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Space Shuttle Payloads and Data Handling Accommodations

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Abstract—This paper provides an overview of the various classes of candidate payloads to be flown on early Shuttle missions and summarizes the communications and data handling services which the Space Shuttle will provide for payloads. The Space Shuttle system mission capabilities are briefly described and data processing capabilities for payload support are discussed for the various classes of payloads.

I. INTRODUCTION

The primary objective of the Space Shuttle Program is to provide an economical transportation system that will support a wide range of scientific, defense, and commercial applications in Earth orbit. The Shuttle will be a manned, reusable space vehicle designed to accommodate these applications. As illustrated in figure 1, the advent of the Space Shuttle will usher in an era of space industrialization and utilization which undoubtedly will result in new products, new services, and new sources of energy.

The Space Transportation System (STS), consists of several elements, the core of which is the Space Shuttle Orbiter vehicle. Shown in figure 2 are the basic elements of the STS which include an external fuel tank and expendable solid rocket boosters that are necessary for the Shuttle launch process, and an Inertial Upper Stage (IUS) which is necessary for placement of certain free-flying payloads destined for high Earth orbit or planetary trajectories. The Orbiter vehicle is a true aerospace vehicle in that it will launch like a rocket, maneuver in Earth orbit like a spacecraft, and land like an airplane.

The STS system will reduce the costs of Earth orbital operations while improving operational capabilities and flexibility. With a due-East launch from KSC, the Shuttle can deliver payloads up to 65,000 pounds to a 150-nmi circular orbit at a substantially lower operational cost per flight than the Titan III-C

Figure 1 Era of Space Industrialization

Manuscript received May 22, 1978; revised June 28, 1978.

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system, which has a payload delivery capability of only 30,000 pounds. In addition, the Space Shuttle can return to Earth with up to 32,000 pounds of payload, a capability not provided by expendable launch vehicles.

Other STS capabilities will result in payload cost savings and operational flexibility. First, the Shuttle will have the inherent ability to retrieve payloads that experience early failure immediately after deployment for subsequent relaunch and use. Second, the large capacity and benign launch environment of the Shuttle Orbiter payload bay will relax the weight, volume, and g-loading constraints imposed on future satellites, allowing design simplification and hence reducing costs. Third, the Shuttle, alone or in combination with the Teleoperator Retrieval System (TRS) or an advanced upper stage, will permit the retrieval of satellites at the end of their service life for refurbishment and reuse. Fourth, the Shuttle can carry replacement subsystem modules to failed satellites on-orbit and extend their life, eliminating the need to recover the entire satellite. Fifth, the Shuttle can be used to perform dedicated space missions, subsystem development tests, or technology demonstrations on a space-available basis or in the sortie mode.

The Space Shuttle operational capabilities and flexibility will permit the on-orbit replacement and/or servicing of malfunctioning satellites, as depicted in figure 3, reducing out-of-service time, and increasing operational availability. In addition, with the Shuttle, breadboards of devices intended for long-term unattended operation in Earth orbit can be deployed and left in space for periods of weeks or months and then retrieved and returned to Earth for examination. This process will enhance the reliability of future satellites and extend their useful life at relatively little cost while reducing development time. The capability for on-orbit servicing will allow the satellites to be updated as the technological state of the art advances, increasing their capability and prolonging their usefulness. On sortie (manned laboratory) missions, the Shuttle will transport up to five scientists, technicians, and/or trained observers into low Earth orbit and maintain them and their experiments or observation equipment for seven days or more. Personnel trained in specific scientific disciplines may conduct their own experiments and make their own observations. The advantage of this type of operation is that experiments can be conducted with combinations of temperature, pressure, and gravity environments not obtainable in Earth-based research centers.

The STS will provide numerous supporting subsystems for exclusive accommodation of payloads. These supporting subsystems and accommodations will include payload mechanical attachments/cradles; a Payload Deployment and Retrieval System (PDRS); electrical power, fluid and gas utilities; environmental control; communications, data handling and display; guidance, navigation, and payload pointing; and certain mission kits which will increase or extend STS mission capabilities, particularly in the area of consumables.

