SYSTEM CONCEPTS FOR THE SCOUT EXPLORER

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Abstract - NASA's Explorer program is being expanded to include a series of "Scout-class" science missions. These small spacecraft will be supported by a Standard System, including a spacecraft bus and a transportable ground station. The system concept is being developed in anticipation of an experiment solicitation in 1988. The spacecraft will be a Sun, vertical and star pointer, momentum stabilized, with S-band communications direct to ground stations. The transportable ground stations allow Principal Investigators to assume complete control of the spacecraft. The Standard System is optional to each mission and may be used in part, in total, or not at all.

INTRODUCTION

The Explorer Program

Since America's entry into space with Explorer I, the Explorers have contributed, often spectacularly, to the space sciences. A quarter century of space exploration has seen the Explorers grow from small, frequent missions to large observatories like International Ultraviolet Explorer and the coming Cosmic Background Explorer. In 1988, NASA plans to augment the current program with a new series of small, frequent missions, reminiscent of the Explorers of the 60's -- dependent, of course, on the vagaries of Federal funding.

The Standard System

In a quest for frequent, quick missions, the small Explorer experiments will be supported by a NASA standard system that provides, at minimum cost, the spacecraft and ground equipment that a Principal Investigator requires for his/her mission.

The Standard System comprises a spacecraft bus, a transportable ground station, GSE (Ground Service Equipment), and requisite software to develop and fly a science mission. The basic premise of the Standard System is that the majority of missions can economically benefit from a common spacecraft bus and ground support facilities. The limited size and lift capability of Scout tend to constrain payloads to a rather uniform performance limit -- the common bus spacecraft seeks to provide this limiting performance to all proposers at minimum cost. To do so NASA must craft a flexible, yet highly efficient system, using both new technologies and proven designs, ingenuity and experience.

Thus the two axes of errors are transposed to (roughly) the sum and difference of the wheel speeds. Sun pointing is a subset of star pointing, in which the star tracker is replaced with a sun tracker. In all cases, magnetic torquing will control the momentum vector.

Power System

The solar arrays, controller and battery can be conventional space designs. The array will be designed for each mission: sun pointers will have a flat array normal to the Sun; star pointers will have a fixed array operable over a beta angle range of 135 degrees; and a vertical pointer will have fixed arrays oriented according to the orbit inclination. The batteries will probably be 20 Ah NiCd cells.

Communications and Data Handling

Communications will be S-band direct to ground. TDRSS does not look practical for Scout missions because of the antenna size -- the Scout heatshield is but one meter diameter -- and the transponder power and cost. Data handling rates and storage will be adequate for 10 kb/s continuous data from low Earth orbit to a single ground station. Experimenters will be provided a "black box" that interfaces with the spacecraft command and data handling subsystem.

TRANSPORTABLE GROUND STATION

In addition to a common bus design, there will be a standard ground station that is self-contained, transportable, and capable of fully controlling the spacecraft in orbit. Where appropriate to the nature of the mission and the capability and interest of the investigators, the station and the operations responsibility will be turned over to the investigation team. NASA will maintain a ground station at the Wallops Flight Facility and an operational control center at Goddard as an alternative, or a backup, to the investigators' control stations. System software will be included for spacecraft operation, orbit determination, preliminary data handling and other essential support functions. Muller and Vermillion discuss the transportable ground station in greater detail[1].

STANDARD SYSTEM PERFORMANCE SUMMARY

Neither the common bus nor the ground station has been designed, though substantial heritage exists for both. Specifications will be developed after potential missions have been identified, to maximize the scientific productivity of the entire Scout Explorer program. Because program funding is essentially fixed, the number of missions that can be flown is directly dependent on the support system cost. Table 1 illustrates the performance anticipated from the Standard System.

The Standard System will not satisfy all experiments. Special needs, such as electromagnetic cleanliness and spinning, will dictate unique support systems. These missions must develop their own custom systems. Some experiments may wish to use only a part of the Standard System, such as the Common Bus or the Ground Station. These too are acceptable alternatives.

The Standard System will be developed concurrently with the first Scout Explorer mission. From now until then, system engineering will refine the performance specifications to reflect the needs of proposed missions and to assure the most economical system approach.

COMMON BUS CONCEPT

System Rationale

There are several advantages to a common spacecraft bus that can meet the support requirements of more than one mission. The most obvious of these is the economy of buying multiple units. NASA experience proves the cost savings, even when moderate differences exist between the units.

A second advantage is the simplification of mission development, when the Investigator is free to concentrate on the unique parts of the mission, rather than re-inventing the spacecraft. The known characteristics of the common bus also expedite experiment development (though perhaps not for the first bus application).

Another advantage is the superior performance of the bus. To achieve broad application, the bus will provide greater performance than most missions require. Individual missions may benefit from these enhancements, which would not be justifiable on a dedicated spacecraft.

There is, of course, an antithesis to the third advantage, namely that the standard bus may be inadequate for some missions. (In fact, the bus would be over-designed if it satisfied every proposed mission.) Several alternatives are available to satisfy these missions: the standard bus can be modified or enhanced for the particular mission; the experiment can be modified (not necessarily compromised); or a new, special spacecraft may be commissioned.

Attitude Control

The bus will provide sun, star and vertical pointing with a momentum-stabilized control. Two orthogonal momentum wheels and optional error sensors permit this flexibility. For vertical pointing, conventional horizon scanning and gyro compassing provide a vertical orientation of one degree or better and yaw to within two degrees.

Star pointing requires the addition of a star tracker and a gyro package, each with two axes of error sensing. The two axes are aligned normal to the instrument pointing axis. The momentum vector is pointed toward the Sun, not toward the target, thus permitting rapid reorientation of the instrument. The two wheels are mounted in the plane of the instrument pointing axis and the sun line. The Sun-target angle is varied by adjusting the ratio of the wheel speeds, while the transverse axis is controlled by altering the total wheel momentum.

Table 1

PERFORMANCE CHARACTERISTICS

Parameter	Units	Value	Notes
Bus mass	kg	100	
Payload mass	kg	50-150	Depends on orbit
Bus dimensions			
Diameter	cm	75	Not including arrays
Length	cm	45	Not including adapter
Pointing accuracy			
Vertical	deg	0.5	Yaw is 1 deg
Sun, star	deg	0.01	Two axes
Data Handling			
24-hr capacity	Mb	700	Tape recorder
Telemetry format	--	---	Variable block
Communications			
Downlink rate	kb/s	2500	S-band
Uplink rate	kb/s	1	
Contacts/day	--	2	Typical
Power for instruments			
Average power	W	30-100	Mission unique
Voltage level	Vdc	28	
Thermal design approach		Instrument module isolated	

CONCLUSION

The Scout Explorer program is an exciting opportunity for space scientists to regain the "access to space" that the NASA Charter proclaims. For us, the engineers, it is a challenge to achieve that access with the best of current technology and thirty years of space design experience.

REFERENCES

1. R. Muller and C. Vermillion, "A Ground Station Concept for Use with Small Satellites," USU Conference on Small Satellites, October 7-9, 1987.