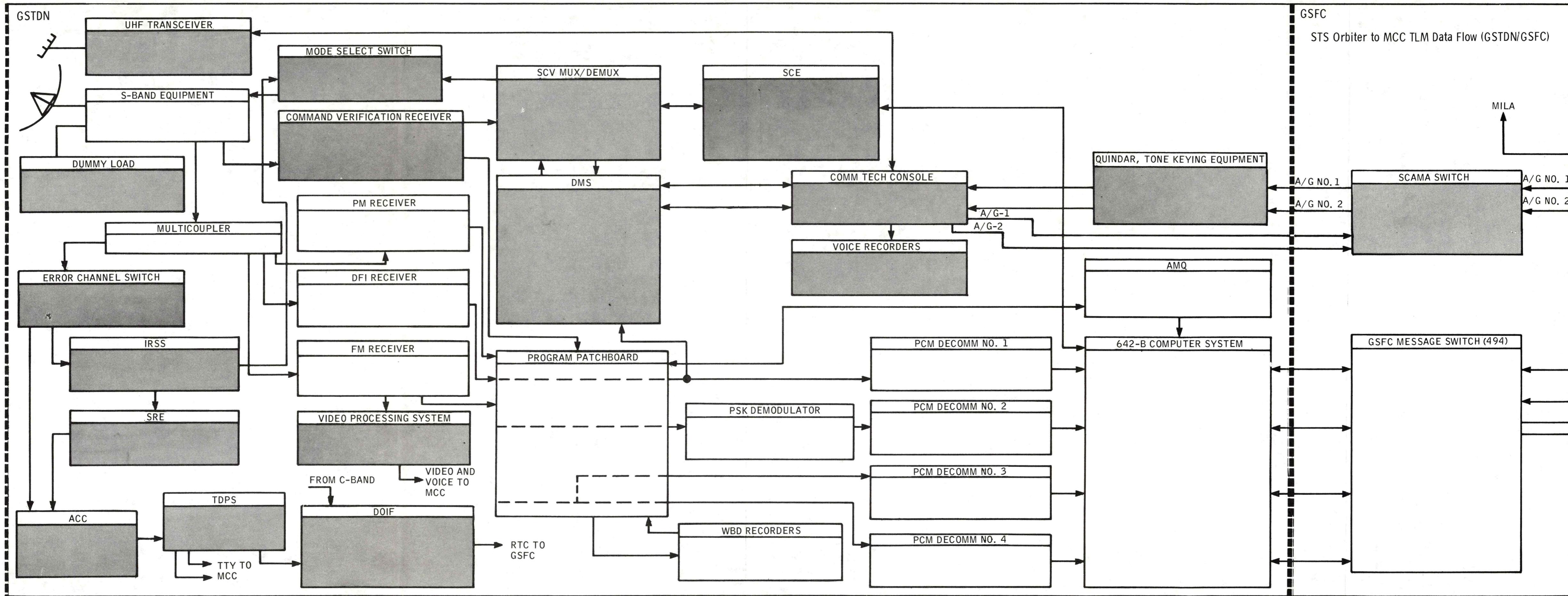
- Reverse dump data minor frame validation
- Transfers status, timing, and format ID to 642-B.

O.

- Routes GSTDN data to MCC (up to 4 sites simultaneously)
- Routes MCC data to GSTDN sites.

P.

- Provides signal strengths for OD, DFI, and FM links
- Provides lock status for the PM receiver and DMS.



PRACTICE FEEDBACK:

Compare your answers with the GSTDN/GSFC telemetry data flow drawing in your Learning Material.

III. Match the groups of functions listed below with the blank STS Orbiter-to-MCC telemetry data flow drawing on the following page.

IOS/STC

A.

- Transmits command and voice signals
- Receives telemetry, voice and ranging data.

B.

- Receives, amplifies and converts S-band signals
- Transmits command, voice and ranging to orbiter.

C. Uplink

- Receives uplink analog voice signals
- Receives Quindar tone keying enabling voice digitizers
- Performs A/D voice conversion
- Outputs digital voice to UMU.

Downlink

- Receives digital voice and telemetry from DSIS
- Demultiplexes (separates) digital voice data from telemetry data
- Performs D/A voice conversion

- Reproduces analog voice over voice system speakers for monitoring

- Reassembles telemetry data and transfers to ACLC.

D.

- Records and provides tape playback of telemetry data and voice data
- Receives command and voice signal
- Transmits voice, telemetry and ranging data.

E.

- Distributes incoming S-Band signal to FM and GRARE receivers.

F.

