SMALL PAYLOAD FLIGHT SYSTEM (SPFS)

by

R.A.K. Mitchell
Teledyne Brown Engineering
Huntsville, Alabama 35807

Developed by Teledyne Brown Engineering, the Small Payload Flight System provides a simple and cost-effective approach to carrying small size experiments on the Space Shuttle. The system uses a bridge-like structure which spans the Orbiter Cargo Bay but is only 3 feet in length. The structure can carry up to 4300 lb of payload weight and can be positioned at any location along the length of the cargo bay.

In addition to the structural support, the SPFS provides avionics services to experiments. These include electrical power distribution and control, command and telemetry for control of the experiments and subsystem health monitoring, and software computations. The avionics system includes a flight qualified electrical power branching distributor, and a system control unit based on the Intel 8086 microprocessor. Data can be recorded on magnetic tape or transmitted to the ground. Finally, a Freon pump and cold plate system provides environmental control for both the avionics hardware and the experiments as necessary.

The bridge structure was used for the first time to carry several material experiments on Flight 7 of the Space Shuttle. Designated OSTA-2, this mission demonstrated the application of the system and was a complete success.

This paper presents the Teledyne Brown Engineering concept for a commercial carrier system envisaged for the future. Teledyne Brown Engineering is presently engaged in discussions with the National Aeronautics and Space Administration with the intent of negotiating an agreement with the Agency for the Company to develop, own, and operate this system in the future. The contents of this paper are therefore presented for information only and do not constitute any commitment by Teledyne Brown Engineering to develop the system.

SMALL PAYLOAD FLIGHT SYSTEM (SPFS)

1.0 BACKGROUND

During the past several years, as part of the payload integration task for the Marshall Space Flight Center (MSFC), Teledyne Brown Engineering has developed the Mission-Peculiar Equipment Support Structure (MPESS). The MPESS is a bridge-like structure, only 3 feet in length, and designed to occupy only a small section of the Orbiter cargo bay. The first payload to use the MPESS was the MSFC-managed OSTA-2 materials science payload which was flown in June 1983 as part of the STS-7 cargo.

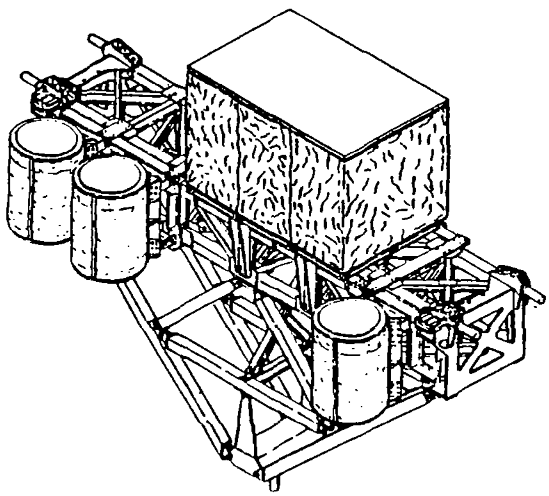
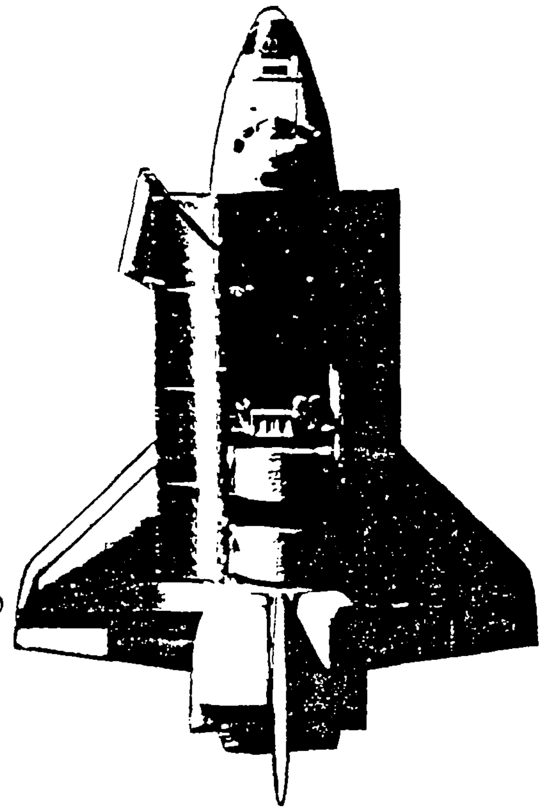


FIGURE 1-1. MSFC OSTA-2 PAYLOAD



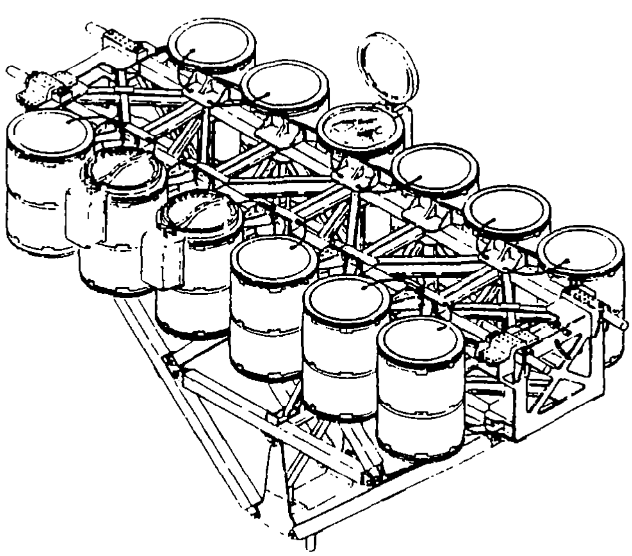


FIGURE 1-2. GAS BRIDGE PAYLOAD

The structure will be used for other MSFC applications and has more recently been adapted for two Goddard Space Flight Center programs, the GAS Bridge and SPARTAN.

In the SPARTAN application, the MPESS will carry a deployable free-flying satellite and in the GAS Bridge program up to 12 cannisters will be mounted on the sides of the MPESS. In some of the MPESS applications, support subsystems to provide power, cooling, and data handling have been mounted on the structure. For example, the OAST-1 payload, shown below, is an MSFC-managed program, and in this application, power and data handling are provided by the avionics subsystem boxes shown.