A two-level crew cabin area is provided at the forward end of the Orbiter to accommodate the crew and passengers as shown in figure 4. The flight crew will control the launch, orbital maneuvering, atmospheric entry, and landing phases of the mission from the upper level forward flight deck. Payload handling will be accomplished by mission specialist and payload specialist crewmen from the aft flight deck (AFD) cabin area on the upper level just forward of the front payload bay bulkhead. Seating for passengers and a living area are provided on the lower deck. With these accommodations and a more benign launch/reentry environment, space flight will no longer be limited to intensively trained astronauts who are in perfect physical condition, but will be available to experienced scientists and technicians who are of normal physical condition.

II. TYPICAL PAYLOAD MISSIONS

The beginning of frequent scheduled flights by the Space Shuttle, to and from Earth orbit in the 1980's, will mark the coming of a new age in space. The Shuttle will turn formidable and costly space missions into routine, economical operations generating maximum benefits for people everywhere. Moreover, the Shuttle will open space to men and women of all nations.
who are reasonably healthy and have important work to do in space.

The Shuttle Orbiter will be capable of carrying a payload or several payloads, and their associated airborne support equipment (ASE), totaling up to 65,000 pounds, into Earth orbit. The crew will generally consist of two pilots plus one mission specialist and one payload specialist. The duties of the latter crewman will include checkout and deployment of free-flyer payloads, or the management of experiments to be performed on space laboratory type missions.

Among the multifaceted uses of Space Shuttle during its operational life, which will extend beyond the 1990's, will be a wide range of applications, such as those listed in figure 5, of the environment of space and of space platforms. STS application will be achieved through operation of satellites, satellites with propulsion stages, space laboratories, or combinations as appropriate to the specific objectives and requirements. The Shuttle will also provide a laboratory capability to do research and to develop techniques and equipment that may evolve into new products, services, and sources of energy. It is important to note that the Space Shuttle will not be limited to uses that can be forecast today. The reduction in the cost of Earth-orbital operations and new operational techniques will enable new and unforeseen solutions of problems.

The STS will be used to carry into space nearly all civilian and military payloads of the future, including automated scientific space probes and Earth-orbiting solar and astronomical observatories. Commercial and agency application payloads will include Earth resources sensing, communications, meteorological, and geodetic satellites.
Current plans are for the Shuttle to conduct up to 60 missions per year with a mission mix of perhaps 40 percent for the Department of Defense (DOD) and the remainder for commercial and scientific applications. The majority of the flights will be concerned with deploying, retrieving, and servicing satellite payloads.

The current NASA mission model for STS (reference 1) covers space activities in four major areas: (1) General Science, (2) Applications, (3) Technology, and (4) Space Industrialization. In addition to the basic NASA mission model, there will be missions for non-NASA civil programs such as domestic and extranational space activities relative to synchronous satellites for communications, meteorology, Earth resources, oceanography and air traffic control. Department of Defense payloads and space activities will be based on a separate DOD mission model.

The General Science Program includes three major areas of investigation: Physics and Astronomy, Lunar and Planetary, and Life Sciences. Projected payloads will enable the continued study of the Earth’s space environment, the structure of the universe, and the effects of the space environment on living systems. The Technology Program is designed to exploit the Shuttle capabilities to extend ground-based technology to the space environment. The Applications Program is directed toward exploitation of the benefits of space in such an area as Earth systems. The objective of the Space Industrialization Program is the utilization of space for economically beneficial industrial activities such as the processing of pharmaceutical, electronic and metallurgical products.