- Receives the OD TDM telemetry and voice PM signal
- Outputs demodulated R/T data
- Transfers OD Link to GRARE output device.

G.

- Receives DFI PM telemetry signal.

H.

- Receives orbiter FM WBD channels for main engine and P/L recorder dumps.

I. Uplink

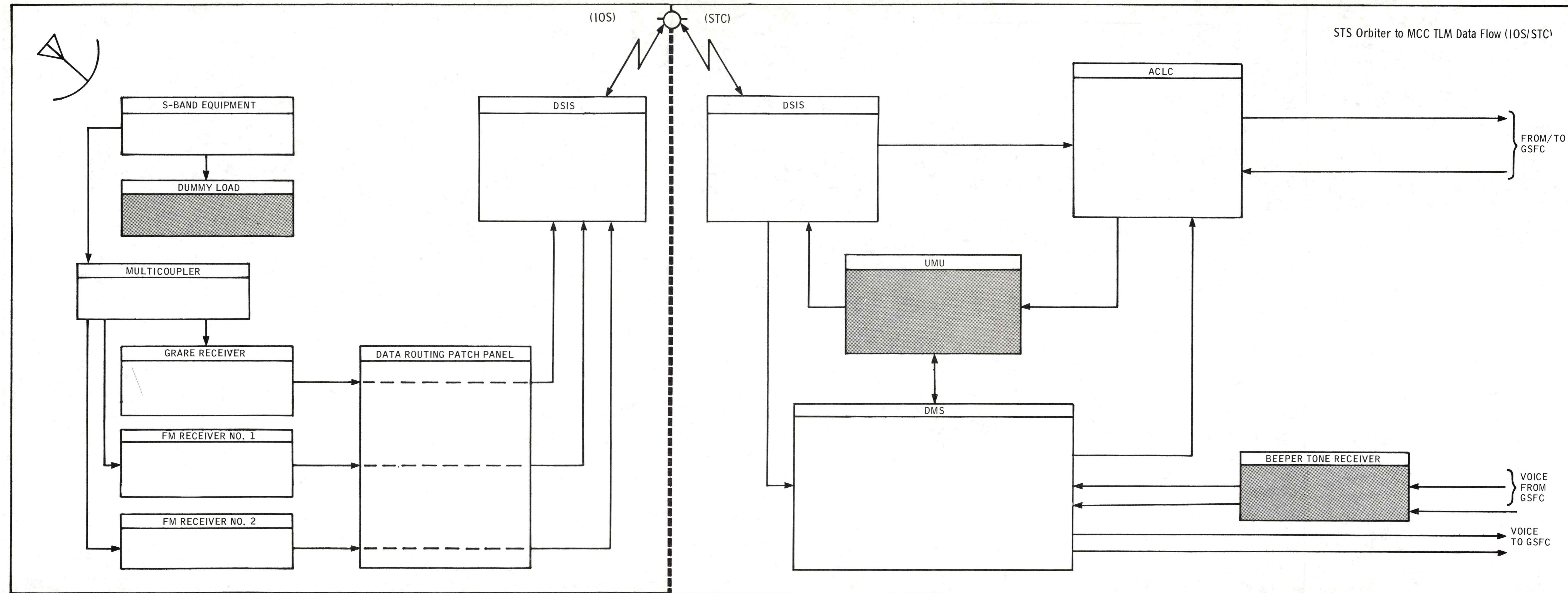
- Accepts command messages in 4800 bit NASCOM FORMAT
- Transfers commands or fill to UMU

Downlink

- Accepts 128 KB/s telemetry data and formats for transmission to GSFC
- Accepts AZ, EL & RR data from IOS and formats into tracking message.

J.

- Communication channels leased from various domestic and foreign common carriers.



PRACTICE FEEDBACK:

Compare your answers with the IOS/STC telemetry data flow drawing in your Learning Material.

IV. Match the groups of functions listed below with the STS Orbiter-to-MCC telemetry data flow drawing on the following page.

MCC

A.

- Perform TM calibration
- TM limit sensing
- Perform TM EU conversion
- Perform R/T TM computation and analysis
- Perform R/T TM data presentation to DTE and DDD's
- Meters command outputs up to 50 per second
- Perform automatic 2-stage command comparison
- Builds & stores orbiter commands for output
- Builds & outputs network TM management commands
- Provides console command displays
- Generates orbiter element/-acquisition message (IIRV).

B.

- Historical recording of all TM data and A/G voice and selected voice loops entering or leaving the MCC.

C.

- MCC consoles
- Input keyboards
- Displays for TV, event lites, SCR's, and clock's.

D.

