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FREE-FLYING PLATFORMS FOR THE INTERNATIONAL SPACE STATION:
LARGE APERTURE SCIENCE AT MEDIUM-EXPLORER COST

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ABSTRACT

We present the concept of a reusable science probe based at the International Space Station (ISS). A wide range of unique scientific and technical investigations will be enabled through the large aperture and high mass capabilities of the platform. The ISS infrastructure is used for servicing the spacecraft and/or scientific instrument, as well as upgrading the scientific payload. During the data gathering phase, envisioned to last six months to two years, the spacecraft will be a free-flyer in the ISS orbit, avoiding operational constraints imposed by the ISS environment and allowing full control of the experiment by the investigation team. Periodic docking with the ISS provides the servicing capability. A limited spare parts cache can be provided by the ISS "mother ship" using excess STS payload capacity to this frequent-flyer destination. By eliminating the need for mission-unique spacecraft and operations infrastructure for a wide range of missions, a tremendous return on investment can be realized.

INTRODUCTION

Many forefront scientific questions now require the use of large aperture instruments or high mass payload capability. The aperture of an instrument is directly related to its resolving power for imaging. In the newly developing far-infrared and submillimeter wavelength regimes, a significant improvement in resolution has a dramatic impact on scientific discovery potential. For missions that require mass for improving interaction probability (as in high energy particle experiments), an increase in mass is directly related to an increase in sensitivity. Such payload capabilities are not readily available with typical Medium-Explorer (MIDEX) launch vehicles, but could be within or below the program cost guidelines.

At the same time, the capabilities of an extensive range of previously used flight hardware are not fully exploited by current or planned missions. The development cost for this hardware can be applied to future missions, eliminating the need for developing mission-specific spacecraft for those missions where existing hardware is a good fit. (This would apply equally to low-cost new designs for reusable spacecraft.)

This hardware could be used in an aggressive, austere, and flexible program that supports a series of forefront scientific and technical investigations. The ISS infrastructure will help to achieve the full return from such a program by enabling an active maintenance and instrument upgrade plan.

THE BASELINE PROGRAM

The fundamental idea is simple. A platform, regarded as a piece of ISS infrastructure, is a common spacecraft for a sequence of missions that can accommodate a wide range of scientific and technical disciplines. This platform is launched into, and maintained at an ISS compatible orbit, and has the capability of redocking with the ISS for servicing operations. Previous studies of a generic Station Keeping Platform (SKP) have shown that such a platform can be sent away and retrieved using only a modest amount of propulsion.

A sequence of scientific and technical payloads are then brought to the ISS. ISS servicing replaces the payload section of the spacecraft, creating a new configuration for the next mission. The mission duration can be specific to the needs of the particular payload, and defines the time that the free-flyer is independent of the ISS. We anticipate that for most missions, this time ranges from roughly six months to two years. During the mission, it operates as an independent spacecraft, allowing for low-cost, simplified science operations using standard infrastructure for the program. For example, there is the proven, low-cost flight operations model through the EUVE Innovative Technology Program (University of California, Berkeley).

The ISS infrastructure is also used for maintaining the spacecraft. When docked, any needed repair and replacement of spacecraft Orbital Replacement Units (ORUs) can be executed (e.g., transponders, batteries, etc.). Many small ORUs and instrument parts can be brought up using excess STS capacity to the ISS and then stored at the ISS for later use. Scientific payload servicing (e.g., cryogenic recharge using SHOOT technology) can also take place, in which case the “next” mission is a renewed version of the previous one.

Note that the uplift capability can be provided by either STS or expendable launch vehicles. This is a detail that depends on the payload requirements and availability of launch vehicles. There is nothing intrinsic in this program that requires the STS to launch all of the components. However, it can make effective use of any excess STS capacity.

The programmatic advantages of such a program are significant. By developing a range of low-cost instruments, the risks associated with any one instrument are spread across the entire program. Extraordinarily capable scientific instruments also result from the higher risk that is acceptable because the instrument is retrievable. By using a standard set of ground test and validation equipment (simulators, tooling, etc.), life-cycle cost for the program is minimized. In addition, the well-defined and tested interfaces on the spacecraft will minimize the cost of integration and testing.

This “science probe” concept will capture public imagination as a prototype for future modes of exploration from a “mother-ship. ” It is a capability that will be routinely required as we expand beyond the low Earth orbit environment.

THE ADVANTAGE FOR SCIENCE AND TECHNOLOGY MISSIONS

In addition to supporting missions that cannot fit within the technical profiles of current programs, such a program can provide other significant advantages as well.

First, it could enable a range of fast-turnaround missions by allowing a larger fraction of resources to be allocated to instrument development by eliminating spacecraft develop-

ment. A highly capable platform will provide relief from weight and volume constraints, potentially lowering cost or easing schedule because the fundamental components do not all have to be exquisitely engineered. By providing this fast-turnaround mode, it enables “proof-of-concept” missions for testing technology and mitigating risk for the largest and most ambitious missions. The scientific community can also use this capability for missions-of-opportunity in the ISS era.

Secondly, the program is ecologically sound. Highly capable hardware is reused to leverage past investments into future exploration. This happens naturally with the spacecraft hardware, but the scientific hardware will also be retrieved and the investment protected. In an era where we are accomplishing ambitious programs in multiple phases, such a capability could reduce overall cost to a long-term investigation.