III. SATELLITE PLACEMENT AND RECOVERY

One very important type of STS mission will be the placement of satellites into Earth orbit or into lunar or planetary trajectories. The Shuttle Orbiter will be used to place all deployable payloads and their associated propulsive stages (if any) into low Earth orbit. Satellites whose missions require attainment of high Earth orbit (such as geosynchronous satellites) or require placement into lunar or planetary trajectories will utilize one of several classes of add-on propulsive stages. The currently planned propulsive stages include the IUS, and the spinning solid upper stage (SSUS) sometimes referred to as the payload assist module (PAM). Currently, there are two versions of the IUS planned—one for DOD applications and one for NASA scientific payload applications, and there are two planned versions of the SSUS.

As many as five deployable payload packages may be delivered on a single mission. Upon reaching the desired orbit, the mission and/or payload specialist will conduct predeployment checks and operations. After determining that a satellite is ready, the crew will operate a payload deployment system, which will either lift the payload (and its propulsive stage) out of the payload bay and release it (as in the case of the PDRS) as illustrated in figures 3 and 6, or eject the payload elements from the mounting cradle by means of a latch release/spring eject mechanism.

The final activation of the satellite can be performed by radio command from the Orbiter or from a ground network. The Orbiter will stand by until the satellite is performing satisfactorily before proceeding with the remainder of the mission. A satellite launched on a previous mission or which fails soon after deployment can be retrieved and returned to Earth for refurbishment and reuse. To recover a satellite, the Orbiter will rendezvous with it (either by itself or with the aid of the TRS), deactivate it by radio command, maneuver close, and grapple it with the PDRS arm. The recovered satellite will be lowered into the cargo bay and locked into place. The Orbiter will perform deorbit maneuvers, enter the atmosphere, and land, returning the expensive satellite for reuse.

Placement of free-flying scientific laboratories and data gathering devices into low Earth orbit can be accomplished by the Shuttle. This type of satellite launch will not require the use of propulsive stages, but will require placement and alignment of the subject scientific facility. Examples of free-flying scientific laboratories to be launched by the Shuttle are the Long Duration Exposure Facility (LDEF) and the Space Telescope. A discussion of these payloads follows later in this paper.

**Inertial Upper Stage (IUS)**

The IUS is an STS system element that will provide the capability to deliver spacecraft beyond the Orbiter’s operating regime, which includes orbital plane changes and high energy orbits. The IUS, as depicted in figure 7, is being developed by the DOD, and consists primarily of the final stage of the Titan 34D vehicle. Flexibility will be provided to accommodate a variety of NASA and DOD missions. Two IUS vehicles, each with attached spacecraft, can be carried by the Shuttle (tandem configuration) and each IUS can carry up to four spacecraft.

Four combinations of propulsive stages using two different sized solid rocket motors, provide a family of IUS vehicles which satisfy the wide range of performance and interfacing requirements for all DOD and NASA missions. The large motor (21,400 pounds of propellant) is used in the first stage of all vehicle configurations. It will also be used as the second stage of the twin-stage vehicles and the three-stage spinner. The small motor (6000 pounds of propellant) will be the second stage of the
two-stage configuration and the third stage of the three-stage spinner.

The IUS vehicles are being designed with many structural elements in common for both DOD and NASA. The small motors will be identical for all missions. The large motors will also be identical except for nozzle lengths. Because of differences in communication link requirements, the two-stage and twin-stage vehicles will have variations between DOD and NASA configurations. DOD vehicles will use communication link equipment that is compatible with the USAF Satellite Control Facility (SCF), while NASA vehicles will be compatible with the ground stations of the spaceflight tracking and data network (STDN) and with the tracking and data relay satellite system (TDRSS).

The IUS vehicle will include stage structure; the solid rocket motors; the reaction control system; avionics for guidance, navigation and control, and for telemetry, tracking and command communications; instrumentation; data management equipment; on-board computer programs, and the electrical power and distribution system.

**Spinning Solid Upper Stage (SSUS)**

The Spinning Solid Upper Stage is a light-to-medium weight class upper stage complement of the STS which is being planned as a final booster stage to support the launch of spin-stabilized Earth synchronous/subsynchronous satellite systems. The booster itself will be spin stabilized and will utilize solid propellants—hence the name Spinning Solid Upper Stage. There are two versions of the SSUS currently planned (SSUS-A and SSUS-D), each designed as a weight-class replacement for the Atlas-Centaur and Thor-Delta launch vehicles, respectively.