- Provides reverse to forward and rate correction for dump OD data
- Temporary storage of dump and R/T OD data for quick access playbacks
- Converts SDPC computer language into dynamic TV video displays
- Controls, switches, and routes all WBD circuits to and from MCC.

E.

- Converts and distributes analog event, and time data to analog and event strip chart recorders.

F.

- Data bus system for multiple data paths between elements of the NIP, NOM, and the SDPC.

G.

- Drives digital display indicators.

H.

- Message processing and routing of all incoming NASCOM 4800 bit block data formatted messages
- Message accounting
- Error statusing.

I.

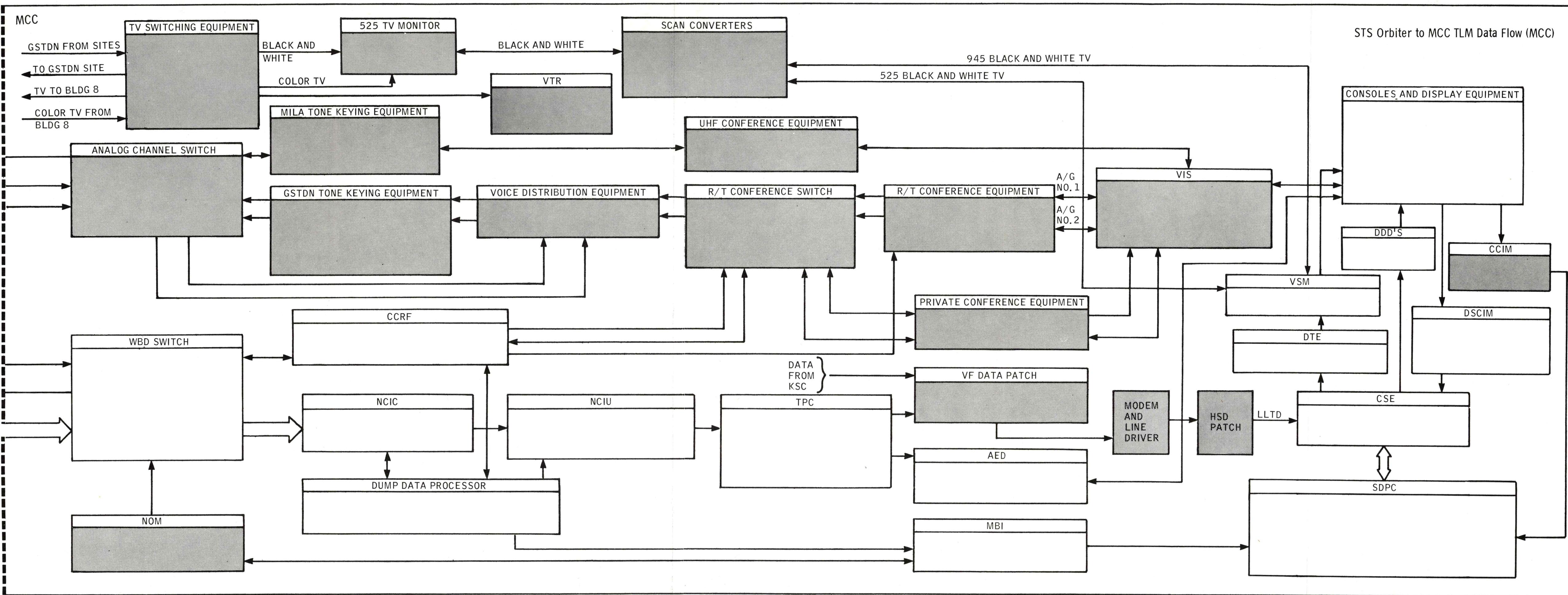
- Master frame validation
- GPC subcom decommutation
- Time calculations
- Sample rate reduction
- Logging
- Status summary
- Outputs preprocessed telemetry data to the AED and SDPC.

J.

- A/G frame sync detection
- Minor frame building
- GRT $\Delta$ T detection for single telemetry stream.

K.

- Detects, formats, and multiplexes display requests from console keyboards to the SDPC.



PRACTICE FEEDBACK:

Compare your answers with the MCC telemetry data flow diagram in your Learning Material..

## SEGMENT 5

### TELEMETRY DATA RATES AND FORMATS

#### OBJECTIVE:

Be able to differentiate between the following:

- a. Telemetry HBR/LBR data rates and data rates formats.
- b. OD downlink HBR/LBR data rates and data rates formats.

#### INTRODUCTION:

The purpose of this segment is to introduce the manner by which the operational downlink (OD) gets constructed and how it's associated, data rates, and formats are derived. This includes how the acquired telemetry input data gets assembled into data set combinations and processed. It then introduces the concept of how telemetry is arranged and formatted, where the telemetry stream gets combined with digital voice, and finally, how the telemetry and voice is formatted into the final resultant OD downlink via the RF system to the Ground Spacecraft Tracking and Data Network (GSTDN).

LEARNING MATERIAL:

Data Rates

Telemetry

LBR = 64 KBS  
HBR = 128 KBS

OD Downlink

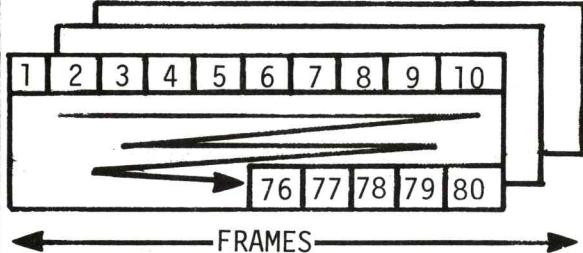
LBR = 64 KBS TLM + (1) 32 KBS  
voice = 96 KBS

HBR = 128 KB TLM + (2) 32 KB  
voice = 192 KBS

Formats

TELEMETRY

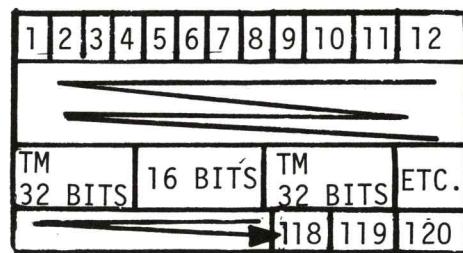
LBR Telemetry (TM) Format



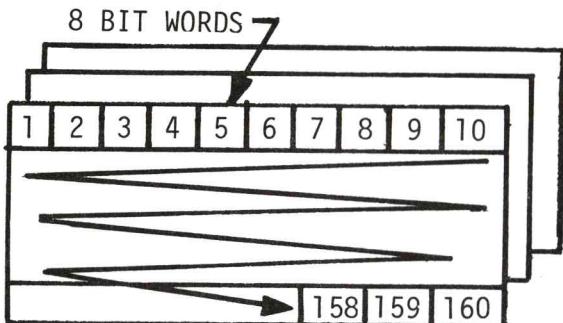
- SAME AS HBR FORMAT EXCEPT 80 WORDS/FRAME

OD DOWNLINK

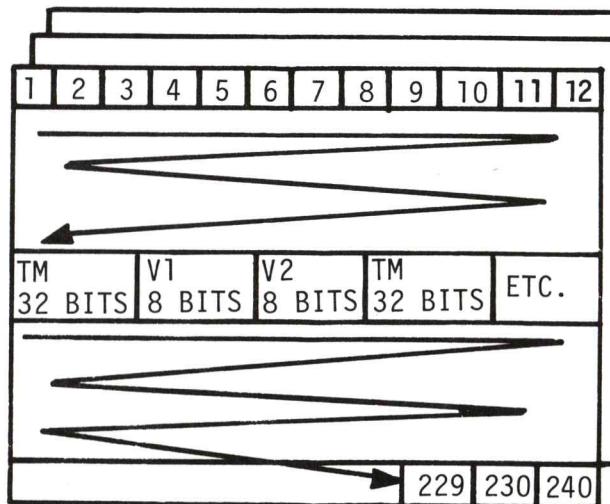
OD LBR FORMAT



HBR Telemetry (TM) Format

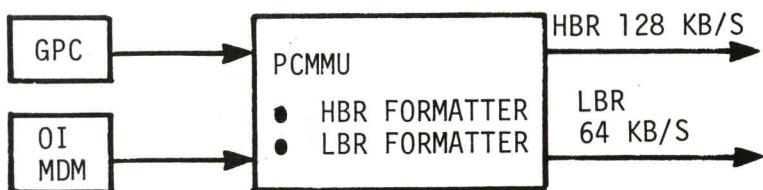


OD HBR Format



SUPPORTING DATA:

OI and GPC data are organized into "combinations" (sets of data) in the PCMMU.



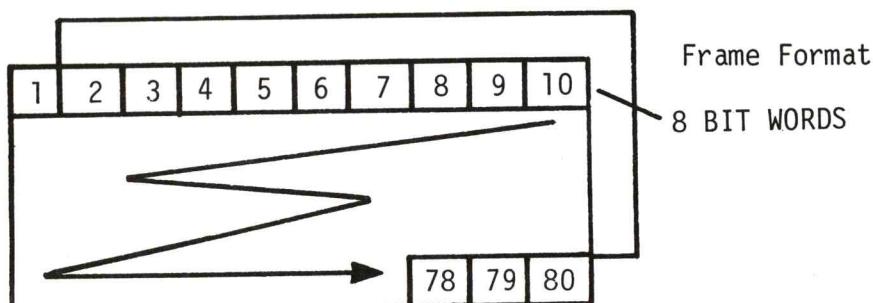
These combinations of telemetry data are assembled and formatted into two data streams, HBR (high bit rate) at 128 KBS and LBR (Low bit rate) at 64 KBS.

In telemetry the word formats is used to indicate both:

- The structure by which telemetry is assembled and transmitted
- The content, sequence and scheme of assigning the actual measurement parameters to fill the frames of data.

For our discussion, we will use the first definition as the slot structure.

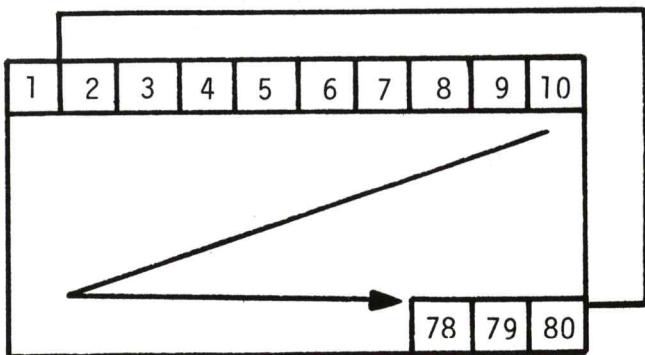
The telemetry format structure that is built in the PCMMU for the HBR is as follows.



Whereby there are:

- 160 8-bit words/frame
- 100 frames = 1 master frame = 1 sec

The LBR format is arranged as follows:



The structure for the LBR is the same except there are only 80 words per frame.

The bit rate and telemetry format correlation is as follows:

HBR

100 frames = 1 master frame = 1 sec  
160 8-bit words/frame = 16000 8-bit word/sec  
= 128000 bit/sec  
= 12 Kbs