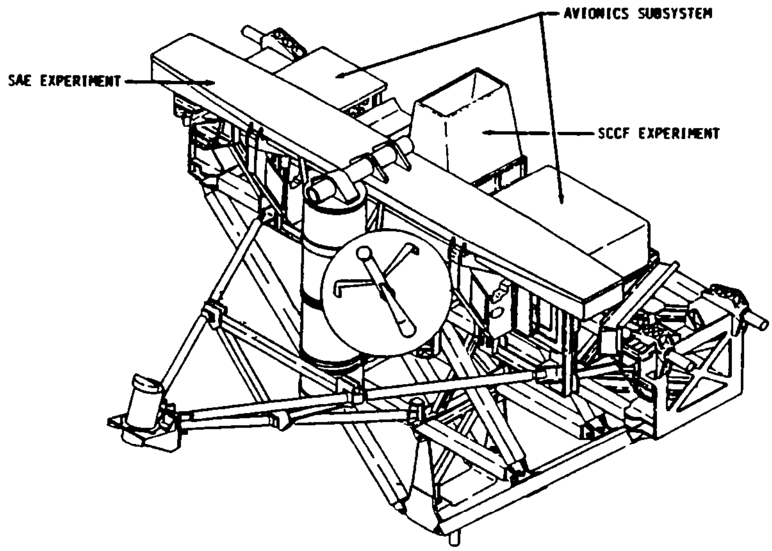


FIGURE 1-3. MSFC OAST-1 PAYLOAD

Teledyne Brown Engineering is now completing the development of the Material Sciences Laboratory (MSL) for MSFC. The MSL is based on the MPESS but will include subsystems for power distribution, command and data handling, high density tape recording of data, environmental control, and low-gravity acceleration measurement. The MSL is first scheduled to carry the MSL-2 payload in December 1984.

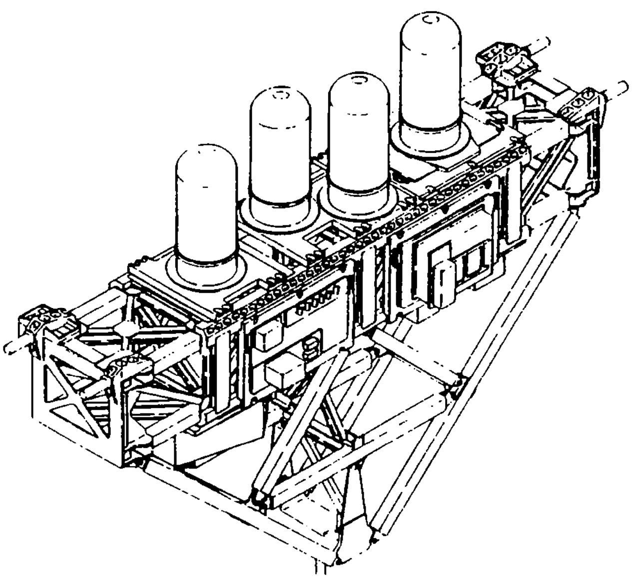


FIGURE 1-4. MSFC MSL-2 PAYLOAD

The evolution of the MPESS-based carrier fleet has led Teledyne Brown Engineering to study the potential need for a commercial carrier system which would be owned and operated by the Company and designed to provide low cost, quick turnaround, and frequent flight opportunities to the user. The result of this research is the Small Payload Flight System (SPFS) representing a step forward in the MPESS carrier evolution and designed toward the ultimate goal of commercialization in space.

2.0 SPFS SYSTEM DESCRIPTION

SPFS is a carrier system to which experiment equipment can be mounted in the Orbiter cargo bay. It is short in length, can be located at a wide range of stations, and offers the standard one-quarter section allocation of STS resources. In addition, the system is designed to meet launch dates as close as 6 months from manifesting.

Standard experiment-to-carrier interfaces and a fixed configuration for sub-system equipment are fundamental to the SPFS concept. These features minimize the cost and shorten the schedule for payload integration, and also reduce the time from manifesting to return of experiment data and hardware. The SPFS carrier system with candidate experiment systems mounted and integrated is shown in Figure 2-1.

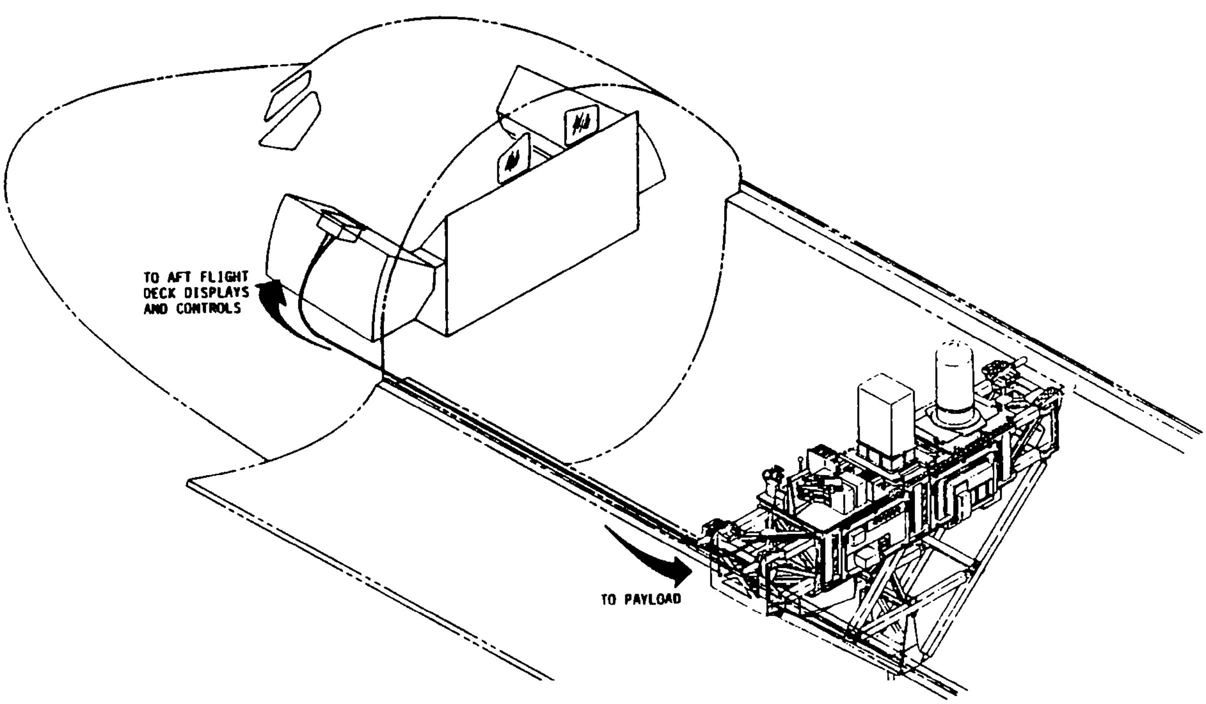


FIGURE 2-1. SPFS CARRIER SYSTEM WITH EXPERIMENTS

The SPFS with subsystems will support up to three experiments on each mission. Subsystem provisions include a standard structural mounting system, electrical power switching and distribution, command and data management, and environmental control. Table 2-1 shows the subsystem provisions and the nominal envelope of accommodations available to each experiment.