As illustrated in figure 8, the SSUS will be mounted on a spin-table/cradle in the Orbiter payload bay. At an appropriate time prior to deployment, the SSUS and its attached satellite(s) will be erected to spin-up position relative to the longitudinal axis of the Orbiter, and the Orbiter will align the spin axis of the SSUS/satellite package along the desired thrust vector. The SSUS/satellite will then be spun up to the desired angular velocity and the Orbiter/SSUS separation maneuver will be initiated. Separation from the spin table will be accomplished via a latch release/spring mechanism such that a relative \( \Delta V \) of approximately 1.0 ft/s will be achieved. A nutation control system on the SSUS will then be employed to damp out tip-off errors imparted from the ejection spring mechanism. When all errors have been corrected relative to SSUS vehicle dynamics and the Orbiter has maneuvered to a safe observation location, the SSUS perigee kick motor (PKM) will be ignited via a timer/sequencer, thereby initiating the transfer orbit burn.

**Teleoperator Retrieval System**

The teleoperator retrieval system (TRS) as shown in figure 9 will be a free-flying orbital maneuvering system capable of operating in conjunction with the Shuttle Orbiter to position spacecraft or free-flying modules to points in space in the near vicinity of the Orbiter (within 300 nmi) and to retrieve spacecraft and ferry them back to the Orbiter for capture and placement into the payload bay for return to Earth. As such, the TRS can be envisioned as a remotely controlled, free-flying extension of the Shuttle deployment/retrieval capability, which will allow the STS more flexibility in the positioning and retrieval of payload modules. This capability can be used to support the build-up of space facilities too large to be launched on a single Shuttle mission, to retrieve or de-orbit satellites which have failed and/or pose potential threat to the Earth's environment, to perform moderate plane or orbital altitude
changes which are beyond the capability of the Shuttle Orbiter to perform in support of satellite placement or retrieval. In view of these capabilities, the TRS is presently planned to support the Skylab boost/deorbit mission in the late 1979 time period.

The TRS will consist of propulsion systems to support rendezvous, docking and spacecraft transportation maneuvers; and avionics systems to support guidance and navigation, antenna selection, systems monitoring, command reception and execution and television transmission. The three major elements of the TRS will be: (1) a control and display console located in the aft flight deck of the Orbiter cabin which provides the control and display data by which the crew can monitor, command and maneuver the TRS, (2) an ASE cradle mounted in the Orbiter payload bay which will contain the spring ejection system and the avionics system which will process the commands and monitor the systems of the TRS and (3) the TRS free-flyer which will be located in the cradle prior to deployment and subsequent to retrieval.

The TRS, by design, will be capable of on-orbit dormant storage for up to eighteen months between the initial deployment mission and the subsequent retrieval mission.

IV. TYPICAL FREE-FLYING PAYLOADS

Numerous free-flying payloads for near-term STS missions have been defined and are currently being developed by various commercial, NASA and DOD organizations. Some of the candidate payloads being planned for early missions are summarized as follows:

Long Duration Exposure Facility (LDEF)

The Long Duration Exposure Facility (LDEF) illustrated in figure 10 is a basic space environmental research project being implemented by the NASA. The LDEF is a reusable, unmanned, low-cost, free-flying structure on which a variety of passive experiments can be mounted to study the effects of their exposure to space over a relatively long period of time (6 to 9 months). After an extended period in orbit, the LDEF will be retrieved by an Orbiter and returned to Earth for experiment analysis. The LDEF comprises over 1300 square feet of surface area experiments to determine the synergistic effects of the near-Earth space environment. The LDEF will provide for testing of biological specimens, meteoroid bumper configurations, solar cells, optical surfaces, thermal coatings and other materials for exposure to radiation and particle impact.

Tracking and Data Relay Satellite (TDRS)

The TDRS satellite (shown in figure 11), which will be launched using Shuttle and a DOD version IUS, is a high-capacity communication and data relay satellite that will be used to support NASA spacecraft (including the Shuttle Orbiter) in low-to-medium altitude Earth orbit. It is intended that the TDRS system—comprised of two operational satellites, one or more on-orbit spares and a ground station located in White Sands, New Mexico—will eventually replace most of the existing STDN ground stations that are in existence around the world.

Satellite Business System (SBS)

The SBS spacecraft, shown in figure 12, will be a spin-stabilized gyrostat coupled with a despun antenna and communications repeater terminal, which will be launched into geosynchronous orbit from low Earth orbit, following deployment from the Shuttle Orbiter, by a SSUS-D upper stage.

The SBS is being planned to serve large industrial, and government users as an all digital domestic communications system independent of the existing telephone system. The emphasis of the SBS will be data transmission in support of computer-to-computer data flow.
Figure 13  TELESAT

Figure 14  INTELSAT V

**Telesat**

Figure 13 illustrates the Telesat payload which will be launched into geosynchronous orbit using the STS. The Telesat will be an upgraded version of the currently operational Canadian satellite communications system which provides relay facilities for television, radio, voice, data and facsimile for all of Canada. Primary service areas include an east-west trunk between Montreal, Toronto, Winnipeg and Vancouver and service to northern remote areas.

**Intelsat V**

The Intelsat V, fifth generation Comsat satellite for commercial communications application, is depicted in figure 14. The Intelsat V will be placed in geosynchronous orbit via the Shuttle and a SSUS-A upper stage. Intelsat V will serve as part of an international commercial point-to-point communications network providing telex, facsimile, telegraph, data, television, and two-way voice transmission world-wide.

**Teal Ruby (Space Test Program P80-1)**

Figures 15 and 16 illustrate the Space Test Program (P80-1) or Teal Ruby System. The STP P80-1 Space System is a satellite comprised of equipment necessary to support three experiments on orbit for a minimum of one year with a three-year goal. The experiments include the Teal Ruby experiment, which will provide infrared multispectral Earth background data; the Ion Auxiliary Propulsion System, which will provide on-orbit checkout of a millipound thruster for satellite position-keeping; and the Extreme-Ultraviolet Photometer, which will provide sky and Earth background mapping. The P80-1 space system is to be inserted in a 160 nmi parking orbit with a 57° inclination by an operational flight of the STS around March 1981. It will then be placed in its 400 nmi operational orbit by an upper stage consisting of two solid rocket motors. It will be operated on orbit for its three year mission by the AFSCF.

**Multimission Modular Spacecraft (MMS)**

The MMS, shown in figure 17, will be a generalized orbital support system spacecraft which is retrievable and reusable for various classes of scientific experiment packages. The MMS will include an electrical power system; a communications and data handling system (designed to interface with the STDN); an attitude control system; and an optional propulsion module.

The MMS will be modular in concept and will be designed to provide orbital support accommodations for a wide spectrum of scientific payloads, the first of which will be the Solar
Maximum Mission Spacecraft as discussed below. Following retrieval and refurbishment, the MMS can be assigned to a new scientific package and launched to serve on a new space mission.

**Solar Maximum Mission (SMM)**

The SMM is scheduled to be launched in late 1979 by a Delta booster and to be retrieved by the STS around October 1981. The SMM, shown in figure 18, will consist of selected scientific instruments mounted on an MMS. The SMM will be a three-axis stabilized vehicle designed for a one-year minimum operational life and a two-year minimum life for STS retrieval.

The SMM will measure the brightness of selected solar phenomena visible in the VU, X-ray and gamma ray regions. Specific emphasis will be given to the study of corona/chromosphere interactions and other Sun characteristics. The complement of SMM instruments will be periodically updated through refurbishment made possible by the STS retrieval capability.

**Jupiter Orbiter Probe (Project Galileo)**

The JOP/Project Galileo spacecraft is shown in figure 19. The JOP is planned to be launched into planetary trajectory via an STS launch, using IUS as the upper stage. The JOP will eventually be placed in orbit about the planet Jupiter and will be used to make remote measurements of Jupiter’s atmosphere. Attempts will be made to determine atmospheric structure, elemental and isotopic quantities, and cloud characteristics. The JOP will also be used to refine previous measurements of the Jovian magnetosphere.

**Space Telescope**

The Space Telescope, as shown in figure 20, represents an international facility for on-orbit research controlled by the investigating scientists on the ground. The Space Shuttle will deliver the telescope to orbit, and the crewmen will assist in preparing the facility for operation. During scheduled revisits to the
facility, the Space Shuttle crewmen would service supporting subsystems, exchange scientific hardware, and several years later, return the facility to Earth at the end of its mission.

The Space Telescope will be an optical telescope system designed to achieve near-diffraction-limited optical performance over a wide spectral range. The mission objective of the Space Telescope will be to extend space astronomy capability with meter diameter optics, thereby performing high resolution spectroscopic and imaging of planetary bodies, stars, nebulae, and galaxies. The Space Telescope will be used to measure the structure of quasars and the state of interstellar and intergalactic matter. The STS will place the Space Telescope into a 270 nmi circular orbit with an inclination of 28.8°.

V. ATTACHED SCIENTIFIC PAYLOADS

In addition to the utility for placement of satellites into Earth or planetary orbit, the STS will also be used to transport into space a complete scientific laboratory called Spacelab, which is being developed by the European Space Agency (ESA).

The purpose of Spacelab is to provide a ready access to space for a broad spectrum of experiments in many fields and from many nations. Spacelab personnel will be men and women who are experts in their fields, and who are in reasonably good health, thereby requiring only a few weeks of spaceflight training. In the pressurized module configuration shown in figure 21, Spacelab will provide facilities for as many as four laboratory specialists to conduct experiments or perform processing functions in such fields as medicine, manufacturing, astronomy, pharmaceutical, and materials. In the five-pallet configuration shown in figure 22, the entire STS payload bay will be filled with structural pallets upon which will be mounted numerous scientific experiments or applications hardware elements to be exposed to the Space environment. Control and management of the pallet systems will be exercised from the STS by payload and mission specialists using various Orbiter and Spacelab control and display interfaces provided for the mission. When only pallets are to be flown, essential subsystems requiring environmental control will be carried in an igloo which will provide a pressurized and thermally controlled environment for them.

Spacelab will provide an extension of the experimenter's ground-based laboratories with the added qualities which only space flight can provide, such as a long-term gravity-free environment, a location from which Earth can be viewed and examined as an entity, and a place where the celestial sphere can be studied free of atmospheric interference.

VI. TYPICAL NATURE OF PAYLOAD DATA

As has been described above, the types of mission cargoes being considered for the Shuttle range from a full payload bay complement of deployable satellite/booster payload elements to a dedicated sortie mission in which the payload bay is filled with an environmentally controlled laboratory and experiment pallets. The types and quantities of data to be processed and/or throughput by the Orbiter will vary widely depending on the composite payload cargo. The Shuttle may be required to handle up to 50 Mbits/s of high rate experiment data while simultaneously performing systems monitoring and control functions, system checkout functions via an onboard CRT/keyboard interface or via one of the uplink/downlink operational data links with ground controllers. For a mission consisting of only deployable satellites/boosters, the data handling requirements may be much less, primarily for systems monitoring/checkout functions.

The Space Shuttle Orbiter is being equipped to provide a variety of data handling services for both attached and detached payloads. Scientific data from attached payload sensors and experiments can be transmitted to STDN or SCF ground stations by the Orbiter S-band communication subsystem, or relayed through a tracking and data relay satellite (TDRS) at S-band or Ku-band. The Orbiter can also record and store scientific information sent over hard line from attached payloads, or relay text and graphics data sent from the TDRSS ground station (at Ku-band).

Engineering health and status data from both attached and free-flying payloads can be processed, displayed and recorded on-board, or sent to the ground.

Ground-initiated commands for both attached and detached payloads can be transferred through the Orbiter communication system and data processing system (DPS). Commands to both attached and detached payloads can also be initiated by the Orbiter crew via the Orbiter DPS.
The Orbiter will initialize a payload guidance and navigation system or update its state vector using on-board data or information transmitted from the ground. Guidance data from an attached payload may be monitored and recorded by the Orbiter crew, or processed by the Orbiter DPS for closed loop pointing, using the orbital maneuvering system (OMS).

Up to five safety-critical status parameters can be hardwired from an attached payload to the Orbiter. The Orbiter crew will monitor these parameters and can take the necessary timely remedial actions. These parameters plus others are also monitored and can be recorded as part of the Orbiter systems monitoring function. Payload caution and warning (C&W) data can be transmitted to the ground through the Orbiter.

**Payload Data Processing/Transmission**

An on-board processing, display and data transmission capability will be provided by the Orbiter as a service to both attached and detached payloads (ref. 2). The Orbiter data processing and software subsystem will furnish the on-board digital computation required to support payload system management. The system management function will be used during prelaunch and orbital phases for payload checkout and status monitoring (passive). Functions in the computer will be controlled by the crew through main memory loads from the mass memory. Flight-deck stations for payload management and handling will have provisions for data displays (CRT's) and keyboards for monitoring and controlling payload operations.

**Data Processing for Attached Payloads**

The Space Shuttle vehicle will provide data processing/handling services for attached payloads in the following areas:

1. scientific/experiment sensor data
2. engineering/systems management
3. hazards monitoring/control data
4. data recording
5. guidance, navigation and attitude control

**Scientific Data Handling**

Only limited processing, that required to throughput data to a ground terminal, will be provided for payload medium-band and wideband scientific data inputs (inputs in the range of 16 kbits/s to 50 Mbits/s).

Wideband science data in the form of a PCM bit stream (NRZ-L, M, or S) at rates between 2 and 50 Mbits/s will be accommodated via the Ku-band link. When operating in this mode (Ku-band Mode 1, channel 3), the input data stream will be convolutionally encoded at rate 1/2 to achieve the necessary error protection on the link. The input payload data stream must be accompanied by a 1 × bit rate clock, which is used to drive the encoder circuitry.

The Ku-band wideband analog channel input (DC–4.5 MHz) can be used by payloads with unique modulation schemes or data formats as a transparent throughput channel, which will provide greater data transfer flexibility and minimum Orbiter processing. Capability will be constrained primarily by the Ku-band signal processor bandwidth.

For data rates below 64 kbits/s, the data can be routed through a payload data interleaver (PDI) to the PCM master unit, where it will be made available to the general purpose computer (GPC) for processing and on-board display. A payload specialist crew member may then interface directly with a specific experiment, as required.

Medium-band scientific data will be routed to the receiving ground terminal either via the S-band FM link or via the Ku-band system as follows:

(a) S-band FM:
   - Analog: 300 Hz–4.5 MHz
   - Digital: 200 Mbits/s–5 Mbits/s NRZ-L, M, or S (or)
   - 200 bits/s–2 Mbits bi-phase-L, M, or S

(b) Ku-band:
   - Analog: DC–4.5 MHz BW
   - Digital: 16 kbits/s–1.024 Mbits/s bi-phase-L
   - 16 kbits/s–2 Mbits/s NRZ-L, M, or S

**Engineering/Systems Data Processing**

The PDI will provide the capability to receive engineering data from up to five attached payloads simultaneously. The PDI will then decommutate up to four of these inputs and provide time-tagged, time homogeneous data from these payloads simultaneously to the Orbiter DPS for on-board display and/or for transmission to the ground via the operational instrumentation (OI) downlink.

The throughput data rate (composite PDI output to the PCM master unit) will be limited to 64 kbits/s on-orbit and 5 kbits/s for ascent.

