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RETRIEVABLE PAYLOAD CARRIER
--NEXT GENERATION LONG DURATION EXPOSURE FACILITY: UPDATE '92--

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ABSTRACT

Access to space and cost have been two major inhibitors of low Earth orbit research. The Retrievable Payload Carrier (RPC) Program is a commercial space program which strives to overcome these two barriers to space experimentation. The RPC Program's fleet of spacecraft, ground communications station, payload processing facility, and experienced integration and operations team will provide a convenient "one-stop shop" for investigators seeking to use the unique vantage point and environment of low Earth orbit for research. The RPC is a regularly launched and retrieved, free-flying spacecraft providing resources adequate to meet modest payload/experiment requirements, and presenting ample surface area, volume, mass, and growth capacity for investigator usage. Enhanced capabilities of ground communications, solar-array-supplied electrical power, central computing, and on-board data storage pick up on the path where NASA's Long Duration Exposure Facility (LDEF) blazed the original technology trail. Mission lengths of 6-18 months, or longer, are envisioned. The year 1992 has been designated as the "International Space Year" and coincides with the 500th anniversary of Christopher Columbus's voyage to the New World. This is a fitting year in which to launch the full scale development of our unique ship of discovery whose intent is to facilitate retrieving technological rewards from another new world: space. Presented here is an update on progress made on the RPC Program's development since the November 1991 LDEF Materials Workshop.

INTRODUCTION

The RPC spacecraft which AmSpace has been developing for the past 4 years is designed for compatibility with a number of active and passive payload classes: materials exposure, space environment characterization, microgravity processing, life sciences, and remote sensing. Serving as a space-based technology test bed, the RPC also enables in situ technology demonstration and Space Station Freedom precursor experimentation. In situ technology demonstration provides for simultaneous exposure to multiple space environments in a manner which cannot be duplicated on the ground. Precursor experimentation permits a phased approach to the maturing of science data and hardware in preparation for more extensive and expensive station-based experimentation, thus reducing long term risk for the investigator.

Progress on the RPC Program has been made on several fronts since the November 1991 LDEF Materials Workshop held at NASA's Langley Research Center, including NASA, experimenters, and the concept itself. The intent here is primarily to provide a program update and not repetition of previously presented material [1]. Included in the following discussion is a brief review of the program components and current status.

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Carrier Element

The baseline RPC spacecraft is designed for shuttle launch and retrieval on a regular basis. The RPC is a gravity-gradient stabilized free-flyer. The RPC maintains the same 13.5 foot diameter cross-section as LDEF, a twelve-sided regular polygon, and uses the same low cost aluminum I-beam construction (Figure 1). However, in contrast with LDEF's 30 foot length, the baseline RPC is only 40 inches long which increases opportunities for manifesting in the shuttle cargo bay for launch and retrieval, helps lower the early launch costs, and reduces orbital life-limiting atmospheric drag effects at lower altitudes. On the first mission, the design provides for 600 W of 28 Vdc electrical power, 9.8 kbps downlink data rate, 10 gigabits data storage, and central computing capability, with even greater capabilities planned for future missions. The empty weight is 2,443 pounds with a maximum payload capacity of 5,600 pounds, for a total maximum weight of 8,043 pounds. Use of the full shuttle cargo bay cross-section increases the volumetric efficiency which reduces the launch cost.

The RPC flies edge-on into the velocity vector (ram direction). The # 6 position is always nadir pointing (toward the Earth's center) and the # 12 position is always deep space pointing. Stabilization booms 33 feet in length with 100 pound payload tip masses project out of the # 9 and # 12 peripheral positions on the RPC. Magnetic torquers provide for additional stability.

A number of experiments can be accommodated on the RPC in stacked or unstacked configurations. In Figure 1, several duplicate experiments are distributed around the RPC in locations which may be of interest for taking simultaneous data: ram direction, trailing edge, deep space pointing (zenith), and earth pointing (nadir). Gravity gradient booms, with powered and controlled pallets at the tips, provide reduced spacecraft-induced environments for those payloads.

Although two duplicate experiments are shown in the # 3 peripheral pallet, 1-4 duplicate or different experiments can be mounted in a pallet equal in size to an LDEF end tray (Figure 2). Multiple experiment capacity in a single pallet may permit larger active and passive sample sizes.

The approach calls for a fleet of at least two of these low cost spacecraft to be alternately launched. As the market grows over time, opportunities will exist for families of dedicated missions.

The overall functional block diagram is included to indicate various services and resources available to payloads, including relatively precise Global Positioning System (GPS) 3-dimensional location information (Figure 3). This may be of use for correlation with, for example, atomic oxygen erosion rates on samples as a function of altitudes which typically range from 150-225 nmi. New, low cost, solid state gyroscopes will provide 3-axis attitude information accurate to 0.1 degree. This position and attitude data can be continuously stored and dumped to the ground on a daily basis along with active sample data.

Carrier Sizing Rationale

With the objective of reducing overall costs, a deliberate attempt to minimize the RPC length has been made because commercially launched shuttle payloads, such as the RPC, must pay NASA on the basis of a launch pricing formula as a function of length or weight. The formula is:

Launch cost = standard transportation costs + optional service costs, where:

Standard transportation costs = (greater of length cost factor or weight cost factor) X (full cargo bay price / cargo bay utilization factor)

RPC length cost factor = RPC length/cargo bay length = 40 in / (60 ft x 12 in/ft) = 0.056

RPC weight cost factor = RPC weight / maximum shuttle payload to orbit performance = 8,043 lbm (assuming a fully loaded RPC) / 65,000 lbm (originally advertised shuttle capability) = 0.124

Cargo bay utilization factor = 0.75 (NASA imposes this additional cost factor to account for average inefficiencies in using the full shuttle payload weight-to-orbit capability; that is, on most missions, the full length of the cargo bay is filled with payloads that cumulatively use only about 75 percent of the full weight-to-orbit capability)

Optional service charges cover those services which are "non-standard" in nature, such as deployment, retrieval, associated training, non-standard altitude, and many others, and are priced according to published NASA rates.

For transportation costs, RPC customer cumulative payload weights in excess of 1,168 pounds drive the cost to the weight cost factor. Early in the RPC life cycle, when still building the market and capital is limited, length is the driver, thus it is important to keep the length as short as possible while still meeting experimenter requirements. However, as the market increases, there is the opportunity to increase the RPC length to meet evolving experimenter requirements, and yet, not suffer an undue launch cost penalty. Because of the simple, bolted construction, the RPC's length can be increased relatively easily.

By using the full cross-section of the shuttle cargo bay and a dense-packaging philosophy, the RPC's volumetric efficiency far exceeds most other carriers. That is, more payload mass is carried in less volume, resulting in approximately a 70 percent payload-to-total-spacecraft mass fraction. This is an important consideration when using a limited national resource such as the shuttle.

In originating the RPC, holding down the development and operational expense is paramount to keeping customer charges affordable. Private sector commercial development and operations costs of a program of this nature have been shown to be 25-50 percent of a government developed program cost estimate and is another important decision factor in today's austere economic climate. Aside from lower costs to the taxpayer, the RPC Program provides for technology transfer to private industry and for creation of a new industry infrastructure element, the cornerstone of the U.S. Government's 1991 Commercial Space Policy Guidelines.

Ground Station/Mission Operations Center Element

The ground station, Mission Operations Center (MOC), is an off-the-shelf, low cost Master Ground Station (MGS) for the command and control of multiple low Earth orbiting satellites, experiments, and remote ground terminals. It provides mission planning, satellite command and control, digital store-forward communications, and spacecraft and experