COMET: GATEWAY TO COMMERCIAL SPACE

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The COMmercial Experiment Transporter (COMET), scheduled to begin its first mission in September of 1992, is expected to be the baseline that is used to measure the capabilities of the next generation of commercial "To Space and Back" systems. This paper provides an overview of the COMET system with emphasis on its operational capabilities. The design of the Service Module (spacecraft bus) will be highlighted and its modular design and flexible architecture will be discussed.

INTRODUCTION

The COMmercial Experiment Transporter (COMET) is a NASA sponsored Centers for the Commercial Development of Space (CCDS) program designed to stimulate the U.S. commercial space industry into providing low cost "round trip" access to space. COMET is a service intended to provide a set of payloads a ride into space, command and telemetry while on orbit and recovery of selected payloads while continuing orbital operation of others as shown in Figure 1.

The program is divided into the following six work packages; Systems Engineering, Payload Integration, Service Module (Spacecraft Bus), Recovery System and Services, Orbital Operations, and Launch Vehicle and Services. The Conestoga Launch Vehicle is provided by EER Systems Space Services Division. Space Industries Inc. is providing Payload Integration, Orbital Operations and Recovery System and Services. Westinghouse Electric Corporation is providing Systems Engineering and, in conjunction with Defense Systems Inc., the Service Module.
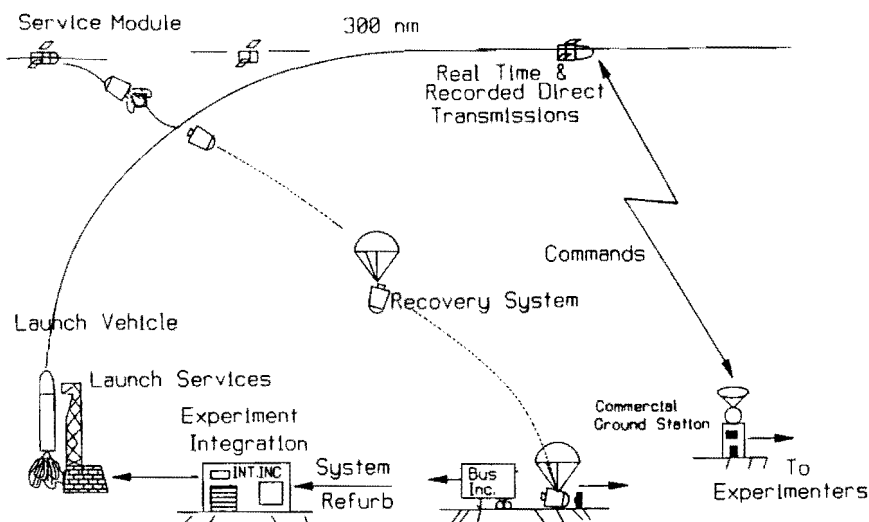

FIGURE 1.   COMET MISSION DESCRIPTION

MISSION DESCRIPTION

Slated for launch from Wallops Island, Virginia in September of 1992, COMET will carry experiments to space and back, and provide basic utilities such as electric power, cooling, data management and communications while on orbit. The modular design of this system provides flexible payload accommodations, recoverable and nonrecoverable payloads, variable flight durations and orbital parameters, increased power capacity. Access to payloads is possible hours before launch for installation of degradable material, and, after landing, payloads are made available for early access. Each mission will launch a two-part spacecraft (i.e., FreeFlyer - Figure 2.) consisting of a Recovery Capsule which returns to earth and a Service Module which provides basic support services on orbit. This dual spacecraft concept provides the capability for two types of services:

o   Recoverable Payload Service - Experiments flown for 30 or longer days, then recovered in a ballistic Recovery Capsule.

o   Nonrecoverable Payload Service - Experiments which remain in orbit for 130 days or longer with continued support from the Service Module.

RECOVERABLE PAYLOAD SERVICE

Payloads up to 300 pounds and 10 cubic feet can be accommodated in the Recovery Capsule. Payloads can be placed in the pressurized payload compartments as shown in Figure 3, or can be placed in an unpressurized area and exposed directly to the space
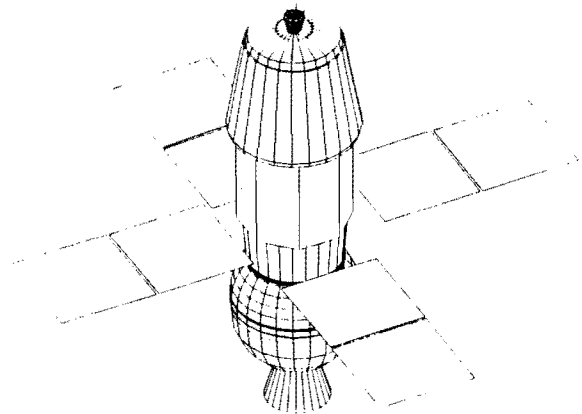

FIGURE 2.   FREEFLYER

environment while in orbit. A microgravity environment better than 10^{-5} g will be maintained during payload operation.

The Recovery Capsule, with access to the full capabilities of the Service Module while on orbit, provides a range of support for payloads:

o   Electric Power:

     28 +/- 4 volts dc
     350 watts continuous
     400 watts for 200 hours
     1000 watts peak

o   Active Thermal Control:

     72 +/- 5° F baseplate
     (98° F maximum during recovery)

o   Communications:

     250 Kbps telemetry downlink
     9.6 Kbps command uplink

o   Video:

     NTSC 4.5 MHz color (compressed)

o   On Board Data Storage:

    3 Megabytes for experiments

o   Access up to T-6 hours for late
    installation of degradable materials

o   Pressurized   or   unpressurized
    payload compartment

o   Launch loads limited to 12 g

o   Reentry loads limited to 10 g
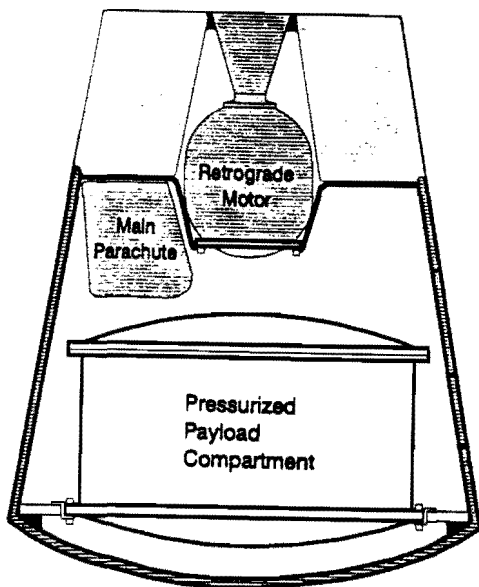
o   Nominal 30 day mission duration

FIGURE 3. RECOVERY CAPSULE

Communications to the payloads is
via 9.6 Kbps uplink and 250 Kbps
downlink. Both event driven and time
tagged experiment commands can be
stored in the Service Module for
autonomous execution. The payload
mounting plate temperature in the
pressurized compartment is controlled to
72 +/- 5° F by the active cooling system.

Late access provisions allow degradable
materials, such as biological samples, to be
installed up to 6 hours prior to launch.
Following completion of the Recovery
Capsule mission, it will separate from the
Service Module and fire a retrograde
motor to initiate reentry into the
Bonneville Salt Flats in Utah. A
parachute system deploys to slow the
capsule for a ground landing. Payloads
are accessible within 4 hours of landing.

