SPACE SHUTTLE PAYLOADS AND DATA-HANDLING ACCOMMODATIONS

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INTRODUCTION

The primary objective of the Space Shuttle Program is to provide an economical space 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. 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. The basic elements of the STS 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 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 q-loading constraints imposed on future satellites, allowing design simplification and hence reducing costs. Third, the Shuttle, alone or in combination with a retrieval system 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 satellites. Fifth, the Shuttle can be used to perform dedicated space missions, subsystem deployment tests, or technology demonstrations on a space-available basis or in the sortie mode.

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 displays; 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. 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 crewmen from the aft flight deck 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.

STS SATELLITE LAUNCH/RETRIEVAL MISSIONS

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. Currently, there are two versions of the IUS planned — one for Department of Defense (DOD) applications and one for National Aeronautics and Space Administration (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), or eject the payload elements from the mounting cradle by means of a latch release/spring eject mechanism.

The final activation of the satellites 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, 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.

STS SORTIE MISSIONS

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.

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, 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, 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.

STS COMMUNICATIONS AND DATA HANDLING

As has been described, 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 cathode ray tube (CRT) keyboard interface or via one of the uplink/downlink operational data links with ground controllers.

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 Satellite Tracking and Data Network (STDN) or Satellite Control Facility (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 TDRS system 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 onboard 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.

An onboard processing, display, and transmission capability will provide by the Orbiter as a service to both attached and detached payloads. The Orbiter data processing and software subsystem will furnish the onboard 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.

The Shuttle Orbiter S-band communications subsystem provides tracking and communications via phase modulated (PM) links direct to ground or through the TDRSS and transmission of data direct to ground via a frequency modulated (FM) link. On the PM link, two digital voice channels, each source encoded with delta modulation at 32 Kbps, are time-division-multiplexed (TDM) with the 128 Kbps telemetry channel to form a 192 Kbps composite TDM bit sequence prior to phase modulating the carrier at frequency 2287.5 MHz or 2217.5 MHz. The telemetry channel can accommodate up to 16 Kbps from a detached payload and up to 64 Kbps from attached payloads. On the FM link, the Orbiter FM signal processor can accept (1) real-time attached payload data in either analog or digital form (analog from 300 Hz to 4 MHz, digital from 200 bps to 5 Mbps) or (2) payload recorder playback data (from 25.5 to 1024 Kbps) to frequency modulate the link carrier (2250.0 MHz). The Orbiter Ku-band system can operate as a radar during space rendezvous maneuvers or can be used as a two-way communication subsystem, transmitting the attached or detached payload data via the TDRS system. There are a total of three channels that can be accommodated via the Ku-band link. Except for the 192 Kbps channel, which is comprised of Orbiter voice and telemetry as described in the S-band PM link, the other two channels can accept attached or detached payload data. From the data rate ranges shown in figure 1, it may be seen that the capability extends continuously from 15 Kbps to 50 Mbps. Similarly, the 4.5 MHz analog channel extends downward to direct current. The unusual signal design provides quadriphase shift keying (QPSK) of a subcarrier (8.5 MHz), and either QPSK or FM of the carrier (15.0034 GHz).

The Shuttle Orbiter S-band Payload Integrator (PI), Payload Signal Processor (PSP), and DOD Communication Interface Unit (CIU) will be used for communications with free-flying payloads. For the STS-to-NASA payload link the PSP can accept up to 2 Kbps command data from the Orbiter general purpose computer, modulate command data onto a 16 KHz subcarrier and deliver the resultant signal to the PI. The PI then phase modulates the carrier (2025-2120 MHz) with the command subcarrier prior to transmitting to the payload. For the NASA payload-to-STS link, the PI can receive and demodulate from the payload, a carrier (2200-2300 MHz) phase modulated by either a 1.024 MHz subcarrier (standard mode) or a base-band signal with a bandwidth less than 4.5 MHz (bent-pipe data). If the 1.024 MHz subcarrier is transmitted, the payload telemetry data which phase-shift-keys the subcarrier can be 16 Kbps or less (in submultiples of 2). The PSP will demodulate the subcarrier and reconstruct telemetry data and associated clock prior to sending to the Payload Data Interleaver (PDI) for further processing. If the bent-pipe data (nonstandard mode) is transmitted from the payload, the PI will demodulate the carrier and forward the baseband signal to the Ku-band system for transmission to the ground via TDRS system (without onboard data processing or display).

On the STS-to-DOD payloads link, the PI will accept ternary frequency shift keying/ amplitude modulation command data from the CIU and phase modulate the command signal onto the carrier (1760-1840 MHz) prior to transmitting to the payloads. For the DOD payload-to-STS link, the PI can receive and demodulate from the payloads a carrier (2200-2300 MHz) phase modulated by a 1.024 MHz subcarrier and/or 1.7 MHz subcarrier. The 1.024 MHz subcarrier can be phaseshift-keyed by the payload telemetry data up to 64 Kbps, while the 1.7 MHz subcarrier can be frequency modulated by three payload analog subcarriers. The CIU will then demodulate the 1.024 MHz and/or 1.7 MHz subcarrier and process the demodulated baseband signals.