TABLE 2-1. SPFS SUBSYSTEM PROVISIONS

SUBSYSTEM	TOTAL AVAILABLE (NET)	NOMINAL 1/3 ALLOCATION (INDIVIDUAL USER)
Structural/Mechanical		
Mass Capability (lb)	3,000	1,000
Mounting Area (ft^2)	58	20
Electrical Power		
dc Power, Peak (W)	2,427	810*
dc Power, Continuous (W)	1,550	515
Total Energy (kWh)	115	38
Command/Data Management		
Switch/Indicator Pairs	10	3
Health Data Channels	176	58
Exp. Command Channels	128	42
Scientific Data Rate (kbps)**	16	16***
Timing Channels (GMT or MET)	3	1
ECS		
Coldplates	2	1
Coldplate Heat Rejection (kW)	2.1	0.7
Cooling Internal (kW)	2.1	0.7

*Peak and Continuous Durations Constrained by Energy Limit
**16 kbps for Continuous PDI or ETR Data. Max ETR data rate is 1 Mbps
***Indicates Time Shared when Downlink is Used.

The following sections provide a detailed description of each subsystem and its capabilities.

2.1 Structural/Mechanical Subsystem

The SPFS carrier provides standard structural mounting for small experiment systems. Experiment hardware may be located either on the top or side surfaces of the SPFS structure. A structural rail and plate system provides a standardized interface approach which reduces new hardware requirements and recurring analysis for reflight of the carrier (Figure 2-2).

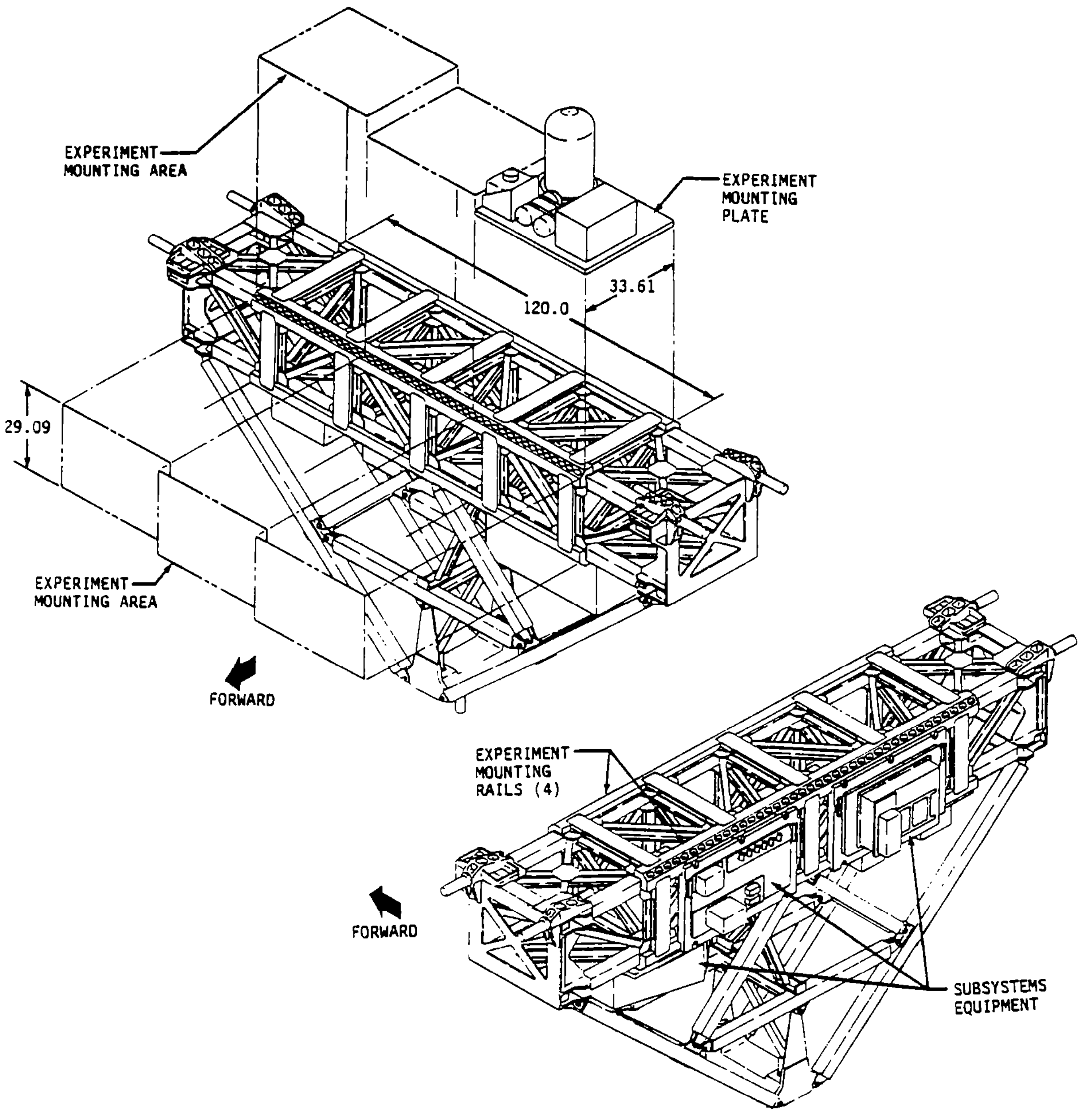


FIGURE 2-2. SPFS STANDARD STRUCTURAL INTERFACE

Each mounting surface has been divided into three sections. The three top sections are nominally 41.5 by 40 in., while the three side sections are nominally 28 by 40 in. For users requiring coldplates, certain areas will contain coldplate surfaces approximately 20 by 35 in., centered within the 28 by 40 in. area.

To interface directly to the SPFS, the experiment developer would provide a mounting plate as part of his experiment assembly. This plate would span the structural rails, Figure 2-3. The mounting plate is not considered an integral part of the structure and, therefore, would not be required to carry any primary structural loads. Where a coldplate is required for heat dissipation, the same attachment concept is utilized.