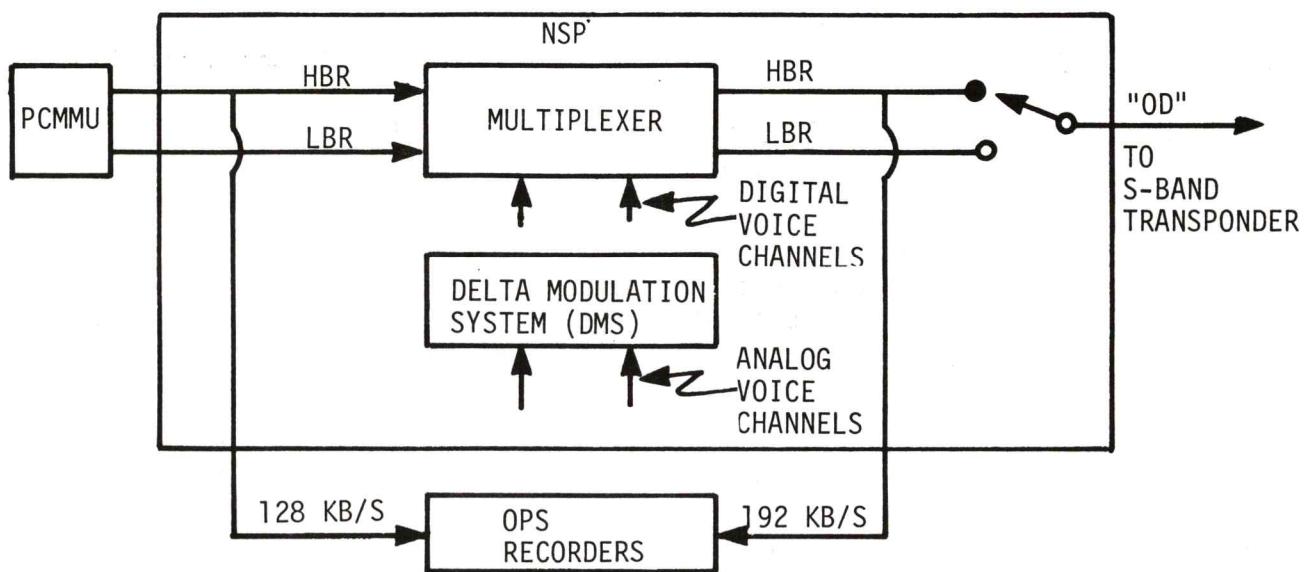
LBR

80 8-bit words/frame = 8,000 8-bit words/sec  
= 64000 bit/sec  
= 64 Kbs

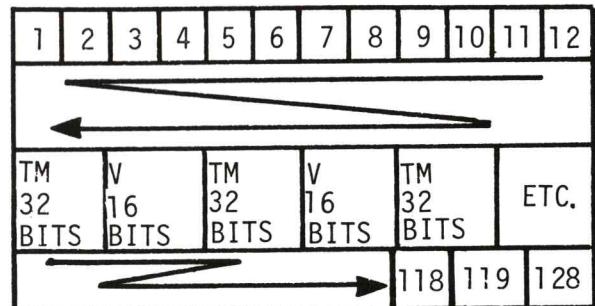
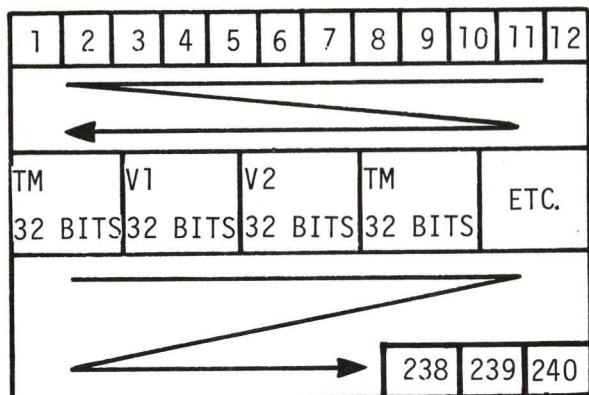
After the PCMMU has formatted the telemetry data streams into the above telemetry formats, the data streams are routed to the NSP. The NSP accepts the two streams of data and time-division multiplexes (integrates) the telemetry data into the resultant OD downlink as follows:

$$\text{HBR} = 128 \text{ Kbs TLM} + 2 \text{ 32 Kbs voice} = 192 \text{ Kbs}$$

$$\text{LBR} = 64 \text{ Kbs TLM} + (1) \text{ 32 Kbs voice} = 96 \text{ Kbs}$$



Correspondingly, the OD formats are increased in work size to accommodate the digital voice as follows:



← OD HBR FORMAT  
FRAME →

- 240 8-Bit Words/Frame
- A Master Frame (or data cycle) = 100 frames
- 1 Data Cycle = 1 second

V1 = Voice Channel 1

V2 = Voice Channel 2

OD LBR FORMAT

Same as HBR except:

- 1) 120 Words/Frame
- 2) V1 only (only one voice channel)

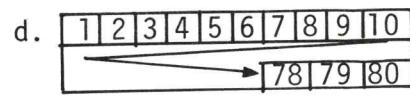
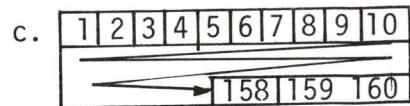
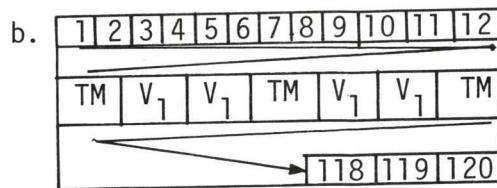
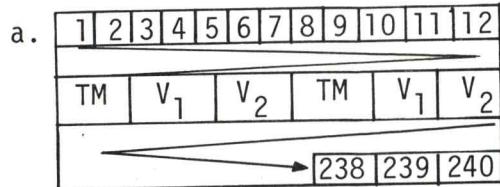
Notice the only difference between HBR and LBR is that in HBR two voice channels are included whereas with LBR only one voice channel is present. (For more information on voice processing refer to the STS A/G Voice Data Flow lesson).

In summary, when we talk about bit rates and formats, we have to be careful to identify at which point in the system we are addressing. The PCMMU formats telemetry into two data rates and formats of 128 KB/s (HBR) and 64 KB/S LBR. The NSP formats telemetry and voice into two formats of 192 KB/s (HBR) and 96 KB/S (LBR). Only one (either OD HBR or LBR) is selected for transmission via the S-Band PM OD link to the GSTDN. This area is discussed further in Segment 5.

PRACTICE:

Match the appropriate description with the proper title.

DESCRIPTION:



e. 192 KBS

f. 64 KBS

g. 128 KBS

h. 96 KBS

MATCH LETTER

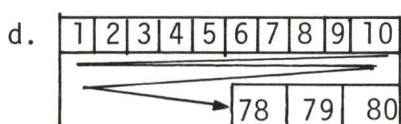
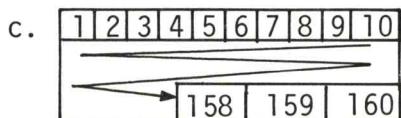
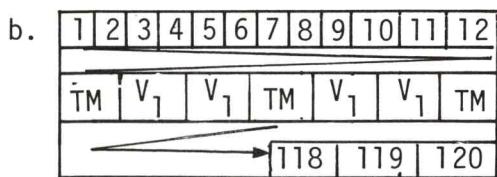
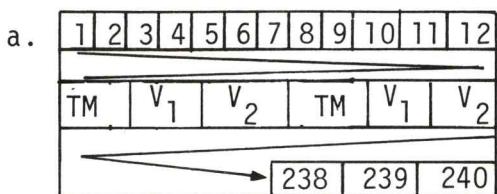
TITLE:

	1. OD HBR (rate)
	2. OD HBR (format)
	3. OD LBR (rate)
	4. OD LBR (format)
	5. TM HBR (rate)
	6. TM HBR (format)
	7. TM LBR (rate)
	8. TM LBR (format)

PRACTICE FEEDBACK:

Match the appropriate description with the proper title.

DESCRIPTION:



e. 192 KBS

f. 64 KBS

g. 128 KBS

h. 96 KBS

MATCH LETTER

	TITLE:
e	1. OD HBR (rate)
a	2. OD HBR (format)
h	3. OD LBR (rate)
b	4. OD LBR (format)
g	5. TM HBR (rate)
c	6. TM HBR (format)
f	7. TM LBR (rate)
d	8. TM LBR (format)

#### WRAP-UP:

As was mentioned earlier, this workbook is not complete by any means, but it does represent a basic introduction to the subject of STS telemetry. Future additions and updates will be provided in the future. In addition, there are some lessons currently being developed which will serve as introductory material for the whole subject of flight operations, data links, mission control, and ground data systems primarily for new people.

In terms of this version of the workbook you have learned the following:

- 3 STS telemetry downlink titles
- The content of the 3 downlinks
- The modulation scheme utilized for each downlink
- The data rates, and formats for the OD downlink
- And the data flow and functions of the major elements from the orbiter to the MCC consoles.

## LIST OF ACRONYMS

ACLC	Adaptive Communication Line Controller
AED	Analog/Event Distribution
AES	Analog/Event System
A/G	Air-to-Ground
AMQ	Analog to Digital Multiplexer Quantitizer
AOS	Acquisition of Signal
BDF	Blocked Data Format
BED	Bit Error Detection
CCRF	Consolidated Communications Recording Facility
DDD	Digital Display Driver(s)
DFI	Development Flight Instrumentation
DLSM	Data Link Summary Message
DMS	Delta Modulation System
DRPP	Data Routing Patch Panel
DSC	Dynamic Standby Computer
DSCIM	Display Select Computer Input Multiplexer
DSIS	Defense Communication System/Satellite Control Facility Interface System
DTE	Digital-to-Television Equipment
EIU	Engine Interface Unit
EU	Engineering Unit
FM	Frequency Modulation
GNC (GN & C)	Guidance, Navigation, and Control
GPC	General Purpose Computer
GRARE	Ground Receiving and Routing Equipment
GRT	Ground Receipt Time
GSFC	Goddard Space Flight Center
GSTDN	Ground Spacecraft Tracking and Data Network
HBR	High Bit Rate
HDR	High Data Rate
ICD	Interface Control Document
ID	Identification
IOS	Indian Ocean Station
JSC	Johnson Space Center
KB	Kilo Bit(s)
KBS (KB/S)	Kilobits per second

LBR	Low Bit Rate
LDR	Low Data Rate
LOS	Loss of Signal
MBI	Multiple Bus Interface
MBS (MB/S)	Megabits per second
MCC	Mission Control Center
MDM	Multiplexer/Demultiplexer
ME	Main Engine
MHZ	Megahertz
MM	Mass Memory
MMU	Mass Memory Unit
MOC	Mission Operations Computer
NASCOM	NASA Communication Network
NCIC (NCI(C))	Network Communication Interface Common
NCIU (NCI(U))	Network Communications Interface Unique
NIP	Network Interface Processor
NOM	Network Output Multiplexer
NSP	Network Signal Processor
OFT	Orbital Flight Test
OD	Operational Downlink
OI	Operational Instrumentation
OPS	Operations
OV-102	Orbiter Vehicle
O <sub>2</sub>	Oxygen
P/B (PB)	Playback
PCM	Pulse Code Modulation
PCMMU	Pulse Code Modulation Master Unit
PL (P/L)	Payload
PM	Phase Modulation
PSK	Phase Shift Keying (Keyed)
RAM	Random Access Memory
RF	Radio Frequency
R/T (RT)	Real-Time
S-Band	Frequency Spectrum of S-Band Equipment
SCR	Strip Chart Recorder
SDPC	Shuttle Data Processing Complex
SM	Systems Management
SRB	Solid Rocket Booster
SSM	Site Status Message
SSME	Space Shuttle Main Engine
STC	Satellite Test Center
STS	Shuttle Transportation System

