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RESEARCH AND APPLICATIONS MODULES (RAM) PHASE B STUDY

EXECUTIVE SUMMARY

GENERAL DYNAMICS
Convair Aerospace Division
San Diego operation

Space Division
North American Rockwell

TRW
SYSTEMS GROUP

Bendix

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EXECUTIVE SUMMARY

12 May 1972

Approved by W W Withee
W. W. Withee
Program Director

Submitted to
National Aeronautics and Space Administration
GEORGE C. MARSHALL SPACE FLIGHT CENTER
Huntsville, Alabama

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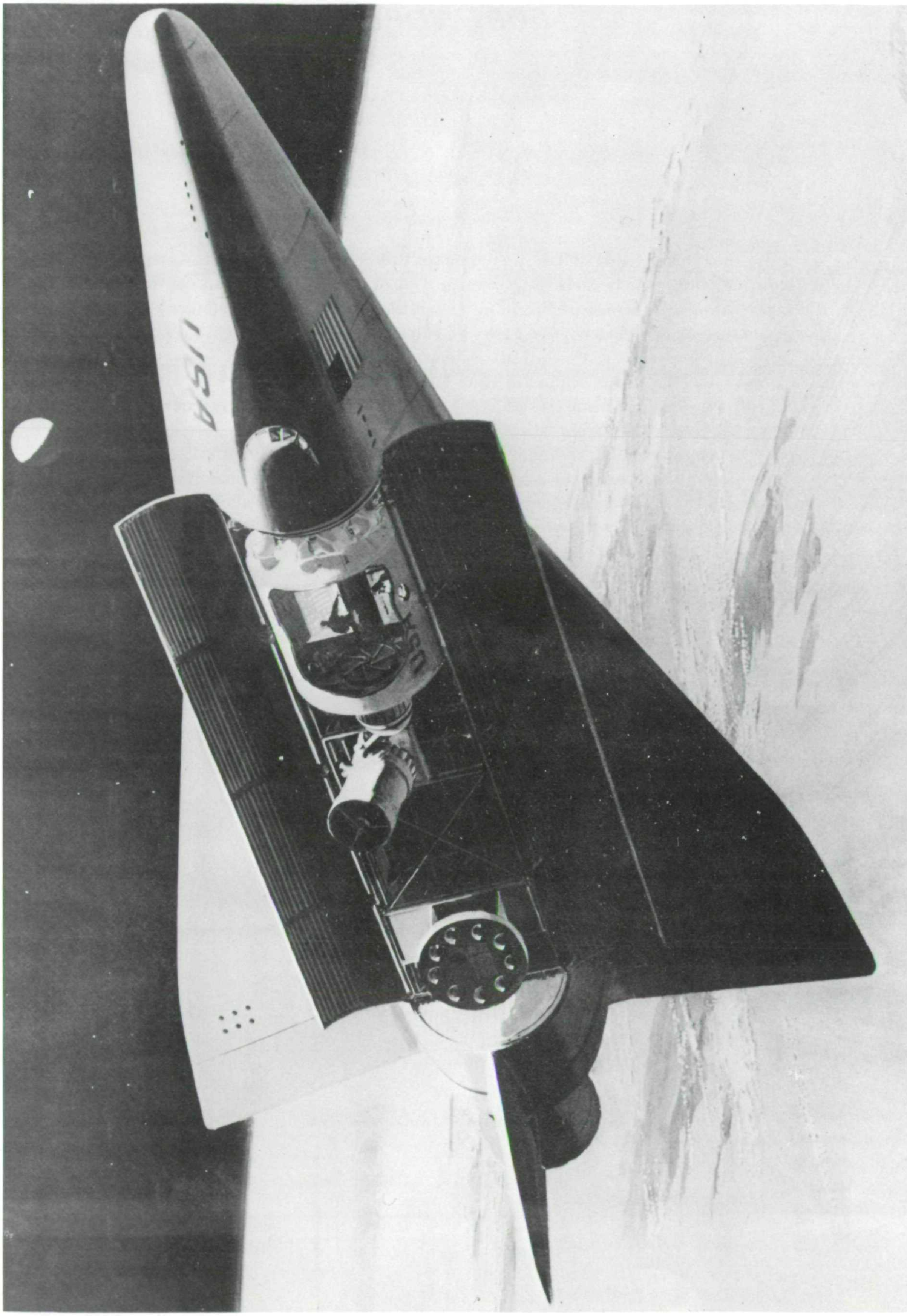
FOREWORD

This document is the RAM Phase B Study Executive Summary and has been prepared in accordance with NASA Data Requirement DR MA-111. It is a part of the final documentation of Phase B of the Research and Applications Modules (RAM) Program accomplished under NASA Contract NAS 8-27539.

The basic study was conducted from 12 May 1971 to 12 May 1972, with certain studies continuing to 12 August 1972, by a contractor team led by General Dynamics Convair Aerospace and supported by North American Rockwell Space Division, Bendix Navigation and Controls Division, and TRW Systems Group. The RAM study team operated under the direction of the RAM Program Office at Marshall Space Flight Center headed by Lowell K. Zoller. Other NASA centers and offices provided significant advice, consultation, and documentation in support of the tasks reported herein. International cooperation and assistance was provided by three European firms: ERNO and Messerschmitt-Bölkow-Blohm (MBB) of West Germany and SAAB-Scania of Sweden. Documentation of these efforts will be submitted to NASA separately.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INTRODUCTION

The Research and Applications Module (RAM) system is a proposed family of payload carriers that can be delivered to and retrieved from low earth orbit by the space shuttle. RAM payload carriers will be capable of supporting diverse technological and scientific investigations and practical applications.

This volume summarizes the Research and Applications Modules Phase B Definition Study. It includes the NASA study objectives, the relationship of the RAM payload carriers to the other systems of the orbital space program, the study approach and assumptions, a summary of study results, and recommendations for additional effort.

STUDY BACKGROUND

At the start of the RAM Project Phase B study, two basic manned space systems were under consideration to satisfy the nation's requirements for using earth orbital systems to conduct space research and to assist in the resolution of some of mankind's problems. This research cannot be conducted economically from the ground, in aircraft, or by unmanned satellites.

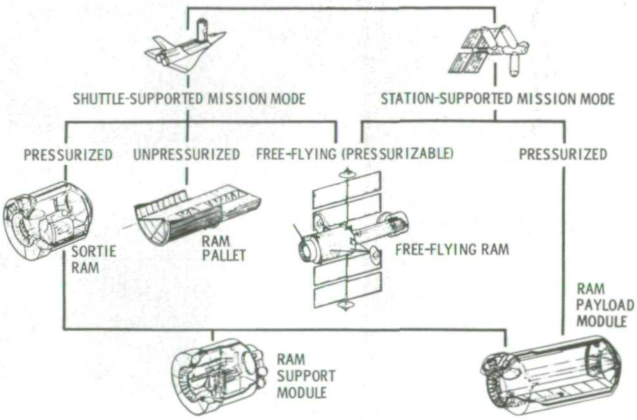
The first system to be conceived provided for sortie missions, which are missions where laboratories would be carried into orbit and remain attached to the space shuttle for operational periods of up to seven days. The second approach was centered on the modular space station, which had semi-permanent general and special purpose laboratories incorporated in its design. Both concepts depended on the development of a low cost space shuttle transportation system.

The RAM payload carrier concept extends the capability of both of these basic systems economically and provides maximum flexibility to the user community. The combined capability of shuttle, space station, and RAM payload carriers is analogous to the highly flexible, multidiscipline research and development capabilities of earth-based research facilities where a continuous man/experiment interface permits appropriate reaction to research phenomena.

During this study, emphasis on the space-shuttle-supported sortie missions was driven by the requirement for austere, low early-year funding with growth capability to meet full experiment requirements with the space station in later years. The approach was to develop versatile, low-cost facilities that would accommodate early low-cost payloads and could be expanded to accommodate more complex payloads.

STUDY CONCLUSIONS

The selected RAM payload carriers will provide economical experiment/payload accommodations for the realization of practical applications of space technology. They provide laboratory and observatory facilities that complement and supplement the space shuttle and, at a later date in their operations, the space station. Their design is versatile and supports a variety of payloads in all scientific disciplines. The RAM payload carriers have been designed for long life through on-orbit maintenance, resupply, and reuse through refurbishment and modification on the ground.



RAM Family of Payload Carriers

The RAM payload carriers may operate in either of two mission modes:

1. **Shuttle-Supported.** All missions, including sortie missions and delivery/service and retrieval of free-flying RAMs, are accomplished using the space shuttle.
2. **Station-Supported.** Ram payload carriers operate in conjunction with and use the resources of the space station. This mode can include the support of free-

flying RAMS. The shuttle in this case provides logistic support.

The three types of RAM payload carriers are pressurized, unpressurized, and free-flying (pressurizable). The pressurized RAM element takes the form of a pressurizable structure and may house supporting subsystems, RAM payload equipment, crew quarters, laboratory facilities, or other equipment in any combination. Adaptations of the pressurized RAM include sortie RAM, RAM support module (RSM), and RAM payload module, defined as follows.

1. **Sortie RAM.** A pressurized RAM that remains attached to the shuttle orbiter and is configured to provide a basic laboratory capability to accept experiments and instrumentation for a multiplicity of disciplinary areas to be flown on shuttle sortie missions of typically seven days in duration. (Longer-duration missions are possible through the provision of additional expendables.) The sortie RAM provides required subsystem resources and services beyond those provided by and used from the shuttle.

2. **RAM Support Module (RSM).** A pressurized RAM that remains attached to the shuttle to provide accommodations for added crew mission/payload specialists and serve as the interface between the shuttle and other RAM elements. The RSM will provide or distribute to other modules such subsystem resources and services as electrical power, thermal control, environmental control, life support, and habitability. It also provides the required subsystem resources and services beyond those provided by and used from the shuttle.

3. **RAM Payload Module.** A pressurized RAM adaptation providing volume for RAM payload installation. The RAM payload module operates attached to a sortie RAM, an RSM, or the space station, and hence has minimal autonomous subsystem provisions.
   a. **Sortie RAM Payload Module.** A RAM payload module used in conjunction with a sortie RAM or RSM, is pressurized to a shirtsleeve environment, and receives life support, power, and other support from the module to which it is attached. Sortie RAM payload modules are configured to provide flexibility for accommodating various experiments/payloads with minimum turnaround time.
   b. **Space-Station-Attached RAM Payload Module.** A RAM payload module that operates attached to a space station, is pressurized to a shirtsleeve environment, and receives life support, power, and other support from the space station. Such RAM payload modules are normally configured to provide a comprehensive laboratory capability in one or more disciplines and are intended to remain attached to the space station for extended durations.

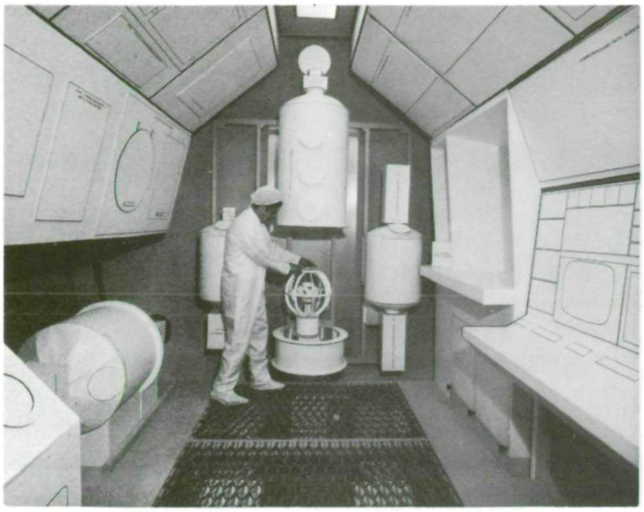
Unpressurized RAM payload carriers take the form of an unpressurized structure called a RAM pallet and always remain attached to a pressurized RAM element. Although it will generally depend on the pressurized RAM element for system support, some mission-unique subsystems may be required. Manned accessibility to the pallet area on orbit will require EVA.

The free-flying RAM is designed to operate in an automated unmanned mode, and is periodically serviced on orbit by man. This servicing can be accomplished by 1) periodic visits to the free-flying RAM by the shuttle using a pressurized RAM element for the manned support or 2) periodic visits of the free-flying RAM to the space station. The free-flying RAM will draw required support from the pressurized RAM element (sortie RAM, RSM, or RAM payload module) or space station during periods of man servicing. When disengaged from the shuttle or station, it is always unmanned.

In the programmatic area, the RAM Project study has emphasized flexibility in accommodating changes in projected funding levels, development and operational schedules, and space research priorities. Minimum development costs and early-year funding can be realized by utilizing a basic design from which the various payload carriers can be evolved that meet the requirements of the user community and are compatible with the availability of resources.

Interproject and intraproject commonality have been prime study considerations. Subsystems are used from other manned space systems such as shuttle, Apollo, and Skylab as well as some unmanned NASA and USAF programs. A high degree of commonality is maintained between the RAM elements themselves; especially obvious is the commonality in the pressurized RAMs (sortie RAM, RSM, and RAM payload modules). The pressurized structural shell is identical for the three modules, and the sortie RAM and RSM also use identical subsystem components.

From the user's standpoint, the selected RAM payload carriers provide convenient and complete laboratory facilities with which it is easy to interface, in which the payload specialist can operate directly on-orbit in a shirtsleeve environment or can monitor and control from the ground, and to which rapid access is possible for accommodation of his experiments. In addition, the RAM Project study has provided design and operational concepts that support quick turnaround of each experiment from initiation to results.



Typical Laboratory Facilities

The RAM elements developed during this study can be combined in a number of ways to create productive programs.

STUDY TEAM

The study was performed for the Marshall Space Flight Center by a contractor team led by the Convair Aerospace Division of General Dynamics and supported by the Space Division of North American Rockwell in the areas of manned operations and habitability, environmental control/life support, and electrical power subsystems; TRW Systems Group in the areas of earth surveys, communications/navigations, and Physics payload requirements and communication/data management, thermal control, electrical power, and reaction control subsystems; and Bendix Control and Navigation Division in the areas of Astronomy payload requirements and guidance, navigation and control, controls and displays, and onboard checkout subsystems. These team members were selected for their outstanding capabilities in these technology areas, which are critical to the RAM program. Each team member has extensive contractual and company-supported experience in space systems related to the RAM Project that proved to be of great benefit in performing this RAM Phase B study.

The continuous coordination of the several NASA centers and agencies involved with the NASA RAM project office has ensured that the interfacing NASA program requirements, operational and technical, were included in the concept formulation. This coordination also ensured maximum utilization of the applicable experience in NASA.

European participation in tasks supplemental to the Phase B study was accomplished by ERNO (West Germany) in the areas of electrical power and thermal control, Messerschmitt-Bolkow-Blohm (West Germany) in the area of solar arrays, and SAAB-Scania (Sweden) in the areas of data processing/image motion compensation, computer trade study, and phased-array antennas.

STUDY OBJECTIVES

The overall objective of the RAM program is to provide versatile and economical manned or man-tended payload carriers (laboratory and observatory facilities) that complement and supplement the space station and/or space shuttle for accomplishment of a comprehensive and viable earth orbital research and applications program. From the user's viewpoint, it is important to provide convenient and complete laboratory facilities with which it is easy to interface and to which rapid access is possible for independent research and applications specialists in government, universities, and industry. An important corollary objective is to provide a practical mechanism by which international cooperation and participation in space research can be achieved. The following paragraphs amplify the discussion of some of the important objectives.

PROGRAMMATICALLY FLEXIBLE RAM PAYLOAD CARRIERS

The RAM payload carrier family of hardware elements must be flexible to the changing funding levels that will be provided, as well as to changes in the accommodations required as priorities shift between technological fields.

ECONOMICAL AND COST-EFFECTIVE RAM PAYLOAD CARRIERS

A major economical consideration is the use of subsystems and components designed for interfacing systems. Use of shuttle system elements is maximized. Since the deployment of the space station will follow the operation of the shuttle and RAM payload carrier systems, attention is given to the use of the RAM payload carrier program elements in providing a modular space station at minimum additional development cost.

Sequential development of the hardware elements of the RAM payload carrier family minimizes the total development cost of the RAM payload carrier system of laboratories and observatories.

FOSTER INTERNATIONAL PARTICIPATION

International participation is possible in three major ways: 1) a Research and Applications Module built by European industry for their use, delivered to the United States, and carried to orbit by the shuttle, 2) European experiments installed in RAM payload carriers furnished by the United States, and 3) participation by European users in the data derived from experiments in orbital space.

RELATIONSHIP TO OTHER NASA PROGRAMS

The RAM Phase B study evolved a family of payload carriers that establishes the means for accomplishing orbital research and man-tending of orbital observatories by providing the modular facilities that supplement the capability of the space shuttle and/or space station. By virtue of their modular nature, the RAM payload carriers provide this supplemental capability as required to meet the specific user needs, within the schedule and funding constraints of the research and applications programs they support.

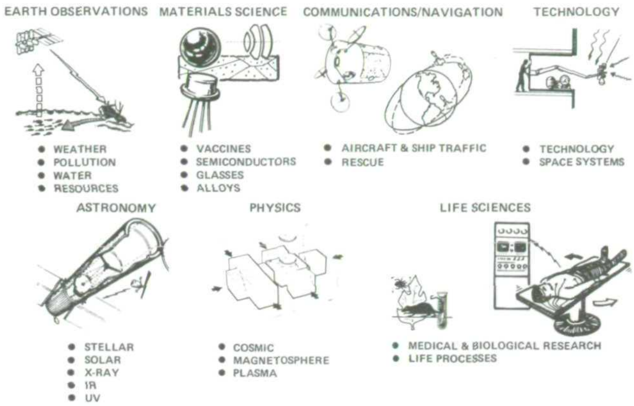
The RAM Phase B definition study has been structured and timed to generally parallel studies of the shuttle, space station, and payloads so that mutual benefits are derived by coordinated definitions of these systems and their interface characteristics.

The NASA space activities efforts in the decade following the Apollo and Skylab programs are oriented toward 1) unmanned and/or man-tended exploration and observation of the universe, solar system, planets, and earth and 2) manned applications and research activities in earth orbit. A vital system for supporting both types of activities is the reusable space shuttle transportation system for delivery of payloads to and from earth orbit. RAM payload carriers are the modular manned laboratories and man-tended observatories for use with the earth-orbiting space shuttle and, ultimately, space station systems for accomplishing these objectives.

The on-orbit participation of man is provided to capitalize on his unique abilities for planning, evaluation, recognition, selection, control, and editing that cannot be readily preprogrammed or achieved remotely. Additionally, on-orbit service, update, maintenance, and repair by periodic man-tending of free-flying observatories allows long operational and scientific life of these facilities.

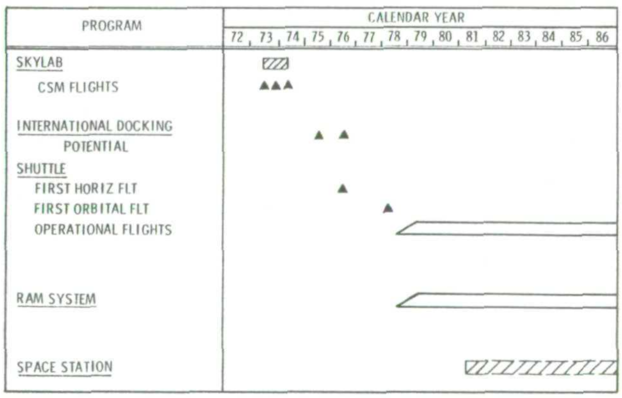
RAM PAYLOAD CARRIERS

RAM payload carriers are intended to support a number of research and applications areas applicable to earth orbit activities when supported by the shuttle or, in later years, the space station. The role of RAM units as the carrier of these payloads is to provide the basic accommodations that meet the configurational and environmental requirements of the payloads and to supplement the supporting resources and operational capability of either the shuttle or space station.



Research and Applications

The RAM Project should become active as an element of the earth-orbiting system shortly after introduction of the shuttle. RAM payload carriers can operate with the shuttle in the sortie mission mode to gain early benefits from the research and applications payloads they carry. Later, RAM payload carriers will be used with the space



Manned Space Flight – Earth Orbital Systems

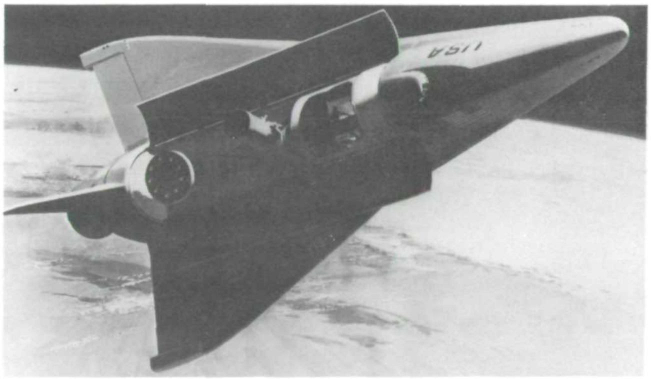
station for more permanent, long-duration activities. The man-tended observatories provided by the RAM Project can be initiated any time, even before the shuttle is available for use. In such an eventuality, orbital placement could be achieved by an expendable launch vehicle such as Titan III and the man-tending operation started when the shuttle becomes available.

APPLICATIONS FOR EARLY BENEFITS. The flexibility of RAM payload carriers in operational modes and in responding to the user's technical and programmatic needs permits their use to achieve early benefits from applications programs. Examples of these application programs and the potential benefits of early activities are listed in the following table. Such early returns from manned experiments can be achieved in the shuttle sortie mission mode with low initial investment using a simple, economical RAM payload carrier to initiate the program. The capability of this low-cost RAM payload carrier can be expanded as benefits are realized and the requirement and funds for increased capability become available.

Example Applications and Early Benefits

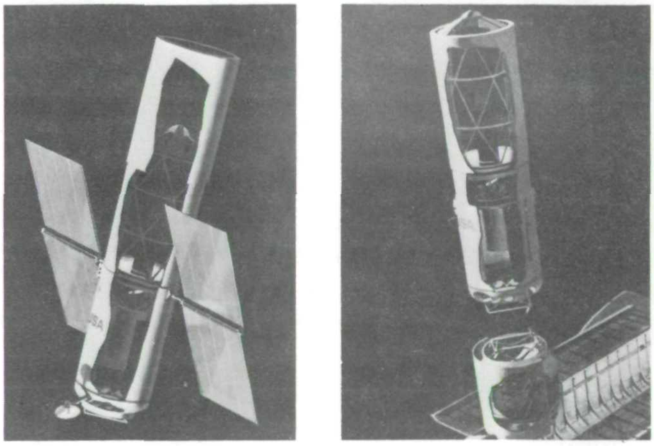
DISCIPLINE	KNOWLEDGE OR DATA	POTENTIAL BENEFIT
EARTH OBSERVATIONS	BASIC INFORMATION TO ENABLE IMPROVEMENT OF MULTISENSOR, MULTISPECTRAL SENSING OF EARTH AND THE ATMOSPHERE.	CAPABILITY TO OBTAIN TIMELY INFORMATION ON EARTH AND OCEAN RESOURCES.
COMMUNICATION/ NAVIGATION	BASIC INFORMATION TO IMPROVE SPACE COMMUNICATIONS/ NAVIGATION TECHNIQUES: INTERFERENCE, LOCATION, WAVE PROPAGATION, VELOCITY MEASUREMENT, DATA RATE, AND POTENTIAL ERRORS.	CAPABILITY TO TRANSFER INFORMATION WITH MINIMUM DELAY AND ALTERATION.
MATERIALS SCIENCE AND MANUFACTURING IN SPACE	BASIC INFORMATION ON BEHAVIOR OF PROCESSES AND MATERIALS COMBINATIONS.	NEW MATERIALS: GLASSES, CRYSTALS, METALS, PHARMACEUTICALS (PURE). IMPROVEMENT OF GROUND-BASED PROCESSING TECHNIQUES.
PHYSICS AND TECHNOLOGY	UPPER ATMOSPHERE INTERFERENCE EFFECTS, MAGNETOSPHERIC VARIATIONS VERSUS SOLAR CYCLE, BEHAVIOR OF FLUIDS IN SPACE.	OBSERVATION, COMMUNICATION, AND FLUIDS APPLICATION TECHNIQUES.

The sortie RAM is mounted in the shuttle cargo bay and remains attached to the shuttle orbiter. It provides the facilities and instruments to conduct observations during a typical seven-day orbital mission period. Missions of this nature can provide quick turnaround for experimenters and early achievement of benefits from an applications program.



Typical Sortie RAM Mission

MAN-TENDING OPPORTUNITIES. A typical observatory (in this case, a large 3-meter optical telescope) is housed in a free-flying RAM as depicted in the figure. The shuttle/ sortie RAM is shown mating to the free-flying RAM in preparation for the service activity.

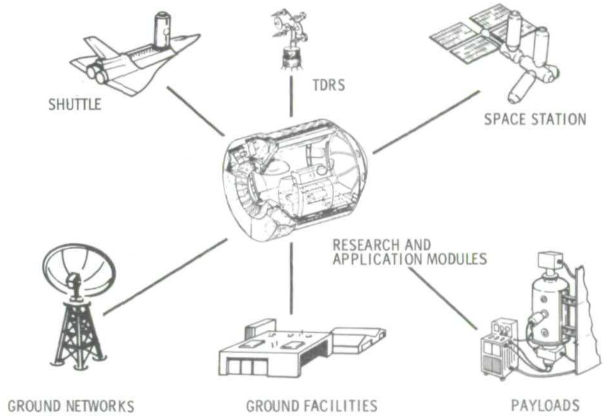


Man-Tending Service Missions

These man-tending service missions will be performed on an as-needed basis rather than to a fixed schedule (about six months to one year, based on equipment reliability predictions).

RAM PAYLOAD CARRIER INTERFACES

The major systems with which RAM payload carriers interface are the space shuttle, space station, communications/data networks, payloads, and ground systems.



RAM Payload Carrier Interfaces

SPACE SHUTTLE. Interface with the shuttle includes the use of the shuttle as a platform for conducting RAM payload orbital operations and as a transporter of RAM payload carriers. This interface is particularly critical in the sortie mission mode where there are important interactions in environmental conditions, resulting in physical and performance constraints on the orbiter and the RAM payload carriers.

SPACE STATION. RAM payload carriers interface with the station to make use of station resources and manning.

COMMUNICATION/DATA NETWORKS. For transmission and reception of both voice and data, RAM payload carriers interface with the tracking data relay satellite (TDRS) and the ground network through the shuttle or the station communication systems. Heavy dependence is placed on TDRS support, with the ground network providing limited support for a small number of payloads. The communication facilities of the orbiter and space station provide complete support for sortie and station-attached mission modes. Free-flying RAMs interface indirectly with these networks.

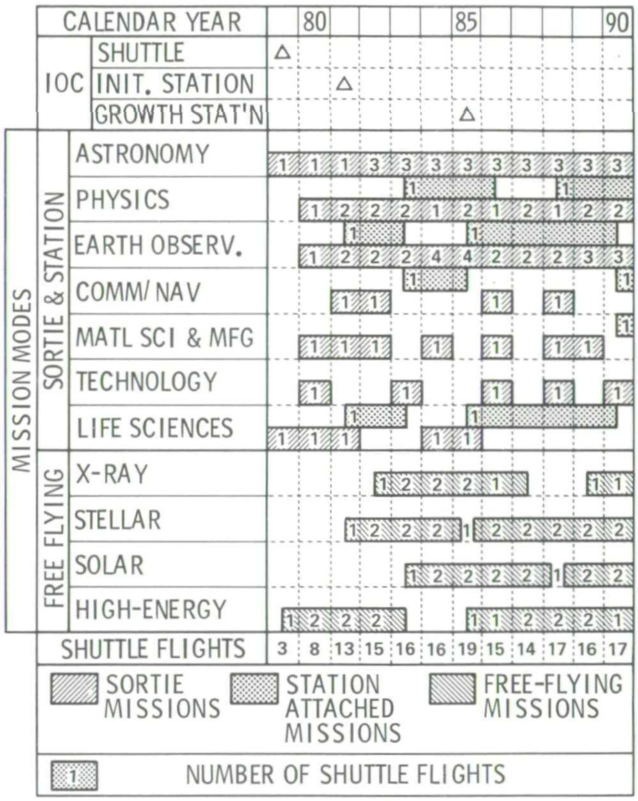
PAYLOADS. RAM payload carrier interface with the payloads includes physical accommodation and provision of resources.

GROUND SYSTEMS. RAM payload carriers interface with a wide variety of ground systems, including integration facilities, checkout and launch facilities, support networks/facilities, and post-landing sites.

METHOD OF APPROACH AND PRINCIPAL ASSUMPTIONS

Major guidelines and assumptions that directly influenced the study approach and the study results are presented in this section. The guidelines were established at the beginning of the study and remained essentially unmodified. As an input to the study, their influence was significant, particularly on program costs and in defining RAM payload carriers that would be relatively insensitive to space shuttle and space station interface and performance variations.

EXAMPLE PROGRAM



Baseline Reference Experiments Plan

GUIDELINES

Contractor guidelines for the RAM were included as Appendix B to the study statement of work. Control of these guidelines was vested in the NASA Headquarters Space Station Task Force. No major changes were approved during the study and, with some qualifications, all guidelines were satisfied. Comments on some key guidelines are given in the following paragraphs.

Guideline 1.2. NASA will provide a Reference Experiment Program (REP) for the purpose of project planning and cost estimating. The plan will include a schedule of RAM launches commencing with the shuttle IOC of July 1979 and continuing through 1990. An initial capability (IC) space station IOC date of July 1981 and a growth space station IOC date of July 1985 will be used to schedule RAMs. The REP may be revised by NASA, as appropriate, based on study results.

The Baseline Reference Experiment Plan represents a maximum envelope within which program-variation planning and costing tasks were conducted.

Guideline 1.8. As a goal, the RAM designs and operational concepts will be compatible with both Phase B Shuttle and Phase B Modular Stations (reflecting both centers' design approaches). NASA will provide the contractor with space station and shuttle data packages.

With the continuing development of the shuttle orbiter and the modular space station configurations during the course of the study, updating of the orbiter and space station interface definitions for the RAM Phase B study was provided by NASA. These definitions are recorded in Appendix B to Volume III, of the Technical Data Document (DR No. SE-268).

Guideline 2.3. A major objective in the consideration of representative payloads, selection of accommodation modes, and the sequence of RAM development and operations will be to minimize early year funding requirements.

Guideline 7.1.1 RAM development will be based on subsystems and components that minimize initial project costs.

In achieving the intent of these related guidelines, several parallel approaches were explored. Both intraproject and interproject commonality has been employed to the maximum practical extent, together with maximum reasonable use of existing hardware and technology.

Guideline 4.1. The design-to dry weight of individual RAM modules shall not exceed 20,000 pounds when fully outfitted. Total allowable launch weight of RAMs on a single shuttle shall not exceed 80 percent of the shuttle performance to orbit for a given mission. The excess of allowable launch weight over the design-to dry weight may be utilized to accommodate expendables and RSM. The RSM shall not exceed 12,000 pounds.

RAM elements developed for all sortie missions, and space-station-attached missions comply with this guideline. The free-flying RAM element, when outfitted with any of the four representative free-flying payloads used in the study, exceeded the required 20,000-pound dry weight limit but retained shuttle delivery capability to preferred orbits. The uncertainty in RAM payload weights, however, does not justify any substantive change to accommodation of free-flying payloads, since the free-flying RAM is well within the weight restrictions.

Guideline 8.2. Maximum use will be made of standard laboratory equipment where cost effective. Modification and space qualification testing will be minimized.

Specific attention was given to the maximum accommodation of standard laboratory equipment on all RAM payload carriers. Power conditioning, thermal control, and mechanical attachment features were designed to provide maximum flexibility and economy to the user.

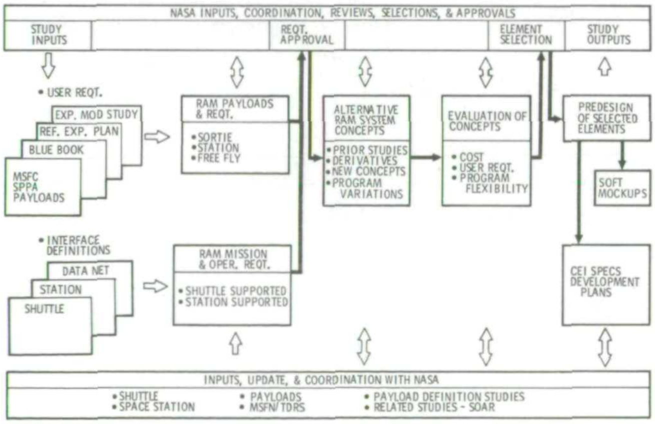
ASSUMPTIONS AND GROUND RULES

The following assumptions were influential in determining the course of study results. They were primarily developed through the working interface with MSFC.

1. Early-capability payloads are determined by the criterion of minimum practical scientific scope and not solely by cost criterion.
2. Shuttle effluent will be controlled so that it will not adversely affect the performance of observational experiments on sortie missions.
3. The shuttle orbiter is the active element in docking with a free-flying RAM. The free-flying RAM is the active element in docking with the space station.
4. The shuttle provides communication links to the tracking data relay satellite.
5. RAM elements or their combinations will be attached in the shuttle cargo bay in such a manner as to provide static load determinacy.
6. Shuttle hardware development will precede the RAM payload carriers. Space station interface hardware development will follow the RAM payload carriers.
7. Shuttle cost per flight is \$4.5M. Weight penalties for operations will be calculated at \$225 per pound in trade studies. (Recent cost-per-flight values of \$10.5M have been estimated with the use of the solid rocket booster concept.)
8. A deployment mechanism or manipulators are available as part of the shuttle for orbital operational use by RAM payload carriers. Manipulators will have RAM external modular subsystem assembly plug-in replacement capability.
9. Experiment integration costs are assumed part of the RAM Project for estimating total programmatic associated cost.
10. There is no study requirement for RAM element removal from and reinstallation to the shuttle orbiter on the launch pad.
11. On-pad escape for personnel carried in the RSM is through the orbiter cabin external hatch.

STUDY LOGIC

The RAM Phase B definition study consists of five major tasks whose output is a set of preliminary designs and supporting analyses of selected RAM elements, CEI specifications, RAM project development requirements, and detailed cost estimates.



RAM Phase B Study Logic

The NASA inputs provided at the beginning of the study were guidelines, definition of user requirements in the form of NHB 7150.1, *Reference Earth Orbital Research and Applications Investigations* (Blue Book) and the MSFC Shuttle Payload Planning Activity (SPPA) payloads, a *Reference Experiment Plan,* and definition of interfacing systems including space shuttle, space station, space tug, teleoperators, and the TDRS and ground network system.