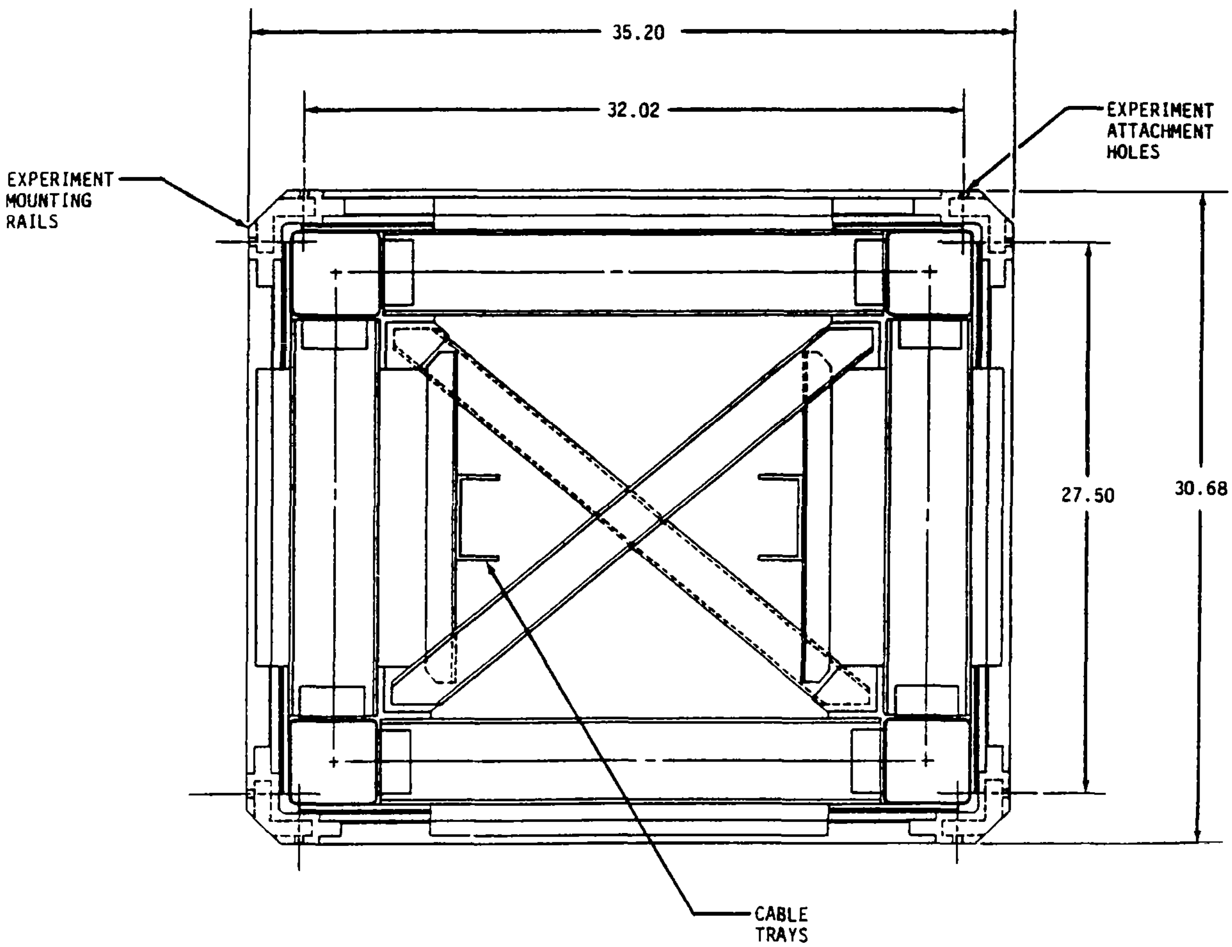


FIGURE 2-3. EXPERIMENT MOUNTING SYSTEM

The SPFS system will accommodate instruments which fit within the mass properties envelope of Figure 2-4 without the need for extensive structural/dynamic modeling. Center of gravity offset is measured from the top of the primary MPESS structure to which coldplates and adapter plates are mounted. Single section instruments with a mass greater than 1000 lb or a severe c.g. offset may be accommodated, but will require a special analysis.

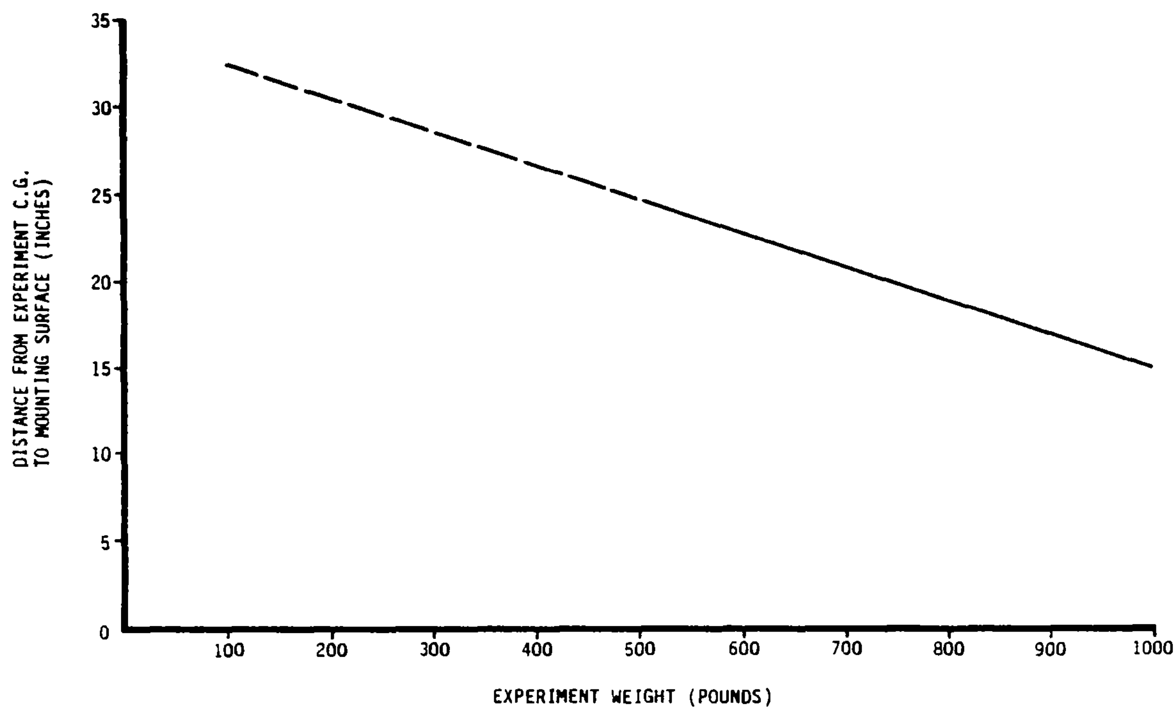


FIGURE 2-4. PAYLOAD MASS CAPABILITY

2.2 Environmental Control Subsystem

A Freon coolant loop system (Figure 2-5) circulates coolant between the SPFS subsystem coldplates, the experiment coldplates, experiment heat exchangers and the Orbiter payload heat exchanger. Freon circulation is provided by the SPFS pump. Multilayer insulation, heater elements, and surface coatings will be used, as necessary, for additional thermal control.

The experiment coldplates will be connected in parallel to the SPFS cooling loop. The temperature extremes of the coldplates will be about 2°C to 49°C and the rejection capacity of each coldplate is expected to exceed 2000 W.

Heat exchangers or coldplates which are integral components of an experiment system could be connected into an existing parallel leg at the Experiment Fluid Service Panel by disconnecting one of the SPFS coldplates.