A MODEL SOLUTION, THE α SCIENCE PROBE

As an example of an implementation of this program, there has been an informal study of reusing the Explorer Platform (EP, currently used by the Extreme Ultraviolet Explorer, EUVE) as the spacecraft. In this new configuration, dubbed the Alpha Science Probe, all of the requirements of the baseline program can be met. The sequence of events required are listed below.

- Retrieve the hardware using an STS flight to the 28°.8 inclination orbit of EUVE.
- Immediately upon return, execute a ground-based refurbishment of the EP spacecraft. The current state of the hardware requires only minimal work: replacing a failed transponder, tape recorder, and batteries. The addition of a modular propulsion unit is needed to enable the docking and free-flying activities.
- Mate the spacecraft with the first scientific payload that has been developed and tested using existing GSE, tooling and simulators.
- Prelaunch into ISS orbit and perform the first α S P scientific mission,
- When ISS is ready for servicing operations (in the 2002 time-frame), dock with ISS and execute the follow-on phases of the program.

This hardware is a good example of what is needed for the program. Almost all of the EP hardware is reused, including GSE and other infrastructure. Together with the tested electrical and mechanical interfaces, this makes the scientific instrument integration a low-risk operation. The platform is modular, and has been designed from the start to support astronaut Extravehicular Activities (EVA) for servicing. Thus, on-orbit refurbishment of the spacecraft is a part of the original intent, and is not only feasible but already accounted for in the design. Furthermore, the scientific payload interface is EVA compatible, remotely commendable, and intended to be used on-orbit.

The technical capabilities of the platform are summarized in Table 1. Clearly, it has the infrastructure to support even the most ambitious of scientific payloads, and demonstrates many desirable features of a versatile platform.

The study also shows that, based on the performance of other spacecraft of almost identical design, a significant part of its useful life still remains (at least 10 years). This life

Table 1: α S P Top-Level Specifications

Category	Item	Value
General Payload	Weight	Up to 5,000 kg (STS)
	Diameter	up to 4 m, launch vehicle limited
	Orbit	ISS co-orbiting (~ 230 nm) 51°.6 inclination
	Life	> 10 years with servicing
	Servicing	6 to 12 month intervals
	Power	300 W continuous, 1 KW maximum
Attitude Control	Type	3-axis stabilized, zero-momentum, stellar reference
	Rates	2°/sec maximum slew High rate: 0°/sec for 5000 slug-ft ² Low rate: 0°/sec for 5000 slug-ft ²
	Pointing	Stability: 10 arcsec (3 σ)
Communications (upgradable)	Telemetry	32 Kbps prime, 1 Kbps backup
	Payload Data	up to 26 Kbps science up to 512 Kbps direct downlink
	Commands	1 Kbps prime (TDRSS) 2 Kbps backup (DSN) 125 bps backup (TDRSS)

is ensured by the availability of servicing operations. This orbital experience also indicates that the maintenance cost of the spacecraft will be small (~ \$10M per science “mission” cycle). The initial refurbishment cost (less than ~ \$10M) is also minimal compared to the development cost of the spacecraft and supporting equipment (~ \$100M). Thus, a very large return can be realized.

THE PROCESS FOR DEFINING THIS PROGRAM

Recognizing the potential benefits of this program to a large scientific and technical community, the NASA Research Management Office (RMO) at the Johnson Space Center in Houston, Texas, in cooperation with NASA Headquarters Offices of Space Science, Mission to Planet Earth, Life and Microgravity Sciences, and Applications, Space Access and Technology, together with the Goddard Space Flight Center is sponsoring a workshop on May 14 and 15, 1996 to explore the scientific and technical logic of a free-flyer science program for the ISS. The main goals will be to assess the utility of such a program to the community, and evaluate possible implementation concepts. The purpose of the

workshop is not to officially solicit proposals for possible funding, but rather to identify generic, functional uses of such a system from a broad range of users. This workshop will be co-hosted by the RMO and the Goddard Space Flight Center in Greenbelt, Maryland, and will be held at the University of Maryland, College Park Campus Conference Center in the Washington, D. C. area. This will be the first step in evaluating the utility of the program and its ultimate potential.

The two-day workshop will provide an introduction to the ISS orbital and operational environment, and address the capabilities of potential free-flyer platforms. Options for implementing such a program within today's tight budget environment will be discussed. To maximize the ability to deliver performance at low cost, various concepts to reuse existing hardware have been explored and will be discussed. A summary of the science instrument concepts that have been submitted prior to the meeting will be presented. Following these plenary sessions, the workshop will operate in parallel sessions allowing participants to discuss the presented information, assess the science mission concepts, and provide recommendations. Reports from all the parallel sessions will be summarized at the conclusion of the workshop. Proceedings will be subsequently prepared and distributed.

We would like to solicit your interest in such a workshop. We have set up an Internet World Wide Web (WWW) homepage at

http://cobi.gsfc.nasa.gov/ISS_SW/ISS_SW.html

that provides the most current information. You will find a survey and registration form there that you may want to complete as soon as possible so we can benefit from your thoughts.

Depending on the recommendations from this workshop, the program may be incorporated into existing opportunities. For example, should such a platform exist, proposers to the MIDEX program may have the option to propose an instrument to fly on the platform.

THE ADVANTAGES TO NASA

- Demonstrates the benefits of bringing together NASA's major elements: ISS, STS and science; to produce greater scientific discoveries at the lowest possible cost.
- Establishes the ability of ISS to become our assembly and servicing depot in space: the cornerstone in space exploration for the 21st century.
- Illustrates the frugality and cost consciousness of the agency through the reuse of previously flown hardware with ISS.

Lower life-cycle cost through reuse and periodic repair of assets.

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