A capability to throughput data which is in non-standard format, or other unique data such as encrypted data, will also be provided by the PDI. In this mode, the frame synchronization circuitry will be by-passed and artificial data blocks will be established to transfer the data to the PCM master unit. No on-board processing or display of the data will be available when operating in the non-standard mode.

**Hazards Monitoring and Control**

A capability will be provided by the STS to monitor, annunciate, and control hazardous parameters. Five hardwired inputs to a caution and warning electronics unit (CWE) will be provided for out-of-limit sensing and annunciation at the forward flight deck panel. In addition, audible tones (siren for fire/smoke and klaxon for rapid depressurization) will be generated and sent to the audio central control unit (ACCU) for distribution. An additional 50 inputs (25 analog/25 discrete) will be accommodated via a multiplexer-demultiplexer unit (MDM) for annunciation by the CWE, as well as fault annunciation display on the Orbiter CRT. System safing will be provided via five dedicated switches located on the forward flight panel or via 36 software-controlled discrete output signals available from the MDM.
A capability for direct recording of certain types of payload data will be provided by the STS. The payload recorder will be a 14-track recorder capable of serial or parallel recording of digital and analog data. Data rates from 25.5 kbits/s to 1.024 Mbits/s and analog data of 1.9 kHz to 2 MHz may be recorded. A minimum record time of 56 min will be provided at the maximum data rate. Simultaneous analog/digital parallel recording will be limited to first record pass. Subsequent passes will be restricted to sequential single-channel digital recording. A total of 14 tape speeds (4 per mission) will be available and selectable by on-board or ground control.

Guidance, Navigation & Attitude Control

Guidance, navigation and attitude control services will be provided for payloads by the STS. The Orbiter will provide state vector up-date data words to payloads, provide target state vector data words to payloads, receive body vector and target vector data for payload pointing via Orbiter attitude maneuvers, and receive attitude errors and commanded angular rates from payload-mounted sensors for cooperative attitude control.

Data Processing for Detached Payloads

A basic capability for low rate data processing/display services will be provided for detached or deployed payloads via an S-band RF communications link between the Orbiter and payload. The Orbiter S-band transceiver (payload interrogator) that supports RF communications with detached payloads will be compatible (frequency-wise) with STDN, SCF, and DSN compatible payloads. The interrogator will be capable of operating at approximately 860 selectable frequencies in the 2200-2300 MHz band. A detailed description of the planned command and data handling capabilities of the STS for detached payloads is contained in reference 3, which appears in this issue.

VII. SUMMARY

The Space Transportation System is designed to provide an economical means of supporting a wide range of scientific, commercial, and defense oriented space missions and will be used to carry into space nearly all civilian and military payloads of the future. The STS system will reduce the cost of Earth orbital space operations while enabling over a decade of technology advancement in the area of new products, new services, and new sources of energy.

REFERENCES


William E. Teasdale (S'62-M'63-M'78) was born in Austin, Texas on September 22, 1939. He received the B.S. (honors) from the University of Texas at Austin in 1963 and the M.S. degree from the University of Houston, in 1969.

From January 1963 through February 1965, he was employed by the Westinghouse Corporation, Baltimore, Maryland, where he was involved in the design of advanced defense communications systems. In March 1965, he joined the General Electric Company, Houston, Texas, where he served as a systems design engineer and a project engineer for space vehicle electronic systems. Since April 1966, he has been employed by the NASA Johnson Space Center, Houston, Texas, where he has been involved in the engineering and development of spacecraft communications systems and flight avionics systems for the Apollo, Skylab and Shuttle Programs.

Mr. Teasdale is a member of Eta Kappa Nu and Tau Beta Pi, and is a Registered Professional Engineer in the state of Texas.
Figure 4  Crew and Passenger Cabin Areas
Figure 6  Satellite Deployment
Figure 10  Long-Duration Exposure Facility (LDEF)

Figure 11  Tracking and Data Relay Satellite (TDRS)

Figure 12  Satellite Business System (SBS)
Figure 21  Spacelab Long Module with 2 Pallets

Figure 22  Spacelab 5-pallet Configuration