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Space Station Rapid Sample Return Revisited

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Introduction

Rapid feedback of experiment results helps investigators to fine tune experiments, shorten experiment cycle times, and reduce development costs for new products. A rapid sample return (RSR) system was studied early in the Phase B Space Station Preliminary Design effort as a means of providing rapid feedback to increase station experimental productivity and reduce mission costs. However sufficient justification for baselining a RSR concept was not found. RSR was deemed nonessential because the Space Station would be serviced by a NSTS flight every 45 days and the design included thorough onboard analytical capabilities.

Efforts at cost reduction have since reduced habitable station volume by 50%, combining separate life science and materials science modules into a single U.S. Laboratory (USL) module. Volume allocated for USL analytical instrumentation was reduced as a result. This decrease in onboard instrumentation has since been followed by a substantial reduction of NSTS station support flights.

The combination of these changes could significantly reduce station based research productivity and lengthen experiment cycle times -- a situation which can largely be ameliorated by use of a RSR system.

The remainder of this paper examines the need for a RSR capability and explores requirements and cost drivers for such a system.

Mission Needs

Efficient exploratory research proceeds by formulation of a series of hypotheses which are accepted or rejected based on experimental results. Delays introduced in this cycle result in a slower, more costly research program. This is also true in the execution of a prototype production program.

The Space Station's USL facilities and support equipment are listed in Figure 1. These include laboratory subsystems such as the process materials management system, gloveboxes, a workbench, various pieces of support equipment, and some materials science characterization facilities. The USL overall layout may be something like that shown in Figure 2, where each numbered location represents an equipment rack which may contain subsystems, payload facilities or support equipment. The USL will support many disciplines involving research stages ranging from small, basic science to prototype demonstrations.

Materials processing science and life science users have expressed a desire for a user-directed, experiment sample

Laboratory Support Equipment

Digital multimeter
Recording oscilloscope
Digital thermometer
Electrical conductivity probe
Microscope system
EM shielded storage locker
Film locker
pH meter
UV sterilization
Camera
Camera locker
Dosimeter, passive
Battery charger
Mass measurement, small
Mass measurement, micro
Incubator
Freezer
Cryofreezer, snap
Cryofreezer, storage
Freeze drier
Hand tools
Cleaning equipment
Fluid handling tools
Cutting, grinding, and polishing system
Etching equipment
Refrigerator
Autoclave
X-ray system
Equipment washer, sanitizer
Specimen labeling
Surgery/dissecting tools

Laboratory Subsystems

Life sciences glove box
Maintenance work area
Process materials management system
Accelerometer mapping system
Materials processing sciences glove box

Figure 1. Space Station US Laboratory Subsystems and Support Equipment [6]

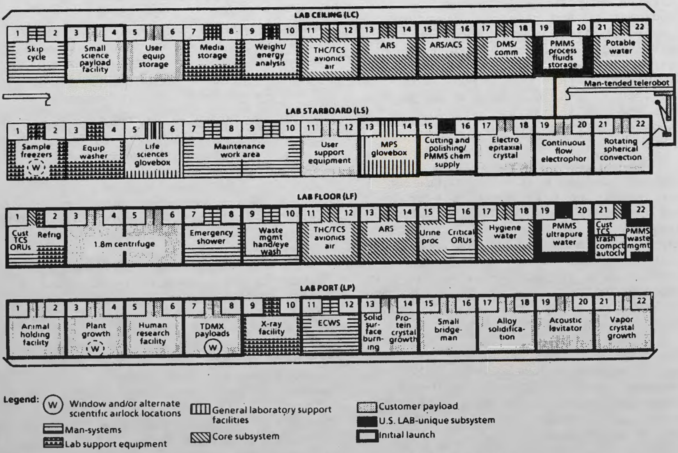

Figure 2. Proposed U.S. Laboratory Module Layout

return capability[1,2]. An estimate of the initial annual user production of material samples requiring ground characterization for selected materials processing science facilities in the USL is shown in Figure 3. This analysis indicates that there are potentially 160 samples to be returned from the station each year for which ground based characterization is necessary. Collectively these samples are expected to occupy a volume of five cubic feet and a mass of 1000 pounds.

Return of these samples does not require a large or complex vehicle, such as the NSTS. What is needed is something small and relatively low cost, like a film recovery capsule which could be jettisoned and returned to a principal investigator whenever necessary. Several of these small capsules could be onboard the station for use in between NSTS visits in order to maximize research productivity.