The inputs were used in the Task 4.1 analysis to produce a consolidated set of RAM mission requirements, consisting of a representative set of RAM payload/experiment groupings and their accommodation requirements and a set of mission and operation plans and requirements. A total of 54 RAM payloads were defined to represent a spectrum of scientific and applications research investigations in a low earth orbit experiment program to determine payload carrier design requirements.

Following NASA approval of the payload and mission requirements, alternative RAM payload carrier concepts were developed in Task 4.2 using the results of prior experiment accommodation studies (space station Phase B studies and experiment module Phase A study). Analyses of potential variations to the *Reference Experiment Plan* were conducted to determine means of minimizing the sensitivity of the RAM project to funding and schedule variations.

Evaluation of the alternative concepts was conducted in Task 4.3, which was performed largely in parallel and iteration with Task 4.2, Concept Development. This evaluation encompassed the many factors influencing final selection of RAM elements, their capabilities, and their configuration. The factors included safety, reliability, refurbishment and reuse, crew and mission operation capability, use of interfacing system capabilities, initial and overall program costs, adequacy of meeting user requirements, and maximum flexibility to variations in program funding, schedules, and priorities.

Task 4.3 considered the limitations of both early year and total program funding, shuttle flight schedules, effects of shifting the schedules for space station operational capability, the desire for early applications, and potential changes in research priorities. These analyses established a set of program requirements that aided the selection and design of RAM elements.

The product of the combined 4.2/4.3 efforts was a set of recommended RAM elements that were approved by NASA and carried forward into Task 4.4, Predesign, and 4.5, Programmatics.

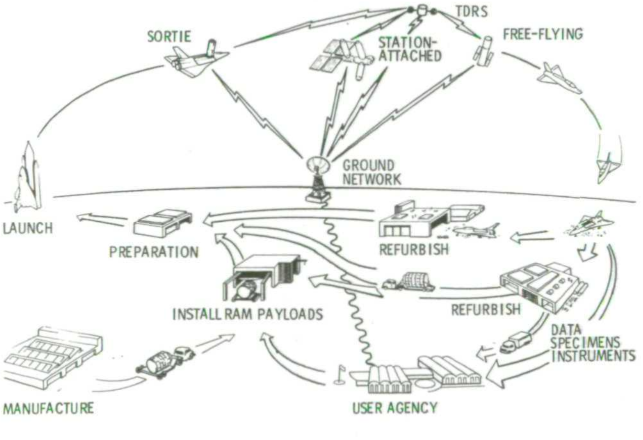
In Tasks 4.4 and 4.5, a preliminary design and supporting analysis and a project development plan and supporting specifications were completed for the selected RAM program elements and their final subsystem selections. Soft mockups were used to proof equipment arrangements, access provisions for operation and maintenance, and the overall habitability aspects of the RAM payload carriers.

BASIC DATA GENERATED AND SIGNIFICANT RESULTS

The RAM system provides a family of payload carriers (system elements) to satisfy the broad-range experiment and mission requirements. The payload carriers, as defined, provide the flexibility needed to be responsive to a wide range of possible program or funding-level requirements. This section defines the RAM operations, the RAM payload carriers, and experiment accommodation and integration.

RAM OPERATIONS

Initiation of a specific mission occurs with the definition of the payload and the launch date schedule. The RAM payload carrier, the payload, and scientist/user participation are scheduled to meet the launch date, as shown in the RAM mission scenario. New payloads are installed in the RAM payload carrier at either the user agency or at a payload integration site. Payloads that are scheduled to be reflown in the near future will normally remain with the RAM payload carrier and be refurbished as required at the launch site. The RAM payload carrier is loaded into the orbiter while the orbiter is in the horizontal position in the orbiter maintenance and repair facility. The orbiter is then mated to the booster in preparation for launch. Time-critical RAM/payload expendables (cryogenics/biology specimens) are loaded at the shuttle launch facility.



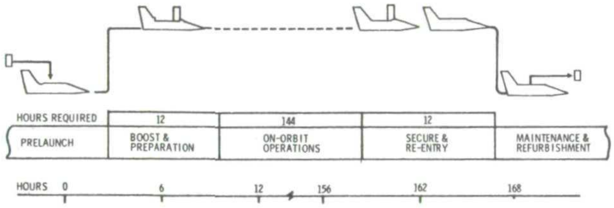
RAM Mission Scenario

Following boost to orbit by the shuttle, RAM operates in one of three mission modes:

1. **Sortie Mission.** These missions are well adapted for payloads that maximize early scientific and applications returns. The sortie payload carriers remain attached to the shuttle during this short-duration mission (nominally seven days). Sortie mission payloads are compatible with the shuttle environments. Sortie RAM, sortie RAM/RAM pallet, RSM/RAM payload module, and RSM/RAM payload module/RAM pallet combinations can be applied to sortie RAM missions.
2. **Free-Flying Missions.** The free-flying RAM is unmanned and free flying during experiment periods, but is serviced periodically on-orbit by either the space shuttle or the space station. Payloads in free-flying RAMs are characterized by extended observation periods, with requirements for extreme stability and a contamination-free environment. RAM elements that apply to this mission mode are the free-flying RAM as a payload carrier and the sortie RAM to provide on-orbit servicing. Free-flying RAMs may be retrieved and returned to earth by the shuttle for refurbishment.
3. **Station-Attached Missions.** The station-attached RAM payload module remains attached to the space station during experiment operations. Crew habitability and subsystem support for operations and servicing are supplied by the space station (except for thermal control). Station-attached payloads require manned attention over extended experiment periods. The RAM payload module is used in this mission mode and may be retrieved and returned to earth by the shuttle.

SORTIE MISSION OPERATIONS. Major operation phases in a sortie mission turnaround cycle are prelaunch and launch, boost to orbit and carrier/payload preparation, on-orbit experimentation, carrier/payload securing for return, carrier/payload maintenance and refurbishment, and payload integration.

The prelaunch phase starts when payload integration is complete and a launch date has been set. Operations accomplished during this phase include RAM payload carrier weight and balance tests, loading of non-time-critical expendables, verification of carrier/payload readiness for installation into the orbiter, installation of the RAM payload carrier in the orbiter, checkout of the RAM/orbiter interface, and orbiter/booster mate. Launch operations begin with transportation of the shuttle to the launch pad, followed by installation of payload interface connections, verification of shuttle/carrier readiness for liftoff, loading of time-critical expendables, and shuttle liftoff.



Sortie RAM Mission

During boost and ascent to orbit, the RAM payload carrier provides environmental protection and subsystem resources (electrical power, thermal control, etc.) to the payload. The RAM payload carrier is deployed from the orbiter cargo bay, if required, after reaching orbit. Deployment may be necessary for payloads with exacting field-of-view requirements and/or high heat-dissipation requirements. Many payloads can operate while in the orbiter cargo bay. When deployment is necessary, the RAM payload carrier is docked to the orbiter topside docking port (if deployment is by manipulator) or remains attached to the cargo bay airlock hatch through a flexible pressure tunnel (if deployment is by a pivot mechanism).

RAM payload carrier subsystems and payload operations are then checked out in preparation for the on-orbit experiment period. Experiments are conducted during a nominal six-day period. During this phase the shuttle is required to:

1. Drift for extended periods to minimize acceleration levels when zero-g laboratory experiments are being conducted.
2. Hold specific attitudes with a ±0.5-degree accuracy during repeated passes over the target area for Earth Observation measurements, which require up to 30 minutes for each viewing opportunity.
3. Permit attitude control to be accomplished by the RAM control moment gyros for extended periods (days) during celestial observation experiments that require extremely high pointing accuracy/stability and a minimum contamination environment.

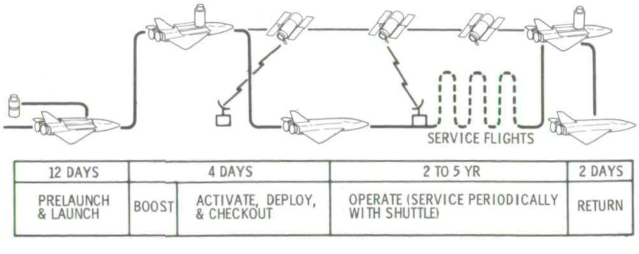
The RAM payload carrier subsystems provide the payload resources during the on-orbit payload operations conducted by the mission/payload specialists. These operations consists of setup, calibration, and conduct an analysis of scientific and applications experiments in the Astronomy, Physics, Earth-Observations, Communication/Navigation, Materials Science, Technology, and Life Sciences disciplines. Sortie missions are particularly attractive for early-program, precursor experiments and provide the capability of attaining the higher inclination orbits (up to polar and sun-synchronous) preferred for some Earth Observation and magnetosphere measurement payloads. Payload crews of at least two are housed in the orbiter. Habitability for a maximum of four additional payload crewmen is provided by the RSM.

At the conclusion of the experimentation period, the payload and the RAM payload carrier are prepared for return to earth. After landing, the orbiter is safed and time-critical data is removed and delivered to the user. The RAM payload carrier is subsequently removed from the orbiter and delivered to the RAM maintenance/refurbishment facility.

The RAM payload carrier and its payload are repaired and maintained, as required, if the same (or slightly modified) payload is to be reflown in the near future. Sortie missions provide the capability for rapid turnaround and reflight of the same payload housed in a sortie RAM or a RAM payload module and for rapid turnaround of RSM subsystems in support of multiple RAM payload carriers. After repair and maintenance, the RAM payload carrier is available for mission/payload specialist training or is placed in storage before delivery to the prelaunch facility in final preparation for the next flight. When a different payload is to be installed in the sortie RAM or RAM payload module, the previous payload is removed and the RAM payload carrier is prepared for the next payload installation.

The refurbished RAM payload carrier is delivered to the payload integration facility where the next payload is installed, calibrated/aligned, and carrier/payload compatibility verified. After payload verification, the RAM payload carrier is available for mission/payload specialist procedures training. The RAM payload carrier is ready for prelaunch operations at the completion of training.

FREE-FLYING RAM MISSION OPERATIONS. The free-flying RAM delivery mission for the shuttle-supported mode begins with ground operations, including prelaunch checkout of the free-flying RAM and payload and loading of the free-flying RAM into the orbiter. After boost to orbit by the shuttle, the free-flying RAM is deployed from the cargo bay and payload activation and checkout activities are initiated. Following preliminary on-orbit checkout



Free-Flying Mission

of the free-flying RAM, the shuttle undocks from the free-flying RAM and moves to a standoff position where ground stations control final payload checkout.

Payload operations are unmanned, with the free-flying RAM supplying the required inertial or solar orientation. Guidance and navigation data is supplied from the ground. The free-flying RAM provides one arc-sec pointing accuracy and 0.5 arc-sec/observation pointing stability for celestial observations. Resources (power, communication/data) required for payload operation are supplied by the free-flying RAM.

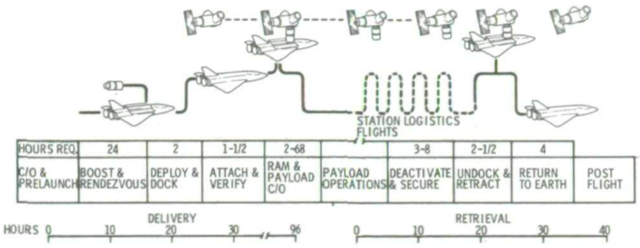
The shuttle can deliver the free-flying RAM and its payload up to altitudes of 450 n.mi. and to orbits with a wide range of inclination angles to satisfy the free-flying RAM payload requirements of orbit altitudes from 240 to 400 n.mi. at inclinations of from 28.5 to 55 degrees. Orbit maintenance is provided periodically by the free-flying RAM for operating altitudes below 300 n.mi. (approximately). The communications/data links between the free-flying RAM and the ground are the tracking data relay satellite (TDRS) system and the ground network. Experiment operations are conducted on-orbit for two to five years. The free-flying RAM may be subsequently returned to earth by the shuttle for refurbishment, recycle, or retrofit.

The station-supported free-flying RAM delivery mission is similar to the shuttle-supported mode when the free-flying RAM is delivered first to its operating orbit. An alternative mode is to deliver the free-flying RAM to the station for preparation and checkout.

Free-flying RAMs are serviced on-orbit by either the shuttle or the space station. In the shuttle-supported mode, the free-flying RAM is visited periodically by the shuttle, which provides rendezvous and docking functions. In the station-supported mode, it periodically translates and docks with the space station for servicing. In both cases, servicing is performed at 6- to 12-month intervals, as required.

During the service mission, the free-flying RAM is pressurized after docking and the mission/payload specialists enter the free-flying RAM for maintenance. These activities include replacing failed or marginal units, alignment, resupply of expendables, and other servicing necessary for the remotely controlled operations in the free-flying RAM. The shuttle undocks and stands off from the free-flying RAM (shuttle-supported mode) or the free-flying RAM undocks from the station and translates to a standoff position (station-supported mode) following servicing operations. A series of test observations is then performed to verify that all of the free-flying RAM subsystems are functioning properly. In the shuttle-supported mode, the orbiter returns to earth following the service operation. The free-flying RAM remains inactive for 24 to 48 hours while contamination and outgassing dissipate and thermal equilibrium is reached. Normal operations are resumed after this is accomplished.

STATION-ATTACHED MISSION OPERATIONS. The station-attached RAM payload module is checked out and mated to the orbiter during prelaunch. Following boost into orbit, the shuttle rendezvous with the space station, docks the payload module to the station, and is then free to return to earth after safety and habitability of the RAM payload module are verified. The RAM payload module is then activated and checked out at the station.



Station-Attached Mission

For experiment operations, the earth and inertial orientations required by the RAM payload module are supplied by the station, along with guidance and navigation information and resources (power, communications/data) required for payload operation. Periodically, the shuttle resupplies the station on logistics flights and the RAM payload module is serviced as needed.

The reference space station orbit is 240 to 270 n.mi. altitude at 55 degrees inclination. RAM payload module operations are conducted while attached to the station, and the station transmits data from the RAM payload module to the ground via the ground network or the TDRS system. When on-orbit, experiment operations are concluded (two to five years) and the shuttle undocks the RAM payload module from the station and returns it to earth for refurbishment, recycle, or retrofit to a different payload.

RAM PAYLOAD CARRIERS

Payloads representing all mission modes and covering a broad spectrum of experiment complexity were used to typify potential usage. These represent selective groupings of the experiments described in the 25 functional program elements (FPEs) contained in NASA document 7150.1, *Reference Earth Orbital Research and Applications Investigations,* known as the Blue Book. The requirements derived from the selected groupings of experiments and an assumed shuttle traffic model resulted in a reference experiment plan. This plan provided the basis for establishing design parameters for the family of RAM payload carriers that evolved.

During the study, additional RAM payload carrier experiment plans were defined to represent a number of programs that were financially constrained at funding levels ranging from $50M to $250M per year. These programs employed mixes of RAM payload carriers and used various combinations of the basic 54 payloads. The type, mix, and relative sophistication of the RAM payload carriers are functions of the definition of a specific experiment program and the related funding level. A single element, the sortie RAM, can provide significant capability in support of all scientific disciplines at any program funding level. Starting with this basic capability, RAM payload carriers can evolve into a family of elements capable of satisfying the requirements of all anticipated and applicable payloads.

To meet the requirements of the payloads, the RAM payload carriers include 1) pressurized elements for the manned laboratories, 2) unpressurized elements to provide additional mounting area for sensors, and 3) free-flying pressurizable elements for the man-tended observatories. These payload carriers are provided in both shuttle-supported and station-supported mission modes.

Additionally, in the shuttle-supported mission mode, a version of the pressurized payload carrier provides a means of increasing the returns on each sortie mission by providing for support of additional payload crew members beyond that provided for in the orbiter. This version can then be used in conjunction with a configuration that houses only the payload.

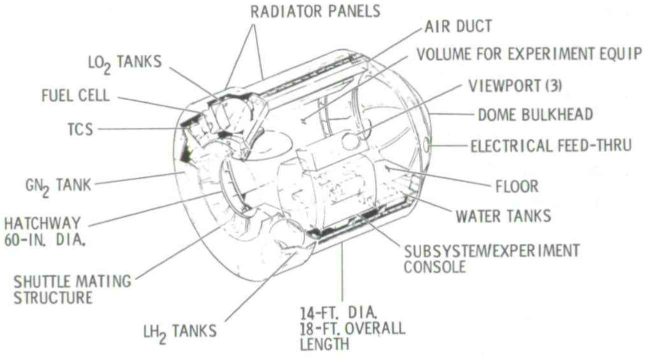
Since the pressurized element is provided by experiment-peculiar structure in the station-attached mode, there is no basic RAM payload carrier for this function.

A narrowing of the potential seven resulting configurations is possible by virtue of the commonality between RAM payload carrier requirements for the two mission modes; the free-flying RAM and the RAM payload module each have only one basic configuration for both modes. Therefore, only five configurations are necessary to accommodate the representative RAM payloads:

Sortie RAM
RAM Support Module
RAM Payload Module
RAM Pallet
Free-Flying RAM

SORTIE RAM. The sortie RAM is a pressurized module designed to operate attached to the shuttle orbiter while accommodating a wide array of experiment equipment and providing the subsystem resources essential for the conduct of the experiment. It also provides support for a crew of two mission/payload specialists, who would be transported to and from orbit in the shuttle orbiter. The module is approximately 18 feet long and has a nominal outside diameter of 14 feet. An interface adapter assembly is provided at the forward end to mate with the shuttle orbiter. The sortie RAM design provides for minimum interface with the shuttle system to minimize shuttle refurbishment costs and recycle time. Some of the orbiter capability is used on a sortie RAM mission, however, including crew seats and restraints during boost and entry, sleeping accommodations, food and hygiene facilities, emergency electrical power, voice communications and tracking, and partial stabilization and attitude control functions.

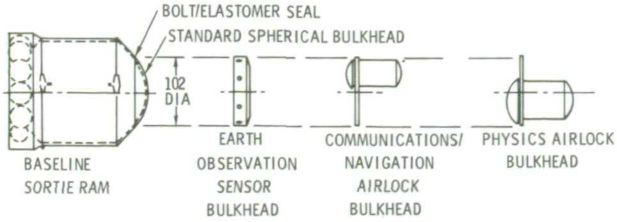
Some sortie RAM subsystem components such as the fuel cells, their reactant storage tanks, high-pressure nitrogen storage tanks, and the thermal control system freon components are mounted externally for safety. The remainder of the subsystem equipment is packaged compactly at the forward end (relative to installation in the orbiter cargo bay) and adjacent to the structural skin to provide a maximum clear interior volume for the installation of the control and display console and experiment-peculiar equipment without impairing access to critical components. The basic subsystem resources provided by a sortie RAM include environmental control and life support, thermal control, data management and onboard checkout, electrical power, and those habitability functions not provided by the orbiter (such as work stations and restraints).



Sortie RAM General Arrangement

To keep development and production costs to a minimum, the RAM project has identified many orbiter components that are compatible with the RAM system requirements. These include items such as fuel cells, reactant storage tanks, nitrogen storage tanks, EC/LS subsystem, and thermal control system components. Candidate components from other active space programs such as Skylab and the orbiting astronomical observatory were also identified. The sortie RAM subsystems are sized to satisfy the requirements of a majority of the representative payloads. Some Earth Observations and Materials Science payloads require additional electrical power and data storage capability; this requirement is satisfied by providing add-on equipment in the form of storage batteries and digital magnetic tape.

The basic sortie RAM incorporates a replaceable domed bulkhead at the aft end. In this configuration, the sortie RAM can accommodate zero gravity experiments in the Life Science, Materials Science, and Technology disciplines. Earth Observations and Communications/Navigation payloads can be accommodated by replacing the

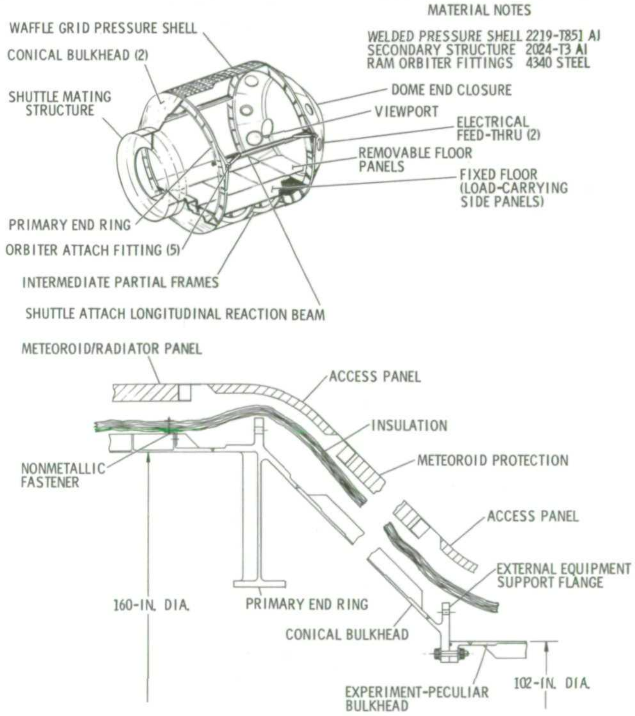


Experiment-Peculiar 102-Inch-Diameter Pressure Bulkheads

domed bulkhead with a bulkhead designed to accommodate the sensors and other equipment.

Sortie RAMs are not dedicated to specific payloads; the interior is configured to accommodate payloads in any of the scientific disciplines. A control and display console is used to control and monitor the subsystems and support selected experiments. Major experiment equipment is installed on removable channels bolted to the floor, permitting ready removal and replacement.

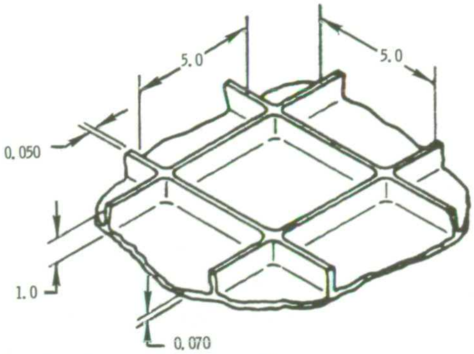
Sortie RAM Structure. The proposed structure for all RAM elements is based on conventional materials using existing manufacturing technology. Each structural assembly has been designed for multiple use. The major structural assemblies consist of a cylindrical sidewall, conical bulk-



Sortie RAM Structure

heads, experiment-peculiar bulkheads, secondary structure, and sortie RAM/orbiter attachment fittings. The attachment concept selected for sortie RAM is a five-point reaction statically determinant system. Three of the five attachment points are located forward and two aft relative to the orbiter.

A waffle-grid-stiffened structure was selected for the cylindrical sidewall. Cost, weight, structural, manufacturing, and functional criteria were evaluated. The waffle structure is 2219-T851 aluminum alloy, which is machined in a 5-inch, 90-degree square grid. Web stiffeners are 0.050-inch thick and are on the outside of the module. Skin



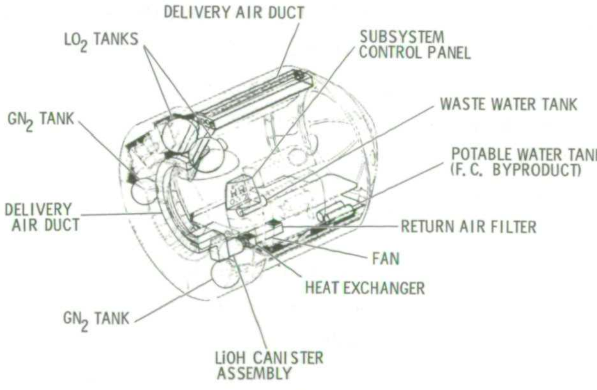
Detail of Waffle Structure (dimensions in inches)

thickness is 0.070 inch and is based on manufacturing and minimum-weight requirements for the designed loading intensity of the selected waffle structure.

The conical bulkhead is designed to accommodate pressure criteria. It has integrally machined, external blade stiffeners to react the expected loading conditions. The bulkhead is made in three segments welded at longitudinal seams. The segments have integrally machined frames to accommodate windows and penetrations.

Sortie RAM EC/LS. The environmental control/life support (EC/LS) subsystem provides the basic function of atmosphere storage, atmosphere revitalization, pressure control, water management, and special life support.

The subsystem provides module pressure control by maintaining the proper oxygen partial pressure. Condensing heat exchangers absorb heat picked up by the cabin air and control the humidity level in the compartment. Odors and carbon dioxide are removed from the cabin air by lithium hydroxide (LiOH) and activated charcoal canisters. All fuel-cell and humidity-condensate water collected during the mission is stored in onboard tankage. Facilities for

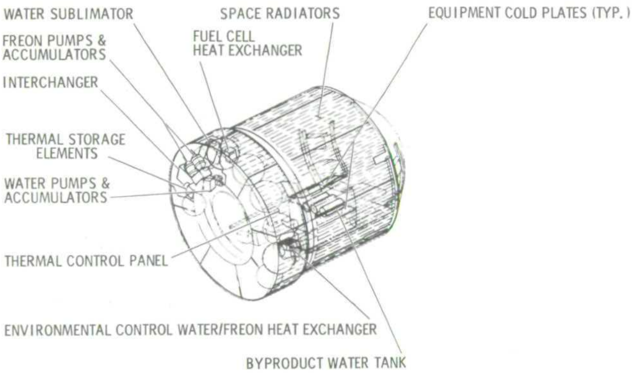


Sortie RAM EC/LS Subsystems

contingency repressurization of the sortie RAM as well as intravehicular activity (IVA) and face mask support are provided by the subsystem.

The EC/LS subsystem selected for the sortie RAM uses the shuttle-developed EC/LS subsystem, although its operation is totally independent of the shuttle. The selection was made because the reduced cost and complexity associated with ground operations and the minimum impact on shuttle design permitted the use of independent subsystems without increasing overall subsystems cost. No fluids cross the shuttle/sortie RAM interface.

Sortie RAM TCS. The thermal control subsystem (TCS) is a two-fluid system using water as the heat-transfer fluid within habitable compartments to meet the requirements of nontoxicity and nonflammability. The water loop interfaces with the freon heat-transport fluid through the interloop heat exchanger. The freon loop is located outside the habitable compartment and transfers heat to the space radiators. Freon is used because the radiator temperature can be well below the freezing point of water. Since the pumps are the least reliable components in the system, redundant pumps are provided in both primary fluid loops.



Sortie RAM Thermal Control Subsystem

For operation with the shuttle cargo bay door closed and during transient peak-heating periods, a water sublimator and thermal storage element are provided. An interface heat exchanger that requires coolant from GSE is used during prelaunch and postlanding operations. The TCS interfaces with the life support subsystem at the air-to-liquid heat exchangers. Module sensible and latent loads are absorbed at this point by the TCS. Warm freon is routed close to the oxygen supply and used to warm the module oxygen supply.

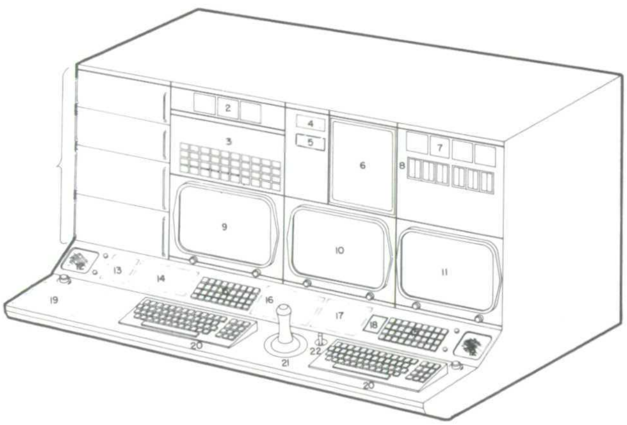
A second water/freon system provides redundancy to meet reliability criteria. The backup system uses the same radiator area as the primary system, but with independent coolant loops.

Radiators are coated with fluorinated ethylene propylene Teflon/Ag/Inconel to achieve proper optical properties for passive thermal control. The overall thermal analysis shows that the TCS can provide up to 20,700 Btu/hr of heat rejection for sortie RAM missions.

Sortie RAM Communications and Data Management. The basic data-handling approach uses permanent digital magnetic tape stored on board. Data volumes ranging from 10^5 to 2.3×10^{12} bits per mission and rates as high as 50 Mbps are recorded. A multiplex data acquisition and command distribution system is used to control and monitor all subsystems and experiment equipment. Remote digital interface units tie in to computer interface units. Interface terminals provide an interface with the orbiter and ground prelaunch equipment. Wideband analog and high-rate digital experiment signals are connected via hardwire.

The orbiter provides all communications support for sortie RAM by sharing its VHF links to the TDRS (voice, low-rate telemetry, and command) and its S-band links to the ground network (1 Mbps digital data transmission).

Sortie RAM Onboard Checkout. The onboard checkout subsystem (OCS) is an autonomous, flexible, job-oriented system. It performs highly organized, repetitive functions such as status monitoring automatically while permitting crew participation in those functions performed periodically. It also accomplishes fault isolation, redundancy switching, and checkout on demand.

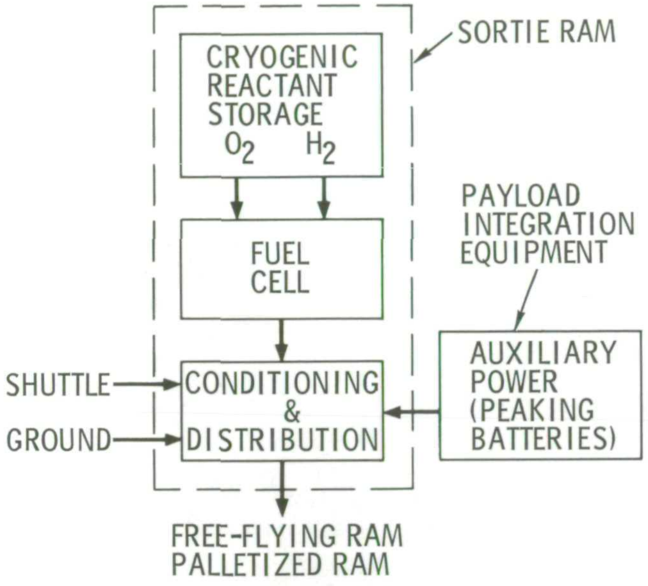


Control and Display Console

The OCS uses the communications and data management subsystem (CDMS) data processor and the data distribution and interfacing units. It includes a stimuli generator that activates subsystems for checkout and fault isolation and contains a caution and warning logic module that monitors caution and warning conditions aboard the sortie RAM. This function is performed concurrently with, but independent of, other checkout functions by the OCS.

Controls and Displays. The controls and displays (C&D) subsystem is the major man/machine interface for effectively controlling and managing payload experiments and sortie RAM subsystems. C&D functions are provided by the data and subsystem console located in the sortie RAM. The console provides for centralized C&D and represents an optimum mix of conventional dedicated C&D and integrated, software-oriented multiple-purpose controls and displays.

Sortie RAM Electrical Power. The basic electrical power subsystem (EPS) consists of a fuel cell, peaking batteries, and necessary conditioning and distribution equipment. The fuel cell generates 7 kW of power. Cyrogenic reactant storage provides a basic energy capacity of 1034 kW-hr. Silver/zinc batteries accommodate load peaks above the 7 kW capacity. The power is supplied to subsystems and experiments at 28 Vdc and 115/200 Vac, 400 Hz, 3 phase.



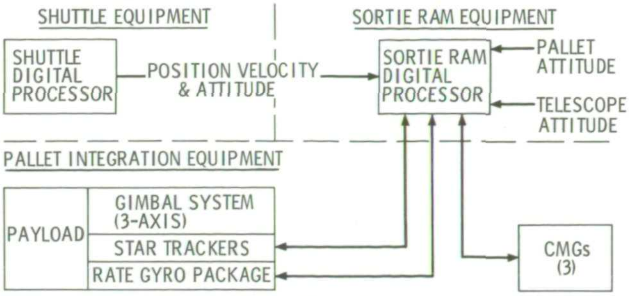
Sortie RAM EPS Subsystem

Sortie RAM Habitability. The sortie RAM habitability subsystem satisfies all mission/payload specialist environmental, physical, functional, psychological, and aesthetic needs that are not met by other sortie RAM subsystems, the shuttle orbiter, or the space station.

The shuttle orbiter provides habitability for two mission/payload specialists and the hygiene, food management, extravehicular activity (EVA) support, and survival gear storage for all sortie missions. Additional habitability items (basically work stations) are provided in the sortie RAM.

Each mission/payload specialist is provided an intravehicular activity (IVA) suit for additional survival backup.

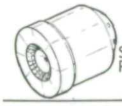
Sortie RAM GN&C. The sortie RAM receives its guidance, navigation, and control (GN&C) support from the shuttle except when it is used with the unpressurized RAM pallet in performing pointing and viewing missions. For such missions, the unpressurized RAM pallet contains GN&C payload integration equipment to augment shuttle capabilities. This RAM-pallet-integral equipment, however, requires support from a centralized digital processor located in the sortie RAM that implements control software for CMG and telescope pointing controls.



Sortie RAM GN&C Subsystem

Sortie RAM Subsystem Capabilities. The sortie RAM will be available to support the earliest on-orbit experiment missions. Accommodation for up to two mission/payload specialists is assumed available from the orbiter. A portion of the RAM spacecraft pressurized volume is required for the housing of subsystems with the remainder allocated for payload equipment. Heat-rejection capability of the sortie RAM is affected by orientation; it is best when pointing away from the earth. Electrical power consumption of the subsystems varies to some degree with the electrical power consumption of the payload. The fuel cell supplies up to 7 kW average of power at 28 Vdc, 4.1 kW of which can be available for the payload. Data is stored on magnetic tape, and communications are effected through the shuttle orbiter systems.

Sortie RAM Capability



SUBSYSTEM PARAMETER	REQUIRED BY SORTIE RAM	AVAILABLE TO USER	TOTAL
STRUCTURAL VOLUME (FT.^{3})	910	1,040	1,950
HEAT REJECTION (1,000 BTU/HR.)	11 TO 16	UP TO 5.4	15 TO 21
LIFE SUPPORT (MAN-DAYS)	–	18	18
MISSION/PAYLOAD SPECIALISTS (EQUIV. MEN)	~0.2	1.8	2
ELECTRICAL ENERGY (KWH)	370 TO 440	590 (MIN.)	1,030
ELECTRICAL POWER (AVG. KW)	2.2 TO 2.8	UP TO 4.2	7
DATA STORAGE (10^9 BITS)	NIL	1,300	1,300
DATA TRANS (10^6 B/SEC.)	–	1.0*	1.0*
DATA PROCESSING			
-MEMORY WORDS	20,000	8,000	28,000
-TIME (mSEC./SEC.)	610	390	1,000

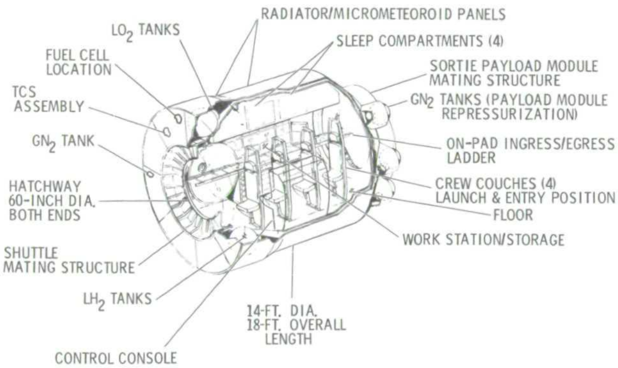
*VIA ORBITER

RAM SUPPORT MODULE (RSM). As stated earlier, the sortie RAM provides a significant capability applicable to practical application for all scientific disciplines. This may be further enhanced in the areas of:

1. **Number of Mission/Payload Specialists.** A significant quantity of additional data could be obtained on some missions if the number of payload specialists were

increased from two to four or six based on multiple shift operations. The orbiter as defined for this study, accommodates only two mission/payload specialists during exit and entry. Therefore, the RAM payload carrier must incorporate habitability provisions for any additional required mission/payload specialists.
2. **Volume.** To provide full Blue Book capability, additional volume must be provided to fully satisfy the requirements of some of the defined payloads.
3. **Traffic Rate.** Each sortie RAM incorporates a full complement of subsystems as basic equipment. Between missions, subsystem maintenance and checkout can easily be accomplished in two weeks or less. To change payloads from one discipline to another, however, may require as much as three months, depending on the complexity of the payloads. For high traffic rates, there is a definite economic advantage in using separate modules for the payload and the subsystems. This permits a single subsystem module to service several relatively inexpensive payload modules.

The basic pressurized RAM payload carrier (sortie RAM) has been specifically configured so that it can evolve into a RAM support module (RSM) and a RAM payload module to satisfy the preceding requirements. The RSM contains the habitability provisions and provides the subsystems resources for itself and the RAM payload module. The RSM uses the same primary structure, subsystems installation, and control and display console as the sortie RAM.



RAM Support Module

The interior is configured to incorporate provisions for as many as four seats and bunks for the added mission/payload specialists. The RSM provides repressurization, atmospheric conditioning, control, data handling, and potable water for experiments to the attached RAM payload modules during sortie missions.

The following RSM subsystem installations are essentially the same as those in the sortie RAM.

1. Structure
2. EC/LS (except capability for six payload crewmen)
3. Thermal control
4. Communications/data management
5. Onboard checkout
6. Controls and displays
7. Electrical power
8. Guidance, navigation, and control

RSM Habitability. The RSM provides the capability for as many as four additional mission/payload specialists. It contains living and working provisions for the payload specialists, except for the hygiene and food management facilities, which are provided by the shuttle orbiter. Launch and entry couches are stowed during orbital operations. The ladder provided for payload crew ingress and emergency egress on the launch pad is stored during orbital and entry flight phases.

An in-line arrangement of couches designed for personnel covering the 5th to 92nd percentile was selected based on the results of a trade study in which simulated emergency egress configurations were evaluated. In these simulations, it was demonstrated that four persons could evacuate the RSM in 18 seconds. The ladder is located adjacent to the seat backrests approximately at a payload crewman's shoulder position. Ladder orientation is with the rings parallel to the RSM floor.

RSM Subsystem Capability. A pressurized RAM adaptation of the sortie RAM known as RAM support module (RSM) will be used to increase the number of mission/payload specialists on-orbit over the basic orbiter capability of two. It uses the same structural shell as the sortie RAM and has the same total pressurized volume. Only nominal storage space is, however, available to the user since subsystems and habitability provisions use most of the volume. The RSM operates in conjunction with a RAM payload module at all times, and heat rejection capability for a given payload must be determined on the combined configuration basis; the RSM alone accounts approximately for the systems installed within. The 28-Vdc, 7-kW fuel cell system provides up to 4.1 kW to the RAM payload module interface.

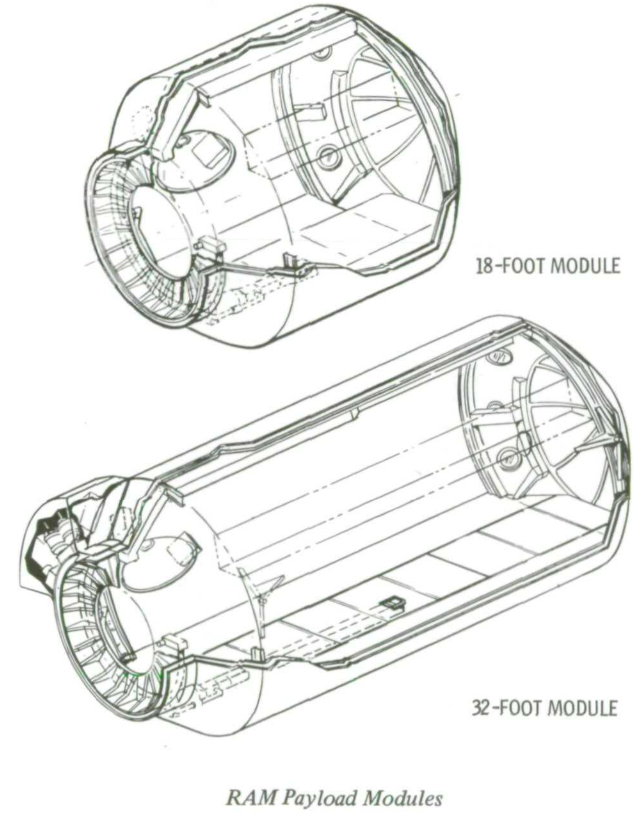
RAM Support Module Capability

SUBSYSTEM PARAMETER	REQUIRED BY RSM	AVAILABLE TO USER	TOTAL
STRUCTURAL VOLUME (FT.^{3})	1,950	NOM. STORAGE	1,950
HEAT REJECTION (1,000 BTU/HR.)	UP TO 21	–	21
LIFE SUPPORT (MAN-DAYS)	–	36	36
MISSION/PAYLOAD SPECIALISTS (EQUIV. MEN)	~0.2	3.8 TO 5.8	4 TO 6
ELECTRICAL ENERGY (KWH)	370 TO 440	590 (MIN.)	1,030
ELECTRICAL POWER (AVG. KW)	2.3 TO 2.9	UP TO 4.1	7
DATA STORAGE (10^9 BITS)	NIL	1,300	1,300
DATA TRANS (10^6 B/SEC.)	–	1.0*	1.0*
DATA PROCESSING			
-MEMORY WORDS	20,000	8,000	28,000
-TIME (mSEC./SEC.)	610	390	1,000

* VIA ORBITER

Integral reactant tankage for up to 1,030 kW-hr is provided. Data storage is handled by the use of magnetic tape. All communications are handled through the shuttle orbiter systems.

RAM PAYLOAD MODULE. The RAM payload module is a pressurized RAM payload carrier applicable to both the sortie and station-attached missions. It is basically a structural shell made in two lengths (18 or 32 feet). The length can be easily and inexpensively modified to provide additional volume for payload equipment. Supporting resources are provided to the RAM payload module by the RSM for the sortie mission mode and by the space station for the station-attached mode (except for thermal control, which is incorporated in the RAM payload module).



RAM Payload Modules

RAM Payload Module Structure. The RAM payload module structure is identical to the sortie RAM except for length of the 32-foot module and some of the attachment fittings.

The five-point reaction system attachment concept employed for sortie RAM is maintained for all other RAM payload carriers/combinations of RAM payload carriers. The attachment fittings for the 18- and 32-foot RAM payload modules designated for station-attached missions are therefore the same as for the sortie RAM (three forward and two aft), because these RAM payload modules will be transported to orbit singly. The 18- and 32-foot RAM payload modules designated for sortie missions will always be used in combination with an RSM, and the 18-foot RAM payload module may be used in combination with a RAM pallet. None of the sortie-mission RAM payload modules will have forward attachment fittings, as these are provided by the RSM. However, all sortie-mission RAM payload modules will have two aft fittings except where the 18-foot RAM payload module is used in combination with the RSM and the RAM pallet. In this instance, the RAM payload module will have no attachment fittings because the RSM will provide the three forward and the RAM pallet the two aft attachment fittings.

RAM Payload Module EC/LS. Resource support is provided by either the RSM or space station, depending on the flight mode. The RAM payload module provides for distribution of resources.

RAM Payload Module TCS. Thermal control of the RAM payload module operating in the sortie mission mode with the RSM has a maximum combined capacity of 53,600 Btu/hr. When operating in the station-attached mode, the RAM payload modules provide their own thermal control with a maximum capacity of 24,400 Btu/hr. The TCS is similar to that of the sortie RAM except that it includes radiator panel bypass valves and does not have a fuel-cell heat exchanger.

RAM Payload Module Communication/Data Management. All communications are provided by either the orbiter or the space station, depending on the flight mode. The sortie-mission RAM payload module data management system is basically a recording function, with the RSM providing other required functions.

For the station-attached missions, all experiment data is transferred to the space station for processing, storage, and/or transmission. The maximum data volume is 3.4×10^{11} bits/orbit at a maximum rate of 51.4 Mbps. The RAM payload module's fully multiplexed system interfaces with the space station data bus for transfer of low-rate data; high-rate data is hardwired to the space station. A small computer is included in the RAM payload module data management system to provide the launch-to-station dock management required by the subsystems.

RAM Payload Module Onboard Checkout. The OCS within the RSM provides the stimuli necessary to activate subsystems and experiment equipment for checkout and fault isolation for the sortie-mission RAM payload module. The OCS for the station-attached RAM payload module mode varies in the following respects.

1. All OCS equipment except the C&D console is located in the RAM payload module instead of the RSM.
2. Checkout and fault isolation functions are initiated and controlled by the mission/payload specialists from

the C&D console located in the space station.

3. Caution and warning (C&W) signals are interfaced by hardwire to the space station C&W panel for crew command action.

RAM Payload Module Electrical Power. The RAM payload module electrical power subsystem provides conversion, conditioning, distribution, and control for the subsystems and payloads. Power generation is provided by the RSM or space station, depending on the mission mode.

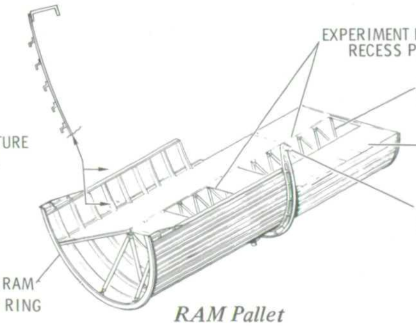
RAM Payload Module Subsystem Capability. RAM payload module will be used to increase the amount of pressurized volume available for the installation of payload equipment. In the sortie mission mode, supporting resources are provided by the RAM support module. The RAM payload module in its 18-ft version uses the identical structural shell of the sortie RAM and RSM and a very similar extended cylindrical section in its 32-foot version. Radiators on the outer shell work in conjunction with the TCS of the RSM to provide heat rejection adequate to cover fuel cell output and cooling, plus loads from peaking batteries integral to some payloads. Fuel-cell reactants required for energy beyond that available from RSM are a concern of the payload integrator, but may be readily installed external to the RAM payload module.

Sortie Payload Module Capability

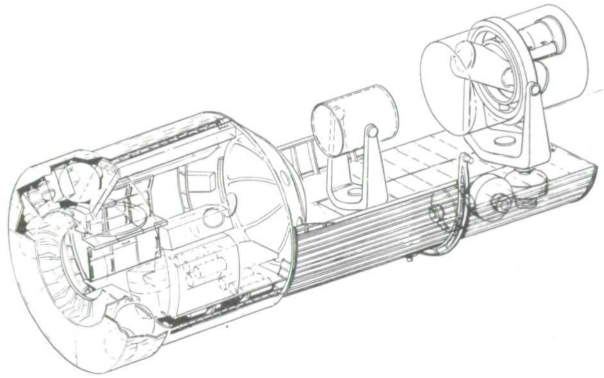
SUBSYSTEM PARAMETER	REQUIRED BY RAM PAYLOAD MODULE (P/M)	AVAILABLE TO USER		TOTAL	
		18 FT. P/M	32 FT. P/M	18 FT. P/M	32 FT. P/M
STRUCTURAL VOLUME (FT.^{3})	533	1,377	3,327	1,910	3,860
HEAT REJECTION (1,000 BTU/HR.)	4 TO 5	UP TO 10	UP TO 25	12 TO 15	UP TO 32
*ELECTRICAL ENERGY (KWH)	35 TO 70	520 (min.)	520 (min.)	590 (min.)	590 (min.)
*ELECTRICAL POWER (AVG. KW)	0.3 TO 0.6	UP TO 3.5	UP TO 3.5	4.1	4.1

*SUPPLIED BY RSM

RAM PALLET. Area to accommodate large sensors required in some configurations such as Astronomy payloads is provided by attaching a skin/stringer RAM pallet to the sortie RAM or sortie-mission RAM payload module. Power, control, data management, and thermal control for the attached RAM pallet is provided by the sortie RAM. The figure shows the RAM pallet configured for a sortie Astronomy mission with a high-energy spectrometer/polarimeter and an infrared telescope, which is protected by a thermal shield. The gimbals and CMGs, when required, are mounted to payload-peculiar mounting plates bolted to the RAM pallet structure. The flexibility provided by the sheet/stringer construction enables the pallet to accommodate payloads with wide variations in mounting requirements.



RAM Pallet



Sortie RAM with Attached RAM Pallet

RAM Pallet Structure. The RAM pallet structure is essentially a half cylinder made from sheet metal. The shell structure is a typical semi-monocoque structure of 7075-T6 aluminum alloy with a skin that varies in thickness from 0.032 to 0.061 inch. It has a series of frames (channel sections) spaced every 20 inches. Attached to each frame is a channel section beam that spans the cylindrical shell and supports the floor. The shell is stiffened with longitudinal zee-shaped stiffeners.

RAM Pallet Thermal Control. Thermal control for the RAM pallet is provided by the sortie RAM or the RSM when a RAM payload module is used. Freon cold plates are located on the RAM pallet to pick up heat loads to 1250 Btu/hr. The freon connections at the RAM pallet interface with either the sortie RAM or the RAM payload module.

RAM Pallet Communications/Data Management. The RAM pallet has no communication requirements. Data management and onboard checkout consists of digital interface units to handle low-data-rate signals and hardwire to transfer wide-band experiment data to the sortie RAM or the RAM payload module.

RAM Pallet Control & Display. Visual monitoring of operations and inspection of pallet-mounted equipment is provided by the orbiter using closed circuit TV cameras and associated floodlights located in the manipulator arms.

RAM Pallet Electrical Power. The RAM pallet electrical power subsystem is limited to distribution, with the prime power source furnished by the sortie RAM or RSM.

RAM Pallet GN&C. Payload integration equipment is provided for the special case of pointing missions. The driving requirements are all-attitude inertial pointing to 0.5 arc-sec and preservation of cleanliness in the vicinity of the orbiter.

CMGs of the type and size used in Skylab provide attitude control of the shuttle/RAM assembly in lieu of the shuttle RCS. This avoids potential contamination by the shuttle RCS and also improves base stability. To minimize the number of CMGs, shuttle attitude is constrained to nose along the orbit normal. To accommodate the orbiter orientations constraint and also because of the typical dual, independently pointed experiment-type payloads, three-axis wide angle gimbaling is provided. This wide-angle gimbaling is driven to payload-integral aspect error acquisition accuracy (30 arc-second) as directed by star trackers and rate gyro package attitude measurement data. Refinement of pointing capability is provided by an additional two-axis narrow-range gimbal capability driven from payload-integral aspect error sensing.

RAM Pallet Subsystem Capability. The RAM pallet will be used to provide mounting space for experiment equipment requiring large areas in the space environment. It has no self-contained subsystems, and draws the required resources from the sortie RAM or RAM payload module to which it is attached. The capability available to the user is, therefore, dependent on the quantities allocated to the user within the attached pressurized RAM. The quantities shown in the table are the maximum available if none is used within the sortie RAM or RAM payload module. Any payload integration equipment, such as mission-peculiar CMGs for guidance, navigation and control, will also draw on the capability.

RAM Pallet Subsystem Capability

STRUCTURAL MOUNTING AREA (FT^2)	270
HEAT REJECTION, LIQUID LOOP* (1000 BTU/HR)	UP TO 10
ELECTRICAL ENERGY* (KW-HR)	UP TO 520
ELECTRICAL POWER DISTRIBUTION* (KW)	UP TO 3.5
DATA HARDWIRE TRANSMISSION** (10^6 BPS)	UP TO 1.0

* SUPPLIED BY PRESSURIZED RAM
** VIA ORBITER TRANSMISSION

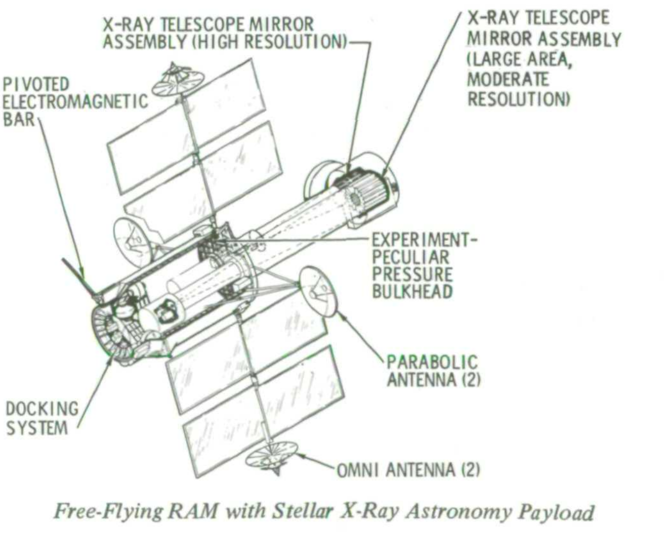
FREE-FLYING RAM. The free-flying payloads are characterized by the requirement for a stable platform for long durations and a contamination-free environment beyond the capabilities of the space station and the shuttle. This has resulted in the selection of a free-flying RAM element capable of operating unmanned and unpressurized for long durations. Periodic rendezvous with the free-flying RAM is required for manned maintenance and servicing. Servicing is accomplished by using either the space station or the shuttle with a sortie RAM deployed from the cargo bay. For shuttle servicing, the shuttle is the active element in the rendezvous and docking; for the station-supported mode, the free-flying RAM is the active element. The free-flying RAMs can be retrieved and returned to earth by the shuttle for refurbishment if required.

During experiment operation, the free-flying RAM must be completely self-sufficient. Major subsystem components include electrical power provided by roll-out solar cell arrays and nickel-cadmium batteries. CMGs for stabilization with electro-magnetic torque bars for momentum desaturation, a dual-loop water/freon thermal control system, a hydrazine propulsion/RCS (in replaceable units on the shuttle-supported free-flying RAM), and VHF, S-band, and Ku-band communications. During service operations, repressurization and EC/LS functions are provided by the sortie RAM.

The station-supported free-flying RAM configuration differs in the number of RCS thrusters employed for translation to the station and in communications requirements.

Free-Flying RAM Structure. The outside diameter of the free-flying RAM is nominally 12 feet to allow space for the external subsystem assemblies, which must remain within the shuttle cargo bay envelope diameter of 15 feet. In an evaluation of potential structural commonality with the 14-foot-diameter pressurized RAM, a 14-foot-diameter free-flying RAM was also analyzed. However, it was concluded that it required unacceptable complex and costly solutions to the problems of RCS clearance and of solar cell array and 8-foot antenna stowage within the 15-foot shuttle cargo envelope.

The free-flying RAM is 22 feet, 7 inches in length with a docking assembly and contamination shield at one end



Free-Flying RAM with Stellar X-Ray Astronomy Payload and open at the other end. The open (viewing) end is closed by the addition of a pressure bulkhead, which varies with each experiment payload accommodated due to different mounting requirements.

Free-Flying RAM EC/LS. The free-flying RAM provides EC/LS subsystem functions consisting of distribution ducting for air supplied from the station or sortie RAM, particulate filtration of the air supply, connections for two IVA umbilicals, and pressure relief valves. Means are provided to pressurize and depressurize the module for the shirtsleeve access from the station or sortie RAM. Supplementary air circulation within the free-flying RAM is provided by portable ventilation fans stowed in the sortie RAM.

Free-Flying RAM TCS. The free-flying RAM TCS contains two fluid systems. Water is used internally because of commonality with the TCS used in the other RAM elements and because of its excellent heat transfer capability. The water transfers heat from all interior heat sources to an external freon 21 system across an interloop heat exchanger. This heat is transferred to the radiator panels and rejected to space. The freon supply temperature to the intercooler is maintained at a nominal value of 35°F for battery cooling by a radiator bypass control. Thermal damping during periods of rapid transients or peaking loads is provided by the thermal storage element. This element is sized for the entry condition, when neither the radiators nor the sublimator can be used.

The warm freon lines are routed close to the propellant tanks and lines to prevent the propellants from freezing. Radiators are sized for the largest free-flying RAM payload heat rejection capability of 10,500 Btu/hr.

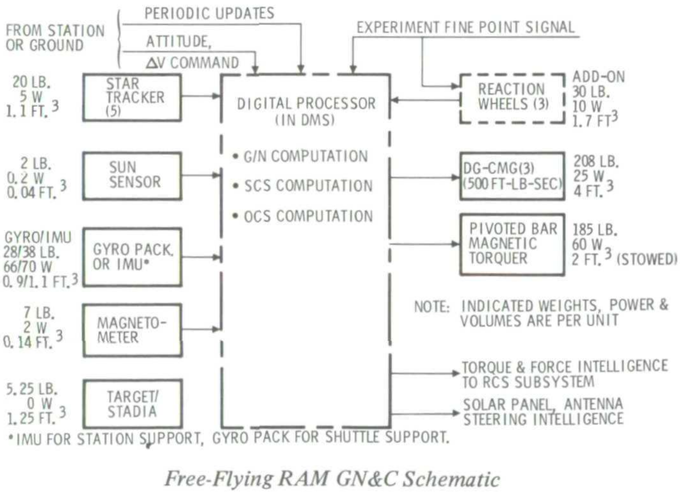
Free-Flying RAM Communications/Data Management. The basic data-handling approach is buffer digital-data storage and data relay to ground. A fully multiplexed digital-data acquisition and command distribution identical to that described for sortie RAM missions is used. Control is via a centralized computer configuration. Data relay is via TDRS using two 8-foot Ku-band dishes (shuttle supported) or by two 2-foot Ku-band dishes (station-supported mode). During rendezvous, orbiter telemetry and command is provided by a unified S-band transponder and ranging by a VHF ranging transponder.

Free-Flying RAM Controls and Displays. The free-flying RAM control and display functions are audio distribution and caution and warning displays and alarm. The primary control and display for servicing the free-flying RAM is provided by the sortie RAM or the space station.

Free-Flying RAM Electrical Power. Solar arrays with an area of 1000 sq.ft. provide prime power generation to 2.8 kW. These are flexible rollout-type arrays previously developed and currently used in flight operation. Free-flying RAMs feature systems with two tandem drums on each side of the vehicle; these extend four solar array panels. Power during eclipse periods is provided by 36 ampere-hour nickel-cadmium batteries at a 20 percent depth of discharge. Power conditioning and distribution is similar to that in the sortie RAM.

Free-Flying RAM Habitability. The only habitability items permanently installed aboard the free-flying RAM are mobility aids and restraints. However, other habitability items are necessary to support crew task performance during free-flying RAM delivery or retrieval and the servicing operations. These items are provided by the sortie RAM/space station during free-flying RAM service missions.

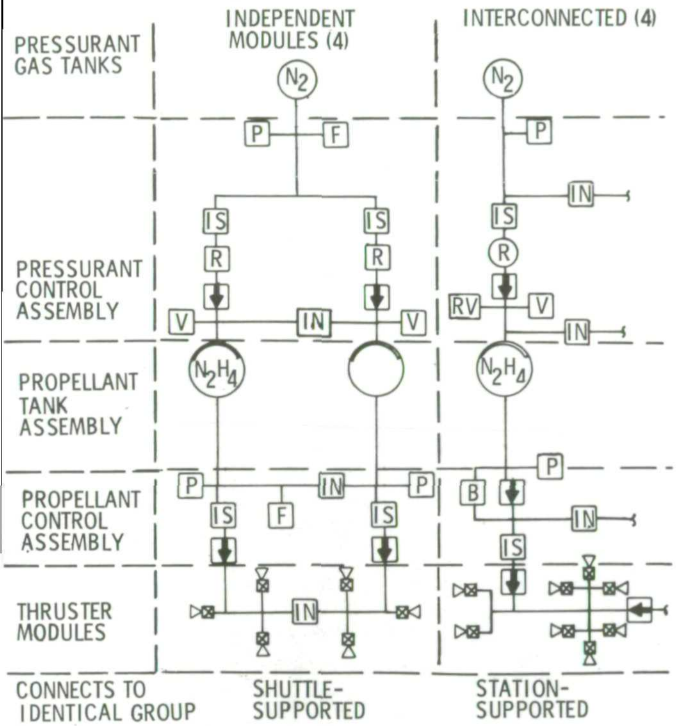
Free-Flying RAM GN&C. Fixed-head star trackers provide all-attitude sensing to 30 arc-sec accuracy to position the free-flying RAM to payload-integral aspect error sensor acquisition accuracy. Precise pointing requirements are provided by sensors integral to the payload. Torquing is provided by three double-gimbal (skylab) CMGs, which stabilize the free-flying RAM body/telescope combination to 0.5 arc-sec. Desaturation of the CMG momentum accumulation is provided by the magnetic torquer, which consists of a double-pivoted bar electromagnet. Some experiments require more stability than the CMGs can provide. These special cases require stability to ±0.005 arc-sec and can be accommodated by payload-integral vernier or modular reaction wheels.



Free-Flying RAM GN&C Schematic

Free-Flying RAM Propulsion/RCS. The basic propulsion/RCS unit for the free-flying RAMs consists of four modules, each containing six 25-lbf monopropellant hydrazine thrusters that supply three-axis torques with couples. Eight 25-lbf thrusters (four sets of two thrusters) are added to the station-supported free-flying RAM because it has a translation and docking requirement and because it is necessary to compensate for differences in center of gravity locations with the different payloads.

For the shuttle-supported free-flying RAMs, individual tanks are nestled in the four thruster modules, and there are no fluid interconnects between the RCS modules. Fluid resupply and hardware maintenance are accomplished by replacing the entire module assembly. This design approach was based on the results of a reliability/maintainability/cost-effectiveness analysis.



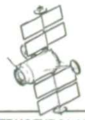
Free-Flying RAM Propulsion/RCS Schematic

The station-supported free-flying RAMs require up to 2000 pounds of propellant, based on a six-month resupply period. To elimiante the excessive tankage and propellant weights that would result from individual tanks for each thruster module, the propulsion/RCS system is integrated into the vehicle and interconnects between the propellant tanks are provided.

Existing components have been selected on the basis of minimum cost, which also eliminated development and qualification risks. The Titan Transtage 25-lbf thrusters are to be used in the RCS and are currently being developed.

Free-Flying RAM Subsystem Capability. Adequate volume is provided within the pressurizable shell for the accommodation of subsystems and experiment sensors. The experiment-provided pressure bulkhead closure provides for both internal and external sensor mounting. Electrical power from solar arrays is used for subsystems and experiments. Heat rejection is through external radiator/micrometeoroid protection panels. Both digital and analog data transmission RF channels are provided. Fine-pointing capability is provided by CMGs; more stringent requirements must be met by techniques such as image motion compensation or trimming reaction wheels. The reaction control subsystem (RCS) stabilizes the free-flying RAM during shuttle docking maneuvers and provides for rendezvous, docking, and stationkeeping needs when the free-flying RAM is operated with a space station.

Free-Flying RAM Capability



SUBSYSTEM PARAMETER	REQUIRED BY FREE-FLYING RAM	AVAILABLE TO USER	TOTAL
STRUCTURAL VOLUME ($FT.^3$)	1,090	920	2,010
HEAT REJECTION (1,000 BTU/HR.)	6	5	11
ELECT. POWER (AVG. KW)	0.8 TO 1.9	1.3 TO 2.0	2.8
DATA STORAGE BUFFER (BITS)	–	UP TO 5×10^{10}	UP TO 5×10^{10}
DATA TRANS.			
- 10^6 B/SEC.	0.01	DIGITAL UP TO 10	10
- MHz	–	ANALOG 2 X 5	2 X 5 MHz
DATA PROCESSING			
- MEMORY WORDS	15,000	9,000	24,000
- TIME (MSEC./SEC.)	520	480	1,000
POINTING ACCURACY (ARC.-SEC.)	–	1.0	–
STABILITY (ARC.-SEC./OBS.)	–	0.5	–
SLEW RATE (DEG./MIN.)	–	6	–
RCS STORED IMPULSE			
- SHUTTLE SUPPORTED (LB. SEC.)	22,000	–	22,000
- STATION SUPPORTED (LB. SEC.)	110,000	–	110,000

EXPERIMENT ACCOMMODATION AND INTEGRATION

Technical requirements for the integration of payloads with RAM elements are described in this section. The determination of requirements for payload integration included analyses of payloads or experiments to define the unique requirements arising from equipment configuration or operational characteristics, operating environment, or supporting resources. Based on these requirements, design concepts were developed for payload integration equipment.

REFERENCE PAYLOADS. Early in the RAM Phase B study, representative payloads were defined. Payload goals, objectives, operations, environments, equipment and data inputs were then analyzed in detail to establish payload capabilities and to define requirements of interfacing systems imposed by the payloads. Operational characteristics of the previously defined mission modes were then compared with the requirements for each payload to determine the mission modes that best meet payload requirements.

The requirements for the representative payloads have been categorized as follows:

1. **Physical.** Total weight and volume, internal weight and volume.

2. **Mission.** Orbit, orientation, pointing, viewing con-

straint, pointing accuracy and stability, and pointing accuracy duration.

3. **Resources.** Crew, power, and data.

4. **Environment.** Acceleration, contamination, radiation, and temperature.

The payloads adequately represent the broad spectrum of potential experiments in terms of physical limitations, common facilities, environment, orbits, and similar research demands. Analysis of this group of payloads has been particularly beneficial in the establishment of basic payload carrier subsystem capabilities for each RAM element. The RAM elements are not designed to specifically accommodate the reference payloads, but consideration was given to satisfying a maximum number of representative experiments while not generating an excess capability that could impose serious technical and economic penalties.

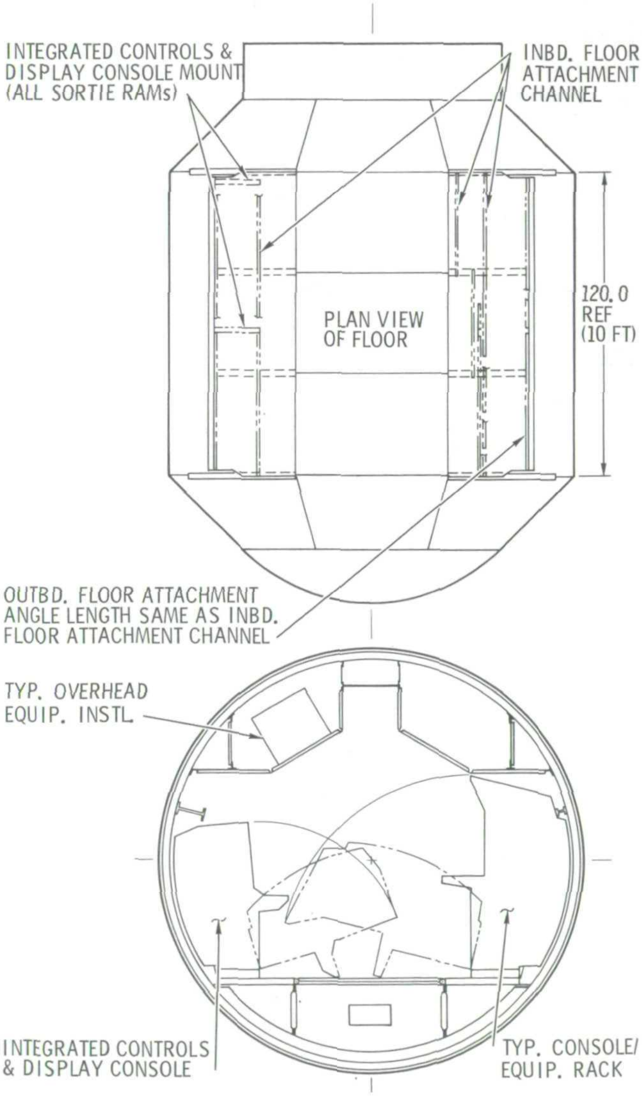
PAYLOAD INTEGRATION REQUIREMENTS. RAM payload integration equipment includes: 1) integration equipment necessary to install the experiment/payload in the carrier, and 2) subsystem add-ons constituting modular additions to basic RAM payload carrier capabilities. Booms, gimbals, environment protective equipment (such as contamination covers, fine thermal controls, radiation shielding, or lint-free garments), sub-satellite control, effluent control, and film storage are in the category of payload integration equipment. These items are not generally specified in experiment definitions but are needed to support unique payload requirements or to adapt the payload to the RAM payload carrier or mission. RAM payload carrier subsystem add-ons include major integration hardware structure and functional equipment such as CMGs, peaking batteries, or other items related to special payload characteristics or frequency of use, which may be added in modular form to extend RAM payload carrier capability.

The payload integration equipment has been categorized and related to experiment disciplines. The equipment installation will vary with each discipline or representative payload since it is dependent on payload definition and the characteristics of the payload itself such as sensitivity to operations, pressurized versus unpressurized location, or natural and induced environment.

INTEGRATION HARDWARE CONCEPTS. The approach to payload integration has emphasized an objective to design the payload carrier laboratories and observatories which will be economically versatile and responsive to experiment requirements. The vehicle arrangement, structure, subsystems resources, and payload integration equipment are combined to provide the required flexibility to support a wide range of payloads and user requirements.

The approach for the physical integration of payloads has been to provide each RAM payload carrier with a basic capability with respect to subsystems performance and accommodation volume. For specific payloads with greater or more stringent requirements, add-on subsystems are provided. For the short duration sortie missions, these add-ons are designed to be easily and quickly installed or removed. For the long duration free-flying or station-attached missions, the add-ons may be a more permanent type of installation.

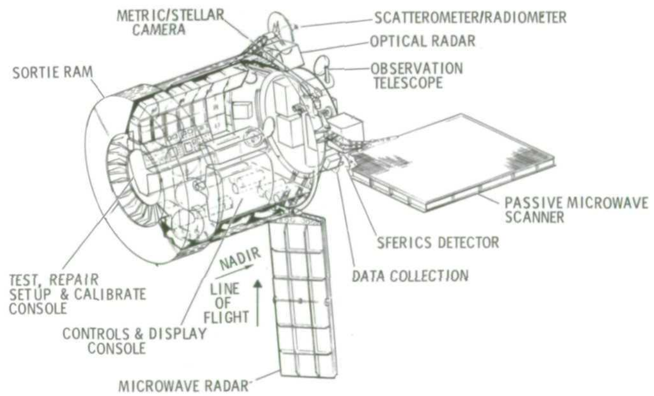
Flexibility in the mounting of various internal payload equipment is provided by means of removable racks and panels that do not affect the basic structure of the RAM payload carrier. The consoles and equipment racks are mounted on channel supports bolted to threaded inserts in the floor. Inserts are installed in the floor to accommodate the different length channels required for various payloads. This arrangement permits rapid removal and replacement. A



Typical Experiment Equipment Installation harness and utility trough is provided at the floor juncture with the side wall. Overhead equipment is mounted to removable honeycomb panels. Harnesses and tubing are routed through the adjacent utility trough to the equipment and then through disconnects to each panel.

To facilitate the use of commercially available laboratory equipment, RAM payload integration equipment includes a standard equipment mounting cabinet that provides the necessary physical and functional interfaces to accommodate such instruments. The cabinet contains an air-to-water heat exchanger and fans to circulate air within the cabinet, which is essentially a closed system. It also contains a power converter/regulator and distribution unit which provides standard voltages of 12 Vdc, 28 Vdc, and 115V, 60 Hz, ac regulated power up to a total of 250 watts. By using this type of equipment mounting cabinet, laboratory instruments that are usually convection cooled could be employed in the pressurized RAM.

External sensors and equipment are primarily attached to removable experiment-peculiar bulkhead structure and/ or an external ring at the aft end of the sortie RAM, RAM payload module and the RAM pallet. The baseline pressurized RAM previously described has a standard spherical closure bulkhead that is attached by means of a bolt and seal attachment at the 102-inch diameter aft ring of the conical bulkhead. For some payloads, this end closure is replaced by experiment-peculiar pressure bulkheads of 102-inch diameter.



Earth Observations Sortie Mission Payload

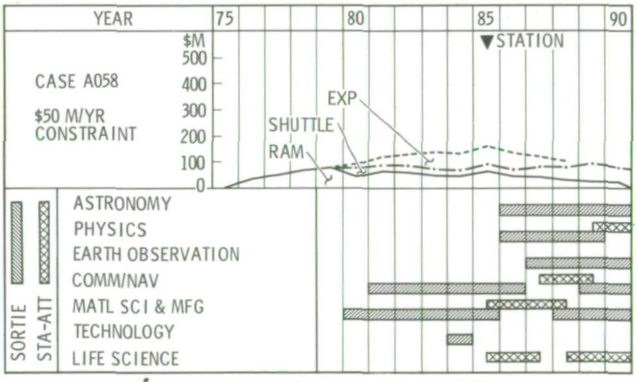
USER PROVISIONS. The basic support capability of a RAM payload carrier was determined from an analysis of the common requirements of the representative payloads. Cost, development and integration schedules were also considered in establishing the basic support capability of a RAM element or combination of elements. The net capability to support a given payload is equal to the total capability of the RAM payload carrier, plus subsystem add-ons, plus optional payload integration equipment, minus payload carrier subsystem support requirements.

SYSTEM COSTS AND PLANS

PROGRAM PLANS. A baseline experiment plan was defined to help in establishing the scope of an experiment program, taking into consideration the variety of experiment disciplines, mission modes, and level of experiment complexity. Subsequent experiment plans were used as a basis for examining the impact of program parameters on RAM payload carrier requirements. Financially constrained programs spanning the range of peak program funding from \$50M/yr to \$250M/yr were examined. The programs employed several combinations of RAM payload carriers and demonstrated the potential of space experimentation at various funding levels. They also served to relate level of program activity to the numbers and types of supporting RAM payload carriers.

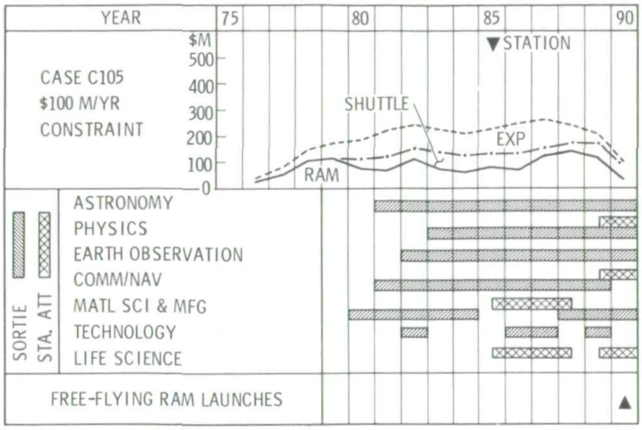
SUMMARY OF PLANS. Examples of programs constrained to peak funding levels of \$50M/yr, \$100M/yr, \$150M/yr, and \$250M/yr are shown in the following figures. Each figure shows typical payload activity by discipline and mission mode and gives a preliminary estimate of total program costs. RAM project costs include development, production, operations, and experiment integration. The experiment cost data was provided by NASA and is representative only; shuttle costs are for operations only and are predicated on \$4.5M per flight. Features of each plan are:

1. **\$50M/yr.** This plan provides for sortie missions that increase in scope and frequency throughout the program. In the latter half of the program, extensive use is made of the station-attached mode. Significant activity is included in all experiment disciplines.



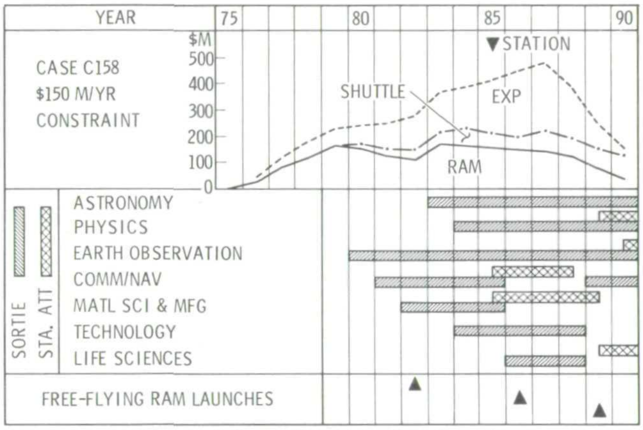
Costs and Payload Activity in A058 Plan

2. **\$100M/yr.** The major characteristic of this program is the active sortie mission mode in early program years, using payloads from all disciplines except Life Sciences. Life sciences activity starts with the station-attached payload in 1985. Free-flying RAM activity is limited to the introduction of a free-flying RAM in 1990.



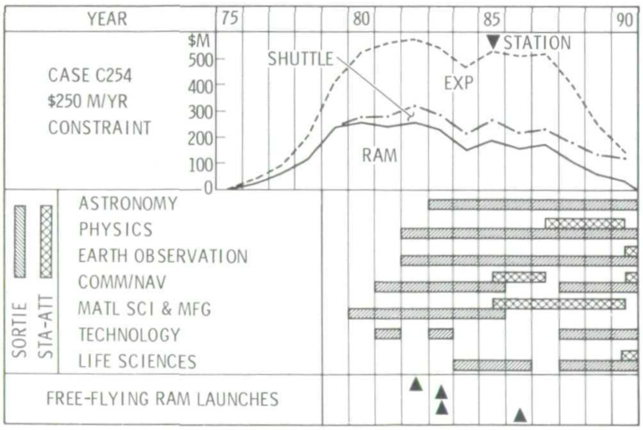
Costs and Payload Activity in C105 Plan

3. **$150M/yr.** This program provides for a balanced program with sortie-mission laboratories in a station-attached mode as early as 1985 and a free-flying RAM program that begins in 1982. An RSM and RAM payload module are introduced in 1984 to provide for advanced sortie payloads and four-man operation in several payload disciplines.



Costs and Payload Activity in C158 Plan

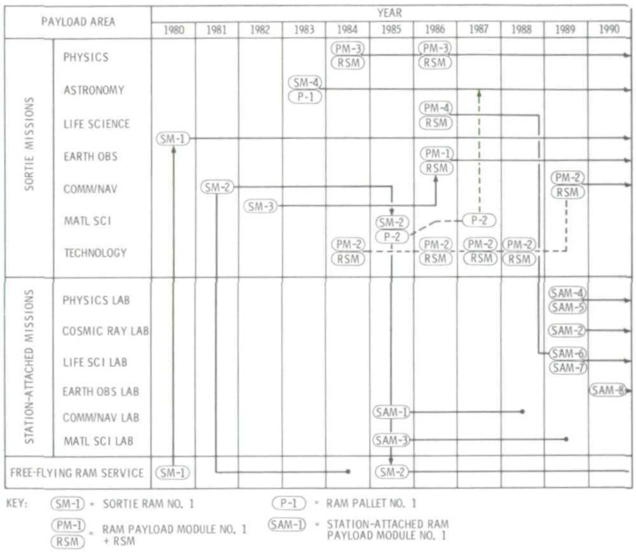
4. **$250M/yr.** This program plan is comprehensive in all mission modes. Low early-year funding is achieved by



Costs and Payload Activity in C254 Plan

delaying the free-flying RAM initial operational capability and reducing the rate at which additional payloads are introduced into the program. Sortie activity in the early years is balanced between the application and scientific disciplines. Four-man sortie payload crews begin operations with the introduction of an RSM and RAM payload module in 1983.

Utilization of the typical RAM payload carriers to support the C158 program is predicated on the assignment of a specific payload in the C158 plan. However, a wide variation in payload assignments could be made without significant change to the RAM payload carrier requirements shown.



RAM Payload Carriers Utilized in Payload Activities
Plan C158 – $150M/yr Constraint

RAM PROJECT FLEXIBILITY. Considering the capabilities of the various RAM/payload carriers to accommodate payloads and the payloads associated with a variety of payload plans, it is concluded that 1) the selected RAM payload carriers are versatile and will support programs at any reasonable funding level and 2) a reduction in the number of RAM payload carrier configurations would reduce effective program implementation at most levels of program funding. The first conclusion is supported by the example of financially constrained programs previously described. The second conclusion is based on the fact that the selected RAM payload carriers are required for the three possible mission modes and for responsiveness to the requirements of the vast spectrum of potential payloads. Utilization of a combination of the RAM payload carriers, i.e., pressurized, unpressurized, and free-flying (pressurizable) RAMs, provides a balanced capability. (The plans shown in the figures use such a combination of the RAM payload carriers.) The types of payload carriers selected for the financially constrained payload activity plans that were examined are shown in the following table. All of the plans require at least one of each type of RAM payload carrier, except the $50M/yr plan.

RAM Payload Carriers and Shuttle Flights Required for the Financially Constrained Payload Activity Plans Examined

REQUIREMENTS	PAYLOAD ACTIVITY PLAN			
	A058	C105	C158	C254
SORTIE MODE				
SORTIE RAM	3	5	4	5
18-FT RAM PAYLOAD MODULE	2+(2)	1+(1)	1+(1)	2+(1)
32-FT RAM PAYLOAD MODULE	0	1	2	2
RAM PALLET	1	2	2	3
RSM	2	2	2	2
STATION-ATTACHED MODE				
18-FT RAM PAYLOAD MODULE	1+(3)	1+(1)	2	2
32-FT RAM PAYLOAD MODULE	0	2	5+(1)	6
FREE-FLYING RAM	0	1	3	4
NUMBER OF SHUTTLE FLIGHT (10 YEAR OPERATIONAL PERIOD)				
SORTIE	79	103	99	10
FREE-FLYING RAM SERVICE	18	18	34	32
FREE-FLYING RAM DELIVERY & STATION ATTACHED	7	8	14	18
TOTAL	104	129	147	159

NOTE: FIGURES IN PARENTHESIS REPRESENT MODIFIED RAM ELEMENTS.

Costs for the RAM Project are generated with a parametric cost model derived specifically for similar projects. Using this model, nonrecurring (development) and recurring (production unit) costs have been estimated for the selected RAM payload carrier configurations. The costs are summarized below showing individual development cost, unit cost, and development cost savings predicated on a prior sortie RAM development that takes full advantage of commonality of structure, subsystems, test articles, and GSE. As shown, the cost of developing all RAM payload carriers individually ($954M) is more than twice the cost of developing them via an integrated development program ($429M).

RAM Payload Carrier Cost Summary

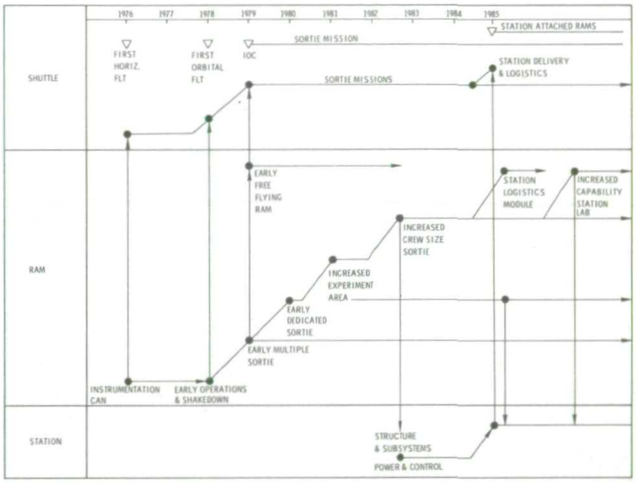
	UNIT COST	DEVELOPMENT COST	
		INDIVIDUAL	SAVINGS FROM PRIOR SORTIE RAM DEVELOPMENT
SORTIE RAM	23.44	192.9	0.0
RAM SUPPORT MODULE	24.14	215.6	173.1
SORTIE RAM PAYLOAD MODULE (18 FT)	5.60	60.6	50.5
SORTIE RAM PAYLOAD MODULE (32 FT)	6.99	70.2	48.4
STATION-ATTACHED RAM PAYLOAD MODULE (18 FT)	9.11	96.1	83.9
STATION-ATTACHED RAM PAYLOAD MODULE (32 FT)	10.72	118.1	107.8
RAM PALLET	1.27	11.7	0.3
FREE-FLYING RAM	23.36	188.5	61.0
TOTAL		953.7	525.0

EVOLVED RAM PROJECT POTENTIAL

During the RAM Project Phase B study, emphasis was placed on defining the RAM payload carriers to meet the guideline of low early-year funding and to provide a system that could expand in capability as needed. The potential application of the RAM payload carriers to operations outside their primary role as a carrier of research and applications payloads was also investigated. The potential uses of the RAM elements include use as:

1. A carrier of flight test instrumentation for shuttle sortie RAM development testing.
2. A means of extending on-orbit operational capability during the first 10 shuttle flights.
3. A method of evolving into a modular space station.

These uses, coupled with the assigned role of carrying payloads of an evolutionary nature beginning with shuttle sortie missions and progressing to the full-capability payloads for use with the space station, suggest an overall evolution of the RAM Project (i.e., from early payload carrier use during shuttle development flights to the final step of evolution to a space-station capability). The evolution of RAM elements to accommodate these varied uses is depicted in the following figure.



Evolutionary Potential of the RAM Project

Evolution of the RAM Project in this concept begins with potential application of the sortie RAM structure and selected components as an instrumentation carrier for the shuttle orbiter flight test program. This could start with horizontal flight tests and continue through orbital flight test. Limited precursor or test versions of some payload equipment could be incorporated into these programs. These early uses also serve as an initial shakedown of the sortie RAM for orbiter interfaces, orbiter/sortie RAM interactions, and investigations of environmental conditions in orbit that are critical to all experiments.

The next step in the RAM Project evolution is its potential use during the first 10 shuttle missions to increase the on-orbit operational capability. These opportunities are summarized in the following table. The first mission is defined as being limited to deployment of a passive payload whose volume prohibits accompaniment by sortie RAM. The alternate mission deploys a shorter micrometeoroid payload and permits the aforementioned shakedown flight

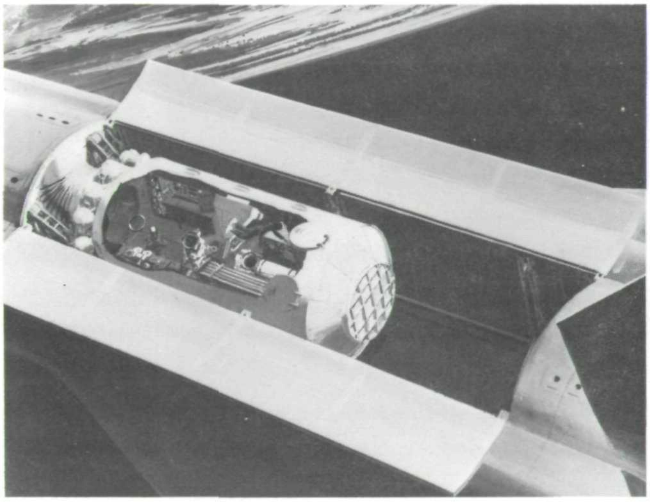
Potential Sortie RAM Utility – Early Shuttle Missions

NO.	MISSION	RAM POTENTIALLY USEFUL	CAPABILITY POSSIBLE TO PROVIDE WITH RAM
1.	METEOROID EXPOS MOD (MEM)	NO	NONE. PASSIVE PAYLOAD
1a.	SORTIE RAM SHAKEDOWN MISSION	YES	MEM PLUS SORTIE RAM/ORBITER TESTS
2.	DOD	–	–
3.	LST MIRROR TEST	YES*	CONTROLS & DISPLAYS (C&D) RESOURCES FOR TEST
4.	DEPLOY SATELLITE, RETRIEVE MEM	YES*	C&D, RESOURCES FOR CHECKOUT
5.	DEPLOY HEAO-D	YES*	CONTROLS & DISPLAYS (C&D), RESOURCES FOR CHECKOUT
6.	ILST FIRST VISIT	YES*	SERVICE EQUIPMENT C&D, RESOURCES
7.	DEPLOY/RETRIEVE BIO-RESEARCH MODULE TELEOPERATOR TEST	YES	STORAGE & PREPARATION OF FREE-FLYING UNITS, C&D, RESOURCES
8.	INFRARED TELESCOPE SORTIE	YES	MOUNTING, C&D, RESOURCES
9.	EDUCATIONAL TV SATELLITE	YES*	C&D, RESOURCES FOR CHECKOUT
10.	POLAR SORTIE – EARTH OBSERVATION & MATERIALS SCIENCE	YES	LABORATORY, SENSOR MOUNTING, C&D, RESOURCES

* CONCEPT DEPENDENT

of the sortie RAM. Missions 8 and 10 are defined as sortie-RAM-type missions.

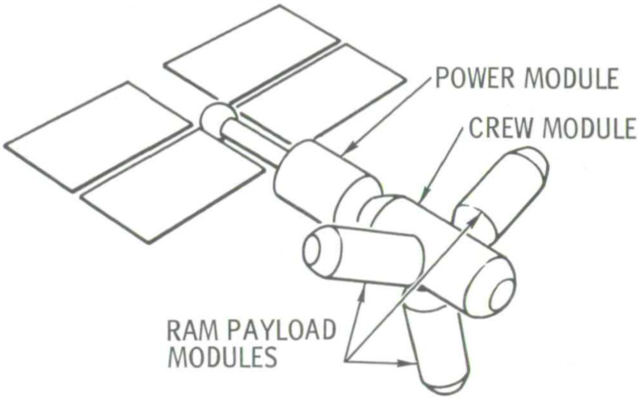
The following figure shows an early sortie RAM concept. This is the first and most economical element of the RAM system considered in the Phase B study.



Sortie RAM in Orbiter Cargo Bay

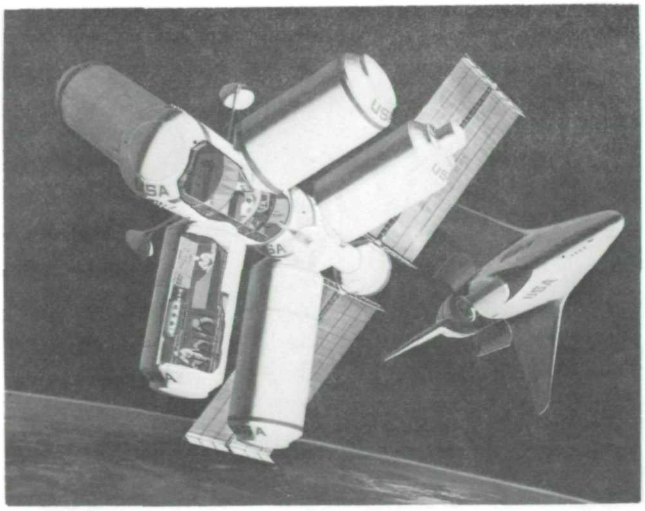
Following the initial sortie missions, sortie RAM operations would probably continue for precursor missions of a multiple-discipline nature. Subsequently, the RAM Project capability would be expanded by adding laboratories dedicated to specific disciplines. RAM Project evolution may include providing for additional payload specialists (beyond the basic two mission specialists provided for in the orbiter) to increase the returns from a given mission. This would be accomplished by outfitting a RAM element as a support module (RSM) to provide crew habitability requirements.

Evolution of the RAM Project is completed as shown in the next figure upon implementation of a space station capability. Although the shuttle sortie mission mode offers an opportunity for early benefits from many experiment areas and the global coverage important to earth-measuring activities, the extensive support and long duration required for many experiments lead to the cost effectiveness of an eventual space station (i.e., capability is required to perform many experiment repetitions to validate results and to provide for experiments requiring long setup and calibration and space for the large physical sizes of certain laboratory equipment).



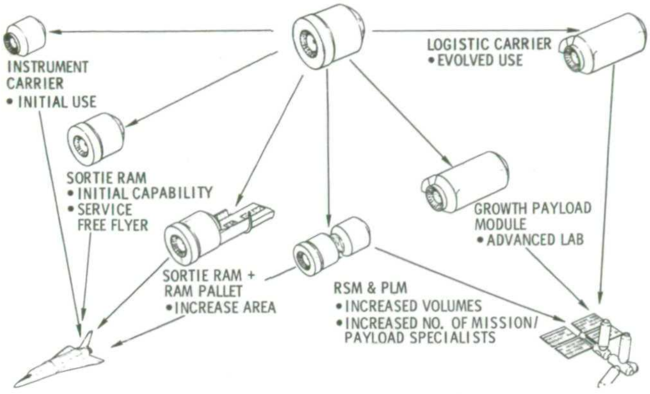
Initial Modular Space Station

A modular space station capability can be evolved by mating the RAM payload modules initially developed for sortie missions to a space station modular-power and crew-provisions core. Retrofitting the RAM payload modules from the sortie to the station mode would require only minor subsystem rework to match station interfaces. All structural and payload items are directly compatible. A typical modular space station that accommodates several RAM payload modules and a six-man payload crew as an initial capability is depicted in the following figure. This capability was defined during recent space station Phase B definition studies. The power module and crew module would benefit and could evolve from the prior design and operation of similar or identical RAM payload module subsystems.



Modular Space Station with RAM Laboratories

Sortie mission operations would, however, continue subsequent to the introduction of a space station to provide the global coverage and non-station orbits that are of considerable value in earth-measuring and solar-viewing experiments.



Pressurized RAM Versatility

The versatility of the basic sortie RAM used in early sortie missions and from which the more advanced missions evolve is shown below. Potential use of RAM payload carriers for the station logistics function is included.

In addition to the RAM payload carriers shown, free-flying RAMs carrying man-tended observatories could be introduced at any point in the evolution, using the applicable components, assemblies, or subsystems available from the pressurized RAMs.

Thus, the RAM payload carriers are envisioned as part of a system whose evolution begins with early limited capability and low-level funding and continues to an expanded capability as user needs, funds, and schedules dictate. Final evolution would be completed when a space station is equipped with the full-capability RAM laboratories. The family of RAM payload carriers and the potential for evolution commensurate with the user and programmatic needs provide a planning base for the entire spectrum of manned earth orbital activities.

STUDY LIMITATIONS

The RAM Phase B study has been performed within the bounds defined contractually by funding, statement of work, guidelines and constraints, and generally by lack of hard information in related areas. However, because of the fluidity of the data pertinent to and descriptive of interfacing projects (i.e., space shuttle, experiments, and TDRS), results of the Phase B study remain valid in their entirety only under the conditions documented. Major changes to interproject interfaces must be investigated on an individual basis.

Definition data of the space shuttle orbiter has been a major driver of study results. The orbiter cargo bay size of 15 feet in diameter by 60 feet long has remained constant. Utility services provided at the cargo bay bulkhead for payload use have varied but remain of a backup nature (except for communications links, which are handled totally through the orbiter system). The baseline orbiter manning of four persons includes two mission/payload specialists for RAM payload carrier operations and provides for occasional monitoring assistance from one of the two pilots. Provision of an RSM element is predicated on the need for multiple-shift experiment manning beyond two mission/payload specialists. Therefore, if the number of persons carried and supported by the orbiter is changed, the applicability of the RSM should be re-evaluated. If the RSM is not employed, there would be significant programmatic and operational benefits to be derived from the use of RAM payload modules with the sortie RAM to achieve flexibility.

A means for deploying a RAM payload carrier from the orbiter bay has been assumed to be available. This has been carried either as a pivot mechanism option or as the use of manipulator arms to berth the RAM payload carrier at an orbiter external berthing port. If deployment means are not provided, limitations on experiment and subsystems performance must be investigated.

The orbiter has not been accurately characterized as a source of contaminants that could affect experiment observation programs. Assumptions were made with respect to waste dumping intervals and general outgassing and effects of the attitude control propulsion subsystem. Experiment payloads proposed for sortie missions and their attendant requirements must be re-evaluated subsequent to the determination of orbiter contamination.

Specified shuttle performance to low earth orbit has not been a significant limitation on RAM payload carrier concept development when the air breathing engine system has not been a mission requirement. Additional orbital maneuvering subsystem propellant provisions in the rear of the cargo bay for the delivery of free-flying RAMs to drag-free altitudes has placed a weight and length limitation on the free-flying RAM. The operational approach of using the sortie RAM in conjunction with free-flying RAM delivery or retrieval is precluded for the four reference free-flying RAM payloads studied.

The space station definition data used during the RAM Phase B study has been a combination of the space station Phase B study results of North American Rockwell and McDonnell Douglas. Except for thermal control capability, interface resources are provided to the RAM payload modules. RAM payload modules attached to the station provide their own heat-rejection capability. The specified energy supply available to RAM payload modules from the space station limits the accommodation of a broad base of experimentation.

Experiment payloads used to drive the evolution of RAM concepts were derived from the NASA Blue Book. The experiment equipment definitions have been elementary in many cases pending the completion of parallel experiment definition studies. Where definition assumptions were made, they have been recorded. Only gross costs related to experiment payloads could be defined, and this inherent uncertainty in payload costs has been compounded in the assignment of costs to areas such as experiment integration.

The Reference Experiment Program provided by NASA inferred early operational capability for all RAM elements and negated the achievement of low early-year funding. However, other variations within this maximum envelope were explored. To achieve low early-year funding, prior development of space shuttle orbiter hardware was assumed to maximum advantage.

As these matters come under better definition, review and updating of study results are warranted. This would be especially appropriate on a continuous basis during the emerging definition of the orbiter to provide a mechanism for orbiter/shuttle payload interface studies and optimization of the interface definition. Similarly, definition of the payload requirements evolving from the various experiment definition studies should be employed to validate the design and operational requirements for the RAM payload carriers that may also impact the orbiter/shuttle payload interface requirements.

IMPLICATIONS FOR RESEARCH

Preliminary design of the various RAM payload carriers was based on existing technology and hardware that is available or expected to be available in a time-frame compatible with the RAM program implementation requirements. Thus, there is no question of technical feasibility of the proposed concept and the RAM payload carriers. The following table identifies supporting research and technology items where significant cost reduction could be realized by improving reliability, maintainability, and/or performance.

Cost Reduction Potential

SUPPORTING RESEARCH AND TECHNOLOGY ITEM	ANTICIPATED RESULTS
COMMUNICATION/DATA MANAGEMENT	
DEVELOP A TAPE RECORDER CAPABLE OF MULTIPLE-CHANNEL OPERATION AT DATA RATES UP TO 220 MEGABITS/SEC PER CHANNEL.	IMPROVEMENT IN WEIGHT, POWER, COMPLEXITY, AND RELIABILITY.
GUIDANCE, NAVIGATION, & CONTROL	
DEVELOPMENT OF FIXED-HEAD STAR TRACKERS AND ASSOCIATED PATTERN RECOGNITION TECHNIQUES (TO SIXTH-MAGNITUDE STARS).	INCREASED RELIABILITY AND MAINTAINABILITY.

SUGGESTED ADDITIONAL EFFORT

Additional study of two areas prior to the initiation of the RAM Phase C/D Project would provide increased efficiency in development and operational usage. They are discussed in this section and are 1) RAM payload carrier/orbiter interface verification and 2) ground operations analysis.

For RAM/orbiter interface verification, the objective of the additional study would be to plan the development flight phase of sortie RAM to verify the interfaces and concurrently verify the orbiter/sortie RAM interactions and capabilities. Methods should be investigated to accomplish these activities during the scheduled development flights of the orbiter. Tests are essential to verify sortie RAM/orbiter capability to support applications and research efforts and are prerequisite to the incorporation of flight experiments in the sortie RAM.

Verification of sortie RAM physical and configuration capability could be accomplished during the orbiter horizontal flight test program. This should include checks of attach points, electrical and plumbing interconnects, and general fit of sortie RAM in the cargo bay. During the development of the orbiter, there will be opportunities for on-orbit verification of interfaces, mission capabilities, mission/payload specialist/orbiter crew interactions, subsystem qualification, and contamination/viewing compatibility.

The RAM payload carrier requirements imposed by the orbital portion of the mission scenario shown earlier have been analyzed and iterated with the design. However, the ground operations depicted have not been analyzed in depth to consider the diversity of ground activities required by the many users of RAM payload carriers. Specific needs of a user during ground operations may affect the design of connections and interfaces or the assembly, installation, and integration activities. Additional requirements may also be recognized in areas of component operating life, wear protection, flexibility of equipment-mounting provisions, end bulkhead assembly sequence and effect on joint and seal design, shipping and storage container attachment, and environmental protection.

Additional study efforts in this area should be directed to the specific needs and potential ground operations of a representative spectrum of users (specific payloads). The RAM payload carrier design and operations requirements that evolve from this analysis will ensure more efficient and effective user operation.

FINAL RAM DOCUMENTATION

DOCUMENT	NASA DR NO.	CONVAIR REPORT NO.	ISSUE DATE
EXECUTIVE SUMMARY	MA-111	GDCA-DDA72-009	12 May 72
TECHNICAL SUMMARY	SE-269	GDCA-DDA72-007	12 May 72
TECHNICAL DATA DOCUMENT (VOL. I, TASK 4.1):	SE-268	GDCA-DDA71-003	
REQUIREMENTS ANALYSIS AND DEFINITION			28 Aug 71
APPENDIX A – DERIVED SYSTEM REQUIREMENTS (REVISION B)			12 May 72
APPENDIX B – EXPERIMENT REQUIREMENTS			28 Aug 71
APPENDIX C – TRADE STUDIES			28 Aug 71
TECHNICAL DATA DOCUMENT (VOL. II, TASK 4.2/4.3):	SE-268	GDCA-DDA71-004	
BOOK 1 – SYSTEM DESIGN			17 Dec 71
BOOK 2 – SYSTEM ANALYSIS			17 Dec 71
APPENDIX A – TRADE STUDIES (I - XVIII)			17 Dec 71
APPENDIX A – TRADE STUDIES (XIX - XXXV)			17 Dec 71
APPENDIX B – CONCEPT DRAWINGS/DATA/MULTIPLE-DISCIPLINE PAYLOADS			17 Dec 71
APPENDIX C – COST MODEL DOCUMENTATION*			17 Dec 71
TECHNICAL DATA DOCUMENT (VOL. III, TASK 4.4):	SE-268	GDCA-DDA72-006	
BOOK 1 – CONFIGURATIONS AND SUBSYSTEMS			12 May 72
BOOK 2 – SYSTEM ANALYSES			12 May 72
APPENDIX A – TRADE & SPECIAL STUDIES (I - XIX)			12 May 72
APPENDIX A – TRADE & SPECIAL STUDIES (XX - XXXIV)			12 May 72
APPENDIX A – TRADE & SPECIAL STUDIES (XXXV - XLIV)			12 May 72
APPENDIX B – INTERFACE REQUIREMENTS			12 May 72
APPENDIX C – SAAB-SCANIA STUDIES			12 Aug 72
APPENDIX D – ERNO STUDIES			12 Aug 72
APPENDIX E – MESSERSCHMITT-BÖLKOW-BLOHM STUDIES			12 Aug 72
APPENDIX F – APPLICATION OF ADVANCED COMPOSITE MATERIALS TO FREE-FLYING RAM			12 May 72
APPENDIX G – SHUTTLE/RAM DEPLOYMENT MECHANISM – CONCEPTUAL DESIGN			12 Aug 72
MASS PROPERTIES DOCUMENT	SE-271	GDCA-DDA71-006A	10 Apr 72
DRAWINGS	SE-266	GDCA-DDA72-011	7 Apr 72
PHASE C/D PROJECT DEVELOPMENT REQUIREMENTS	MA-110	GDCA-DDA72-010	12 May 72
PROJECT SPECIFICATION	CM-061	71X0030	12 May 72
PRESSURIZED RAM CEI SPECIFICATION, PART I:			12 May 72
SORTIE RAM, BASIC SPECIFICATION	CM-062	71X0031	
ADDENDUM FOR RAM SUPPORT MODULE	CM-062	71X0035	
ADDENDUM FOR PAYLOAD MODULE	CM-062	71X0036	
UNPRESSURIZED RAM (PALLET) CEI SPECIFICATION, PART I	CM-062	71X0032	12 May 72
FREE-FLYING RAM CEI SPECIFICATION, PART I	CM-062	71X0033	12 May 72
GROUND SUPPORT EQUIPMENT SPECIFICATION, PART I	CM-062	71X0034	12 May 72
COST ESTIMATES DOCUMENT	MF030U1	GDCA-DDA72-008	12 May 72

* General Dynamics Proprietary Information

GENERAL DYNAMICS

Convair Aerospace Division