Figure 1 illustrates overall payload/Orbiter communications system and data rates.

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, 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 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 observations. 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 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 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. DOD payloads and space activities will be based on a separate DOD mission mode.

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 resources, meteorology, and communications. 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.

Numerous free-flying paylods 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.

Tracking and Data Relay Satellite

The TDRS, 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 onorbit spares, and a ground station located in White Sands, New Mexico, will eventually replace most of the existing STDN ground stations.

Jupiter Orbiter Probe (JOP)

The JOP/Project Galileo spacecraft is to be launched into planetary trajectory via the STS using the IUS. The JOP will eventually be placed in orbit about the planet Jupiter to make remote measurements. 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.

Telesat

The Telesat payload, which will be launched into geosynchronous orbit using the STS, 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, 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 worldwide.

Teal Ruby (Space Test Program P80-1)

The Space Test Program P80-1 or Teal Ruby System is a satellite comprised of equipment necessary to support three experiments onorbit 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 onorbit 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 onorbit for its three-year mission by the Air Force Satellite Control Facility.

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 will reduce the cost of Earth orbital space operations while enabling the use of more than a decade of technology advancement in the area of new products, new services, and new sources of energy.

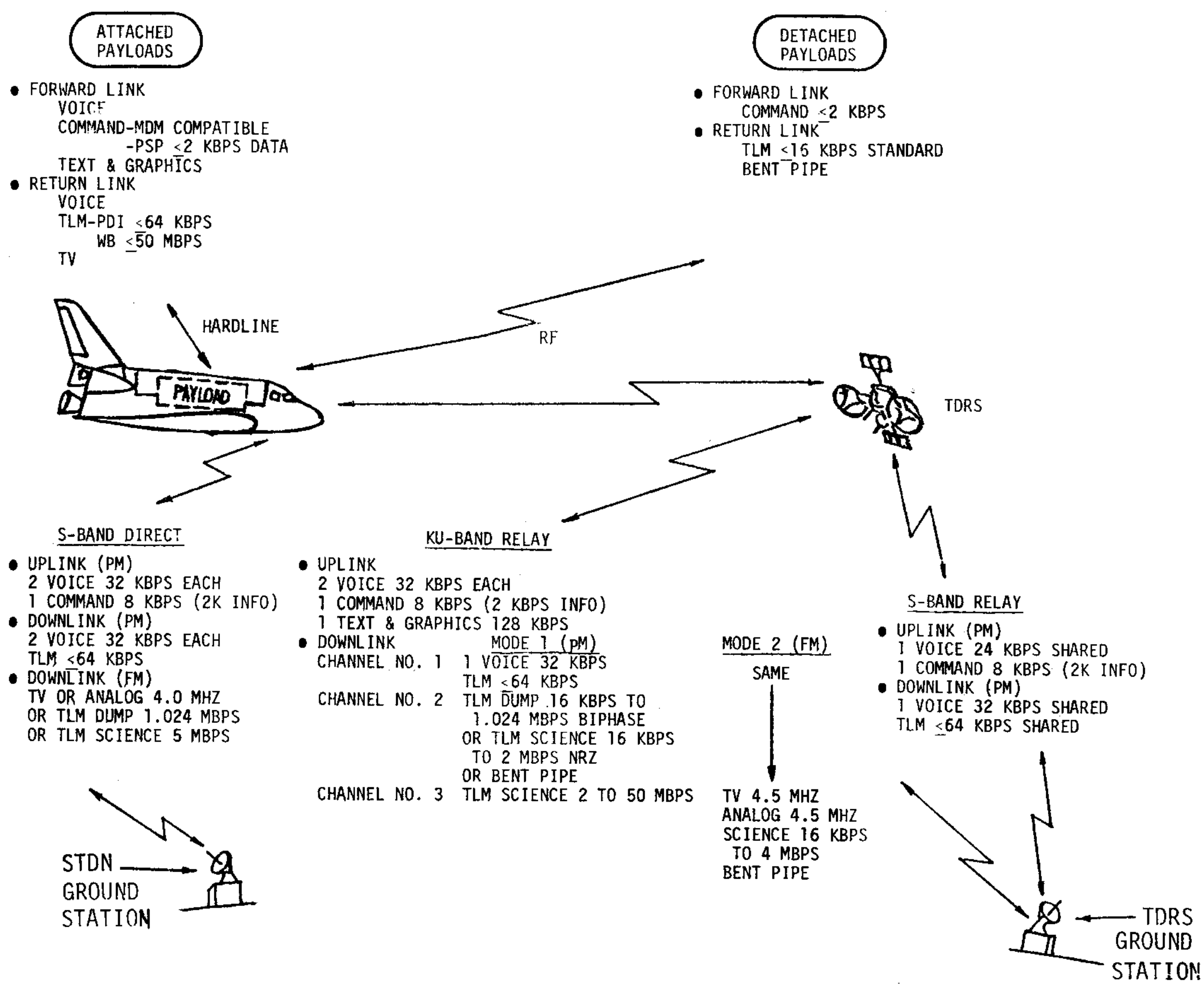

Figure l.- The overall payload/Orbiter communications system and data rates.