**NONRECOVERABLE PAYLOAD
SERVICE**

Payloads up to 150 pounds and 15
cubic feet can be accommodated in the
Service Module as shown in Figure 4.
The nominal mission will place these
payloads in a 300 +/- 20nmi, 40.6 +/-
0.2° inclination orbit. A microgravity
environment better than 10^{-5} g will be
maintained during payload operation.
Payloads are installed on the payload
mounting plate using a standard interface.
The plate is controlled to 72 +/- 5° F by
the Service Module active cooling system.
All communication, command and data
processing capabilities available to
recoverable payloads are also available to
nonrecoverable payloads for the full
duration of the mission. The following
options are available to nonrecoverable
payloads:

o   Exposure   to   the   Space
    Environment

o   Earth or other pointing modes with
    +/- 0.5° accuracy on each axis

o   Mission durations up to 180 days
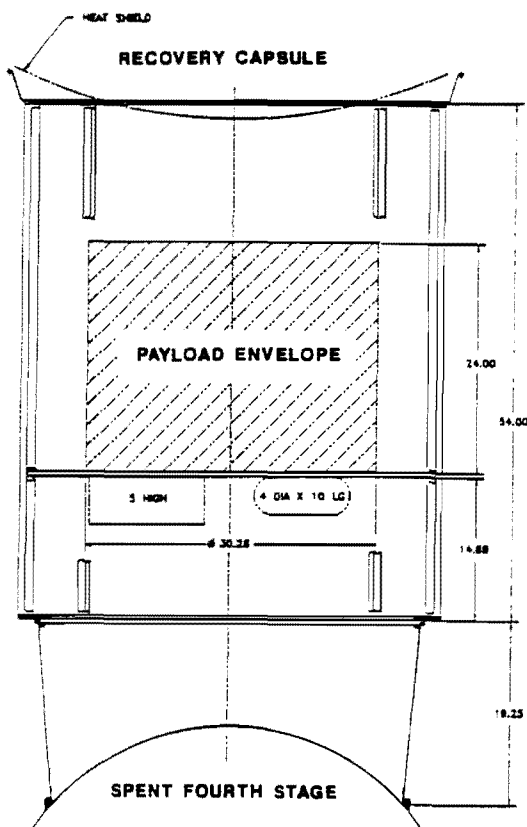   or longer

COMET SERVICE MODULE SUBSYSTEMS

FIGURE 4. SERVICE MODULE

The six major subsystems of the Service Module are; structure, thermal, attitude control, power, RF, and digital. These are all designed to provide the experiments within the Service Module and Recovery Capsule with a quiet, temperature controlled environment. Other than the necessary delays in issuing commands and retrieving data from his experiment, the experimenter will see the COMET system as transparent.

STRUCTURE

The Service Module (SM) structure must carry its own weight, the weight of the experiments within the SM, and the weight of the Recovery Capsule (RC). The weight targets for the COMET program are for 800 lbs. for SM and 1000 lbs. for RC inclusive of experiments. The SM structure then must carry 1800 lbs. to space with expected loads of 12 g longitudinal and 3.5 g lateral. A structural design that has been flight proven on other satellites has been chosen that incorporates longitudinal stringers tied rigidly to end plates or annulus rings and light weight side panels. The SM is eight sided, 44 inches across the diagonals and 54 inches in length, with a solid bottom plate holding core subsystems, a non load bearing equipment deck, and a top annulus to interface with the RC spin table. The side panels carry little shear and two panels are removable for access and for carrying externally mounted experimenter sensors. This design has resulted in a lightweight structure that is only 12% of the total weight of 1800 lbs. The SM also provides a 150 pound payload capability for experimenters within a 15 cu. ft. volume. The equipment deck is temperature controlled and can bear weight at 3 lbs/sq. in. Table 1 is the current SM weight statement showing the breakdown for the major subsystems.

TABLE 1
SERVICE MODULE Wts.

Ballast	25
Payload	150
Structure	190
RF	9
ACS	89
Power	161
Digital	29
Thermal	52
Harness	20
Margin	75
	800

THERMAL CONTROL

The SM uses a Capillary Pump Loop (CPL) two phase ammonia system to transport heat from the experiments within the SM and RC to the body mounted radiators on six of the eight sides of the SM. The CPL system is designed to maintain the equipment decks at 72° +/- 5° with an input of up to 400 watts. The experiments are currently limited to a heat input of 5 watts/sq. in. although the CPL system can withdraw over 20 watts/sq. in. The CPL system is essentially isothermal, reducing significantly the thermal gradients between inlet and outlet ports on the equipment plates. A significant benefit of the CPL is the absence of mechanical pumps and valves which have the potential for creating microgravity disturbance to the experiment environment.

ATTITUDE CONTROL

The SM Attitude Control System (ACS) has six major modes of operation; alignment for orbit insertion and 4th stage burn, sun pointing with the RC, RC reentry pointing, sun pointing without RC, earth pointing, and SM de-orbit burn. Three of these modes, sun pointing with and without the RC and earth pointing, are required to maintain a 10^{-5} g. During alignment and release of the RC, the requirement is relaxed to not exceed 10^{-2} g. These very low g levels are maintained by use of two 2 lb. reaction wheels for attitude control being off-loaded as necessary by three axis torque coils. Sun Pointing of +/- 0.5° is achieved by a fine sun sensor and earth pointing of +/- 5° is controlled by the reaction wheel operating in a momentum bias mode. Pointing accuracies of +/- 0.5° are achievable in any orientation for limited periods based on IMU drift rates. Roll knowledge in both sun and earth pointing modes is supplied by a horizon scanner. Operation in the earth pointing mode will allow the SM to fly with one of its side panels facing the "RAM" direction for those experiments requiring such exposure.

A cold gas system with 10 lb. thrusters is used for orbit insertion maneuvers, for alignment for RC reentry, and offsetting the spin table torque during the Recovery Capsule spin prior to reentry release. Orbit insertion and alignment for RC reentry are controlled by a three axis IMU.

POWER

The SM power subsystem provides 28 +/- 4 volts dc for the SM and RC experiments and core functions. Four deployed solar panels generate a peak of 970 watts which, after orbit, Beta angle, and other loss considerations, supply 600 watts of power for all activities in the sun pointing mode. The Experiments are allocated 400 watts continuous, the SM core 50 watts average and the RC 20 watts. Thus, a margin of 100 watts is provided for peak loads and aging. Power available during the earth pointing mode is significantly reduced since the panels are no longer sun pointing at all times. Available experiment power in this mode varies from 46 watts to 100 watts based on orbit considerations.

DIGITAL

The SM employs two 80C186 processors with Error Detecting and Correcting Memory as well as radiation hardened RAM. One processor is dedicated to ACS functions and the other

to control of the SM, experiments, scheduling, and telemetry. This command and Data Handling (C&DH) processor also has a 4 Megabyte memory partitioned with 1 Megabyte for SM telemetry and 3 Megabytes for experimenter data. This memory is allocated into mailboxes for the experiments but can be reallocated by ground command for changing mission profiles.

The data interface with the experiments was chosen to be RS422 with X-modem as the operating protocol. This interface was based on several design goals; ease of implementation, availability of off-the-shelf tools to aid in testing, expandability for future modification, and simple for the experimenter to implement.

Each experiment port, of which there are 4 in the SM and 6 in the RC, has RS422 data interface as well as a standard NTSC format video port. The video is digitized, compressed and stored as part of each experimenters data. The compression parameters are commandable from the ground so each experiment can optimize their video data.

RF DATALINK

The SM uses a 250Kbps Bpsk downlink at 10 watts with a carrier stability of 1 part in 10^{10} available. The requirement for high carrier stability is driven by the use of the ground carrier recovery system to track doppler for in track positioning. However, for COMET, NORAD is expected to provide precise orbit parameters. Given the normal 300 nmi orbit, pass times of at least 40 minutes per day are expected. At the downlink data rate, the 4 megabyte memory can be dumped in just over two minutes.

The uplink is FSK at 9600 Baud. Both receiver and transmitter are continuously on during a pass for each to track doppler. The data and commands are passed using a handshake and error checking process that reduces the expected bit error rate to below 1 in 10^9.

SUMMARY

At the time of this writing, all COMET contractors had completed their preliminary design reviews and are well on the way toward completing final design. Once completed, this design will serve as the baseline for the next generation, fully commercial payload service.