TDM	Time Division Multiplexed
TDRSS	Tracking Data Relay Satellite System
TLM	Telemetry
TM	Telemetry
TPC	Telemetry Preprocessor Computer
TV	Television
UST	Unblocked Serial Telemetry
V1	Voice Channel One
V2	Voice Channel Two
WB	Wide Band
WBD	Wide Band Data

## APPENDIX B

## REFERENCES

<u>TOPIC</u>	<u>APPLICATION</u>	<u>SOURCE</u>
Orbiter Downlinks	<ul style="list-style-type: none"><li>• Types, definition, and contents</li><li>• Modulation methods</li><li>• OFT-1 OD Telemetry bandwidths, data rates, and formats.</li></ul>	<ul style="list-style-type: none"><li>• JSC No. 11890 Shuttle Orbital Flight Test Program Introduction Document (September 1, 1977).</li><li>• JSC No. 11891 Shuttle OFT Flight - Program Requirements Document, (September 1, 1977).</li><li>• ICD No. 2-0D004 JSC/GSFC Space Shuttle RF Communications and Tracking.</li><li>• JSC-11384 Volume I, OFT Telemetry Data Format Control Book, September, 1976.</li></ul>
Data Flow	<ul style="list-style-type: none"><li>• Orbiter</li><li>• GSTDN</li><li>• GSFC</li></ul>	<ul style="list-style-type: none"><li>• SD-72-SH-0105-2 Communications &amp; Tracking Requirements/- Definition Document.</li><li>• SK1000 Station Configuration for Shuttle Orbital and Landing Support, August 22, 1977.</li><li>• Garland Hector, GDSD</li><li>• JSC/11534 JSC/GSFC Communications Interface Control Document, May 1977.</li></ul>

<u>TOPIC</u>	<u>APPLICATION</u>	<u>SOURCE</u>
	• MCC	• JSC-10013B Mission Control Center (MCC) System Specification for the Shuttle OFT Timeframe.
		• JSC-10466 OFT TPC Preliminary Software Design Specification (10-77).
		• JSC-10472 Dump Data Handling Subsystem Specification (8-77)
		• JSC-10233 OFT NIP Subsystem Specification (4-77)
		• JSC-10273 Analog/Event Distribution Equipment Performance Specification.
		• JSC-10261 Multi-Bus Interface Performance Specification (6-76)
• General		• JSC-10074 Rev. B Communications and Data Systems Integration (CADSI), End-to-End Configuration Book, October 15, 1976.

MAIL TO: CG3/Ground Systems Training Section  
CG3/Johnson Space Center, NASA Rd 1, Houston, Texas 77058

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LESSON CRITIQUE SHEET

LESSON CODE GND TM 2102A DATE OF MATERIAL 3/28/79

Please explain any negative answers to the questions below in specific terms.  
Use the back of the sheet if required.

1. Was the lesson material presented in a logical manner?
  
2. Comments on handout organization:
  
3. Were the figures and diagrams optimum to understanding the material?
  
4. Did the lesson start from your entry level?
  
5. In you opinion, was the level of detail about right?
  
6. Additions or deletions from the lesson?
  
  
7. Prior Knowledge: Considerable \_\_\_\_\_ Some \_\_\_\_\_ Very Little \_\_\_\_\_
  
  
8. Other comments (or questions):

MAIL TO: CG3/TRAINING COORDINATOR

WORKBOOK TRAINING REPORT

INSTRUCTIONS:

When you have completed this lesson, please fill this sheet out and return it to the Training Coordinator (CG3) in order to have completion entered on your record.

STUDENT

STUDENT NAME

MAIL CODE

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LAST NAME

6	7	8	9	10	11	12	13	14	15	16	17	18
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INITIALS

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LESSON CODE

PART 1

G	N	D	T	M							
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PART 2

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37	38	39	40

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41

ENTER TIME TO COMPLETE THIS LESSON

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47	48	49	50

HR:MIN

DATE COMPLETED (M/D/Y)

52	53	54	55	56	57	58	59
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WORKBOOK DATE (M/D/Y)

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61	62	63	64	65	66	67	68

I certify that I have completed the above described lesson.

STUDENT SIGNATURE

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