If a moderate cost RSR system becomes available to Space Station users, demand could grow significantly beyond these predictions, as is shown in station user demand models[3]. However, the innovation process frequently is highly competitive and dependent upon rapid progress to reap a profit or niche in the marketplace. Research, technical, and commercial functions occur in parallel and are interdependent throughout the innovation process[4]. If principle investigators need to wait three months for samples to be received for characterization, productivity will be much lower and demand growth will be slower.

System Drivers

Analysis of user requirements indicate that there is a need for a low cost sample return system which is capable of frequent return of small samples on a user demand basis. Such a system would of necessity be independent of the NSTS return flights, operating in a fashion as depicted in Figure 4. The RSR system could use a tether deployed ballistic re-entry capsule as depicted, an integral propulsion system, or alternative design.

The NSTS would transport RSR vehicles to the station and provide scheduled sample return, accommodating all large volume or mass cargo needs. Infrequent NSTS return flights would be supplemented by RSR return flights on a demand basis. Sample production rates and the analytical needs of diverse users[5] will determine the optimum size and configuration of the sample return vehicle.

Experiment Facility in US Lab	Analytical equipment required but not available on-orbit	Sample frequency (samples/yr)	Sample volume per year (ft3)	Sample mass per year (lbs)
Acoustic levitator	• Scan. elec. microscope • UV/VIIS/NIR spectrometer	60	0.2	79
Alloy solidification	• Scanning electron microscope	40	0.9	432
Continuous flow electrophoresis	• High performance liquid chromatograph	20	1.9	154
Vapor crystal growth	• GC-mass spectrometer	40	2.0	337
Totals		160	5.0 ft3	1,002 lb

Figure 3. Estimated Earth-Based Sample Analysis Requirements for Selected USL Experiments

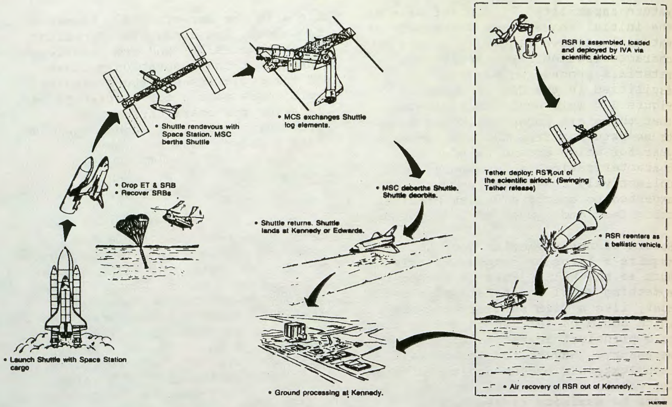

Figure 4. Potential Dual Path Sample Return Operational Scenario

Launch and operations appear to be the dominant cost drivers. Launch costs place severe limits on the size and mass of the return vehicle. On-orbit operations costs increase dramatically when vehicle assembly and deployment includes storage and transfer operations carried out external to the pressurized environment. Ground operations costs are dependent on system design and planned recovery mode and can be a significant driver. Multiple usage of the RSR vehicle hardware also appears essential to a successful design.

Conclusion

Significant productivity benefits can be derived from a Space Station rapid sample return (RSR) system which is relatively low cost and capable of returning experimental samples to Earth laboratories for analysis between regularly scheduled Shuttle visits. It is felt that early Phase B station RSR trades should be revisited in light of reductions in onboard characterization capability and reductions in planned Shuttle support.

References

1. NASA. Proceedings of the Space Station Evolution Workshop, Williamsburg, Virginia. July 29-August 1, 1986. Office of Space Station, NASA Hdqtrs, Wash. D.C..
2. NASA. "Space Station Laboratories". SESAC Task Force on the Scientific Uses of the Space Station, Summer Study Report 5-4, 1986.
3. Buddington, P. "Microgravity and Materials Processing Facility User Demand Model", Boeing Aerospace Company, May 1, 1987. NAS8-36122.
4. Schmidt-Tiedemann, K. J., "A New Model of the Innovation Process", Res. Mgt. March, 1982, pp. 18-21.
5. NASA. Microgravity Materials Processing Facility (MMPF) Study. Volume II: "MMPF Experiment and Equipment Development", February 2, 1987. NAS8-36122.
6. NASA. United States Laboratory Module Contract End Item Specification, SS-SPEC-0002, MSFC, December 15, 1986.