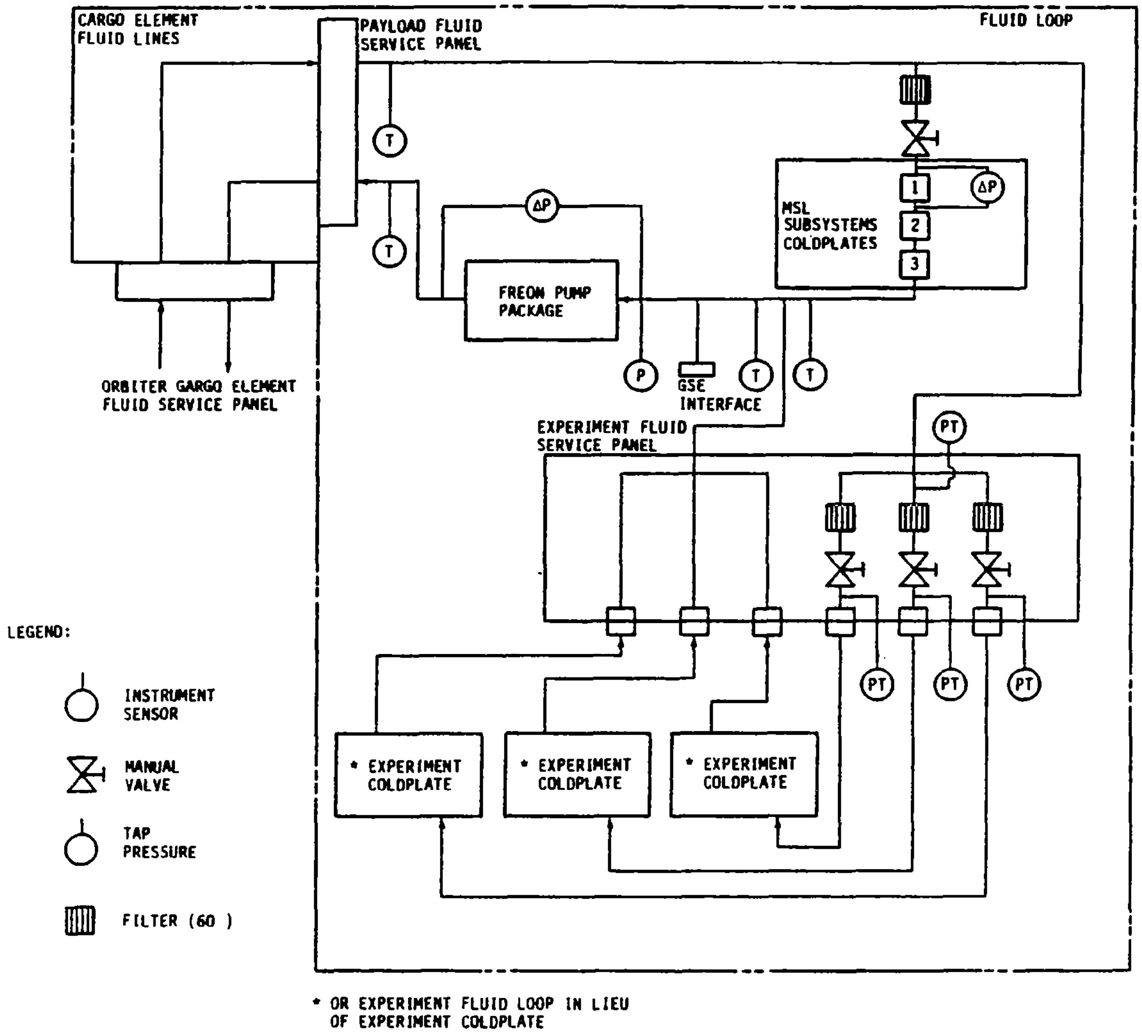


FIGURE 2-5. ACTIVE COOLANT LOOP

2.3 Power Control Subsystem

The SPFS concept includes a power distributor to provide 28 Vdc power to the subsystems and experiments. Latching relays in the distributor enable individual circuits to be energized from the AFD by crew commands. A switch on the AFD standard switch panel will activate the Power Distributor main power, while commands which control power circuits to the experiments are entered at the Command Display Management Panel (CDMP).

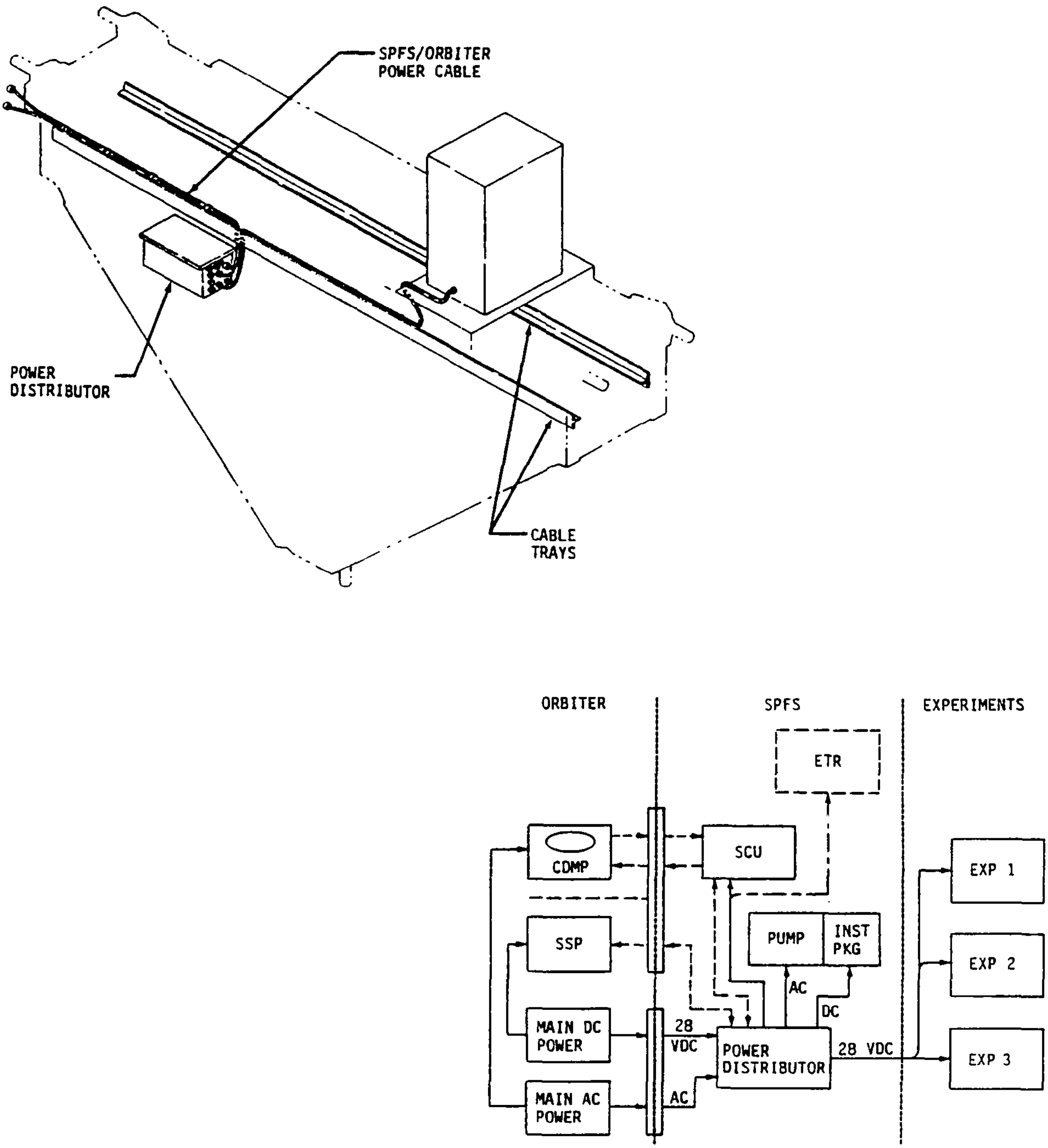


FIGURE 2-6. ELECTRICAL POWER SUBSYSTEM

A total of 222.5 kWh will be available to the SPFS. Based upon a 6-day usage of energy, nominal 28 Vdc, and considering the power for the SPFS subsystems, 115 kWh will be available to the experiments at rates as high as 2427 W (for short duration) or 1550 W continuously.

2.4 Command and Data Subsystem

Experiments are expected to range from those that are autonomous to those that will require the full SPFS resources. The following SPFS command and data accommodations are presently planned:

- Aft Flight Deck (AFD) Standard Switch Panel (SSP) operations
- Crew control using the CDMP
  - Crew initiated commands and command sequences
  - Onboard display of health/status data
- Experiment data downlinking at up to 16 kbps
- Experiment PCM data recording at up to 512 kbps
- Experiment timing accurate to ±10 msec
- Preflight interface verification at the user facility
- Crew training.

The command and data system to support experiment operations is shown in Figure 2-7. Note that the SPFS does not interface with the Orbiter General Purpose Computer (GPC), thereby avoiding the need for long-lead time GPC software development.

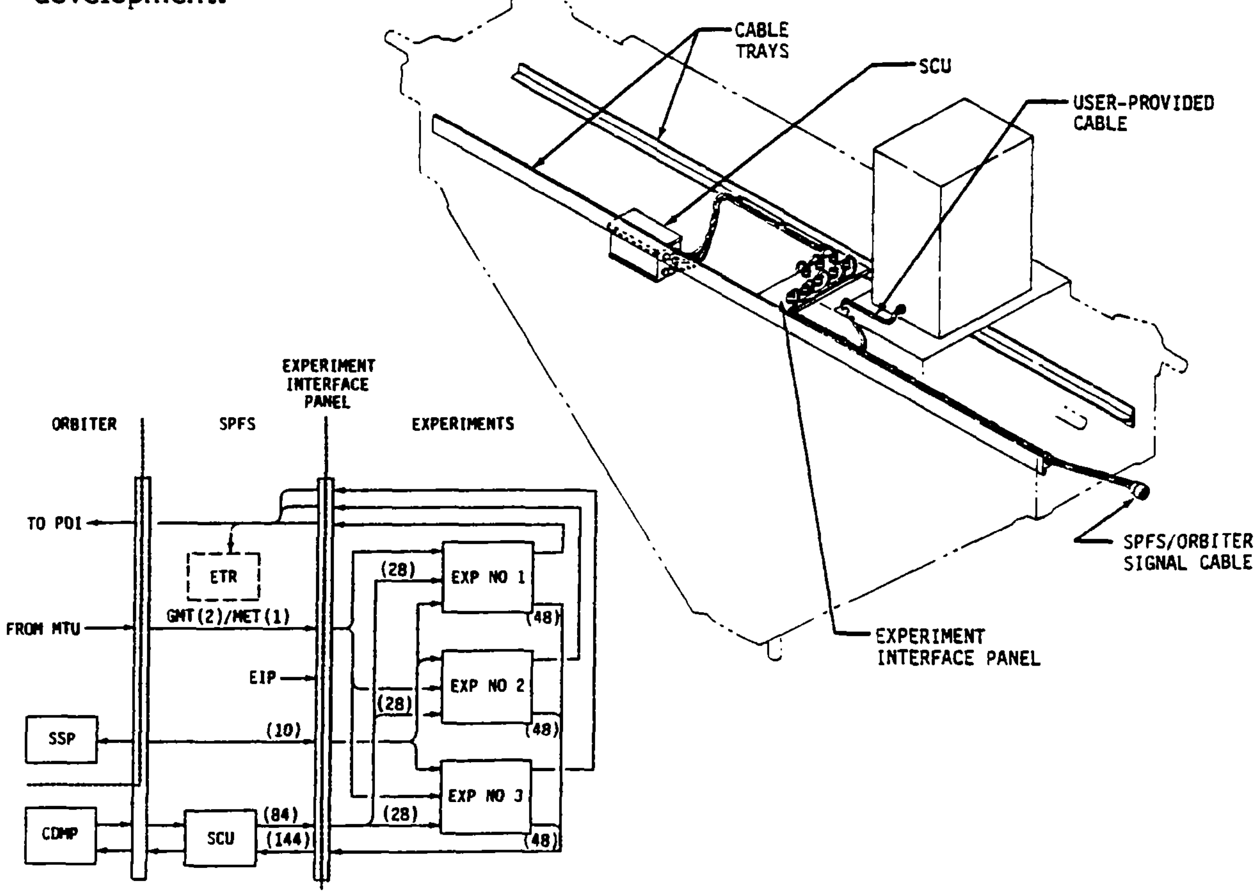


FIGURE 2-7. CDMS CONCEPT

For control purposes, 10 switch/indicator pairs are available on the SSP for sharing among the experiments. Three of these constitute the standard allocation for an individual experiment.

The SPFS Command/Display Management Panel (CDMP) is a computer terminal in the AFD which will interact with the System Control Unit (SCU) 8086 microprocessor-based computer through an RS-422 link. Together they provide a commanding capability as well as a means of monitoring experiment health and status data. A total of 84 commands and 144 measurement type channels are available for experiment sharing. The individual user allocation is 28 commands and 48 measurement channels.

The Experiment Tape Recorder (ETR) is provided for onboard recording of SPFS data. The ETR has a capacity of 2.5×10^{10} bits of data and can accept biphase PCM at rates of up to 512,000 bits per second. Nominally, the ETR will record experiment analog and digital data collected by the SCU at rates of 3,000 to 32,000 bits per second. The system can be reconfigured to accept direct experiment PCM or analog data.

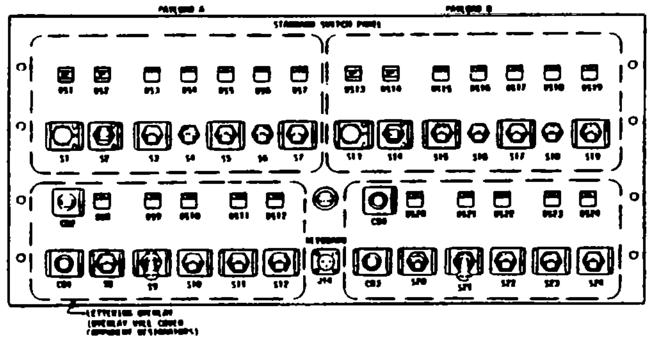
As an option, users can transmit PCM data to the ground through the Orbiter PDI at a rate of up to 16 kpbs. User data may be fed to the PDI directly or indirectly through measurements acquired by the SCU. The SCU can simultaneously record data on the ETR while transmitting data to the ground through the PDI.

Time data originates at the Orbiter Master Timing Unit. The user may accept serial time data directly or may have his data time tagged upon collection by the SCU.

2.4.1 Crew Interface

Experiment operation may be autonomous or permit crew interaction from the Aft Flight Deck Standard Switch Panel (SSP) and the SPFS CDMP, Figure 2-8. Through the CDMP the crew may change the operational mode of the experiment system, initiate a special sequence, change data rate, check critical voltages, etc.

The CDMP is a SPFS-dedicated unit containing a plasma screen for data display and a keyboard for commanding. As a standard service, up to 96 measurements will be converted to engineering units and displayed on the CDMP. Also, 96 commands will be available for keyboard commanding to user instruments via the SCU. These measurements and commands will be shared among users.



STANDARD SWITCH PANEL (SSP)

COMMAND/DISPLAY MANAGEMENT PANEL (CDMP)

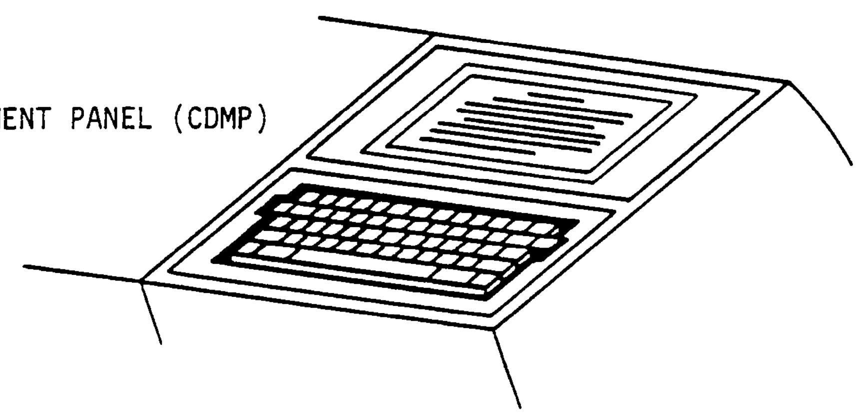


FIGURE 2-8. CREW INTERFACES

3.0 SPFS SERVICE TO THE USER

Figure 3-1 illustrates the range of services which Teledyne Brown Engineering expects to provide to the user.

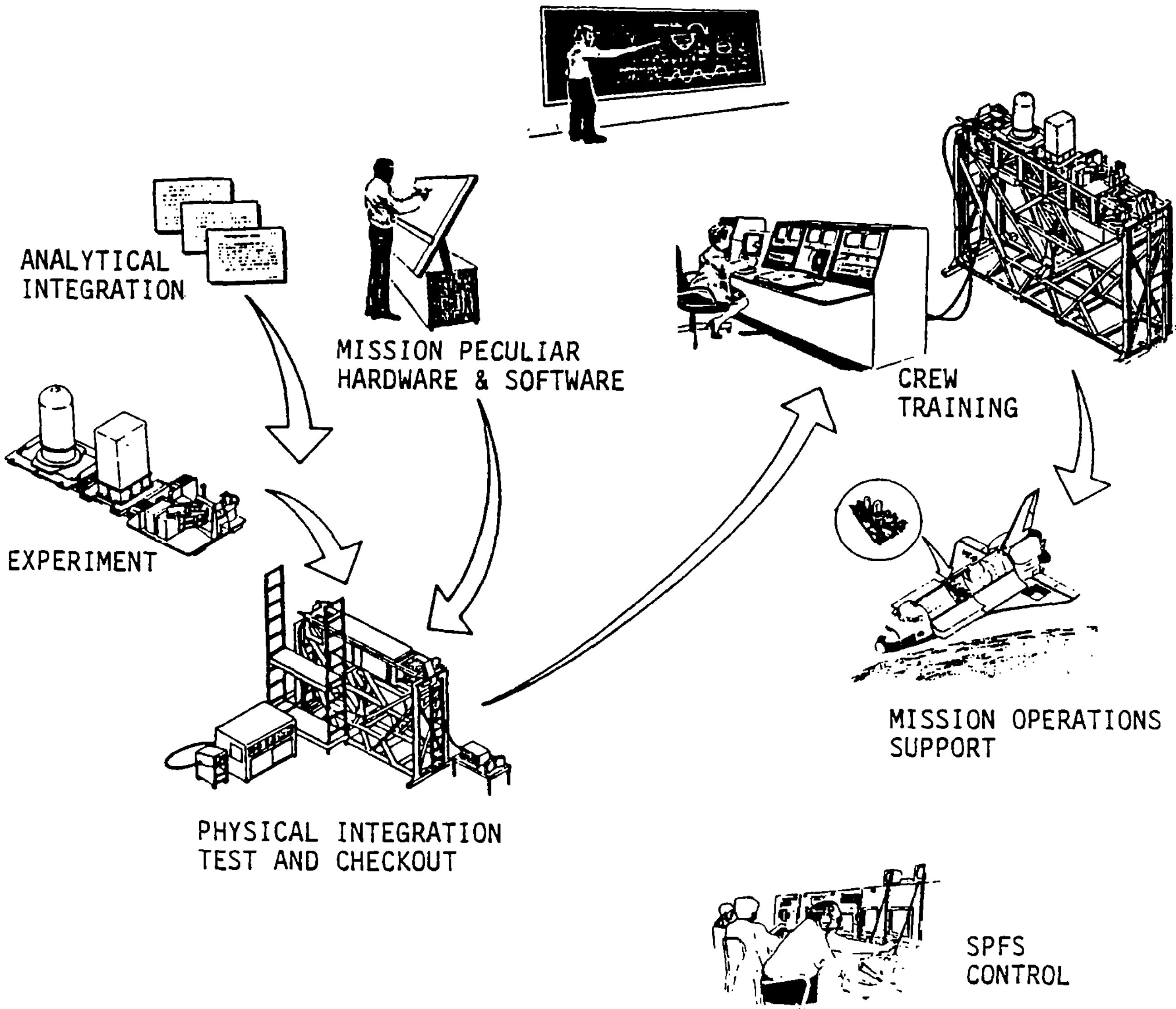


FIGURE 3-1. SPFS USER SERVICES

These services include analytical payload integration and the associated development of mission-peculiar hardware or software if this is required to interface with the experiments. Physical integration test and checkout of each payload will be conducted by Teledyne Brown Engineering; a more detailed integration test and checkout configuration is illustrated in Figure 3-2.

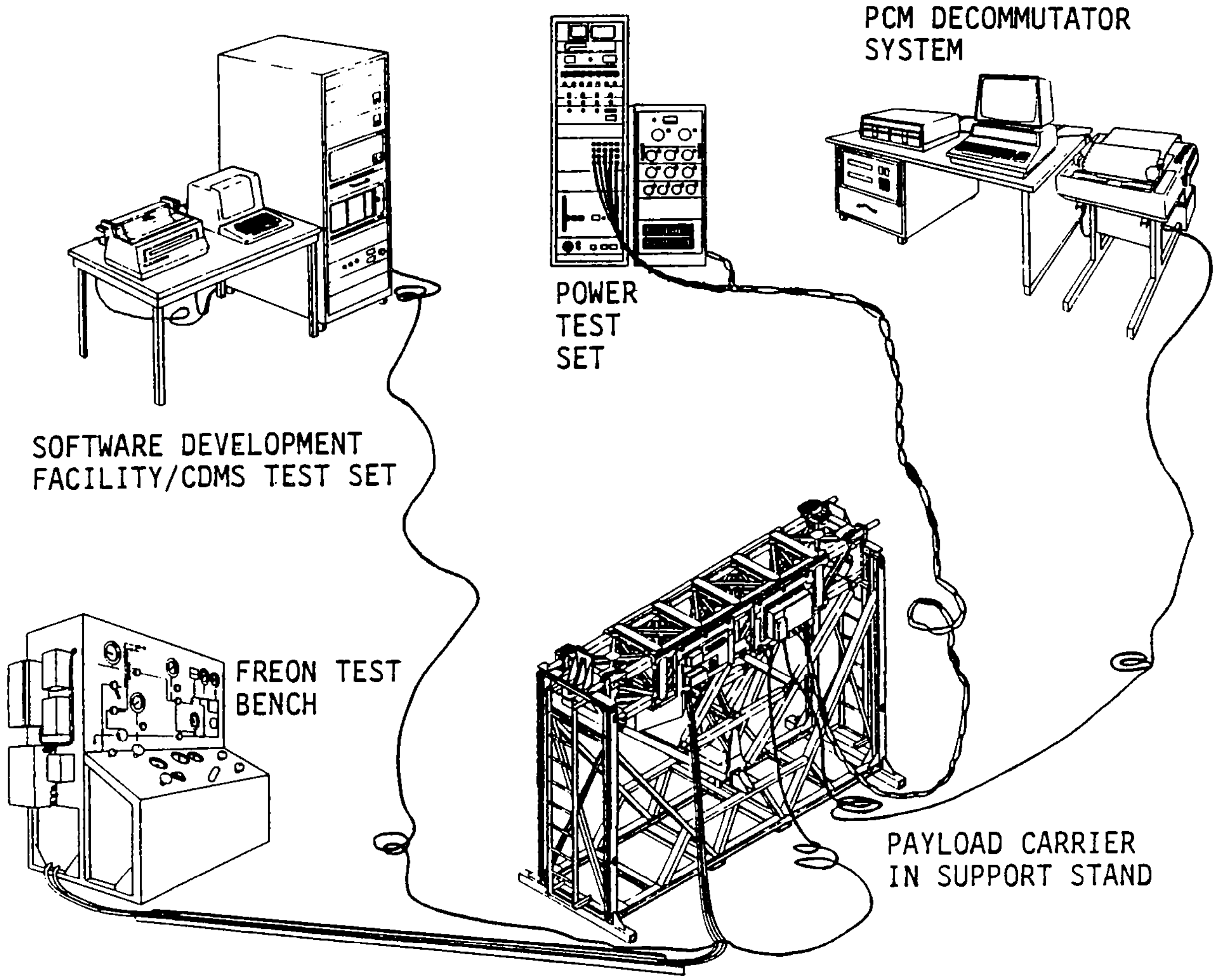


FIGURE 3-2. SPFS INTEGRATION AND TEST CONFIGURATION

Crew training, if necessary, will be conducted using a CDMP simulator which will enable the crew to exercise each SPFS flight configuration and become familiar with the experiment operational requirements. Finally, Teledyne Brown Engineering will provide real-time mission operations support to ensure smooth operation of the SPFS payload in flight.

Figure 3-3 shows the overall plan to complete the SPFS development and prepare the system for flight. Integration of the first payload is expected to require about 10 months, but the ultimate objective will be to reduce this period to 6 months.

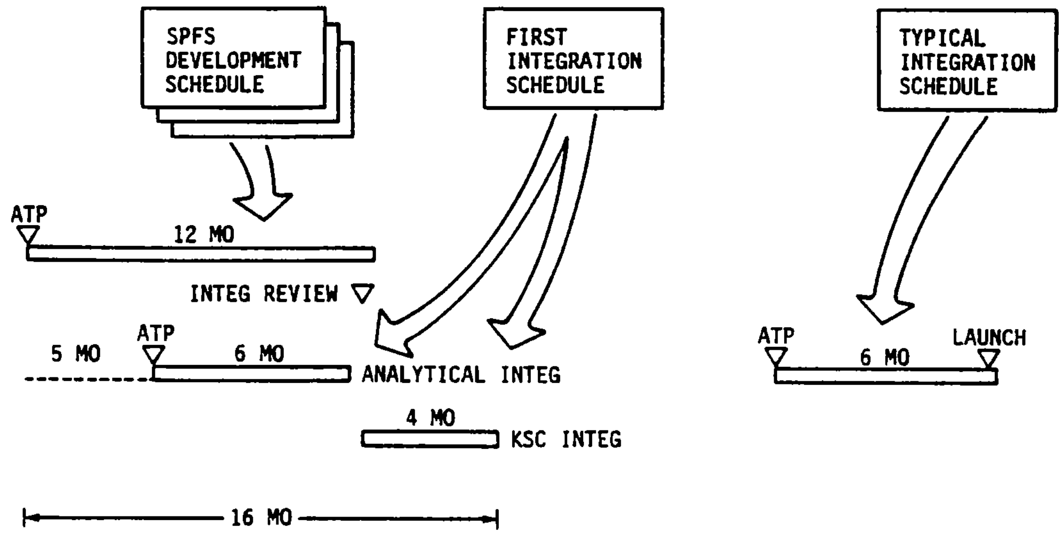


FIGURE 3-3. DEVELOPMENT AND INTEGRATION PLAN OVERVIEW

4.0 SUMMARY

In summary, Teledyne Brown Engineering has developed a concept for a future commercial carrier system. The SPFS is designed for low cost and rapid turnaround. The system provides a structural support using the Mission Peculiar Equipment Support Structure (MPESS), equipped with a full range of support subsystems including power distributor, command and data control, data recording and environmental control. The system will provide standard services to the user and will, in turn, operate within the STS standard services. This approach will ensure that the integration process is simple and can be provided at low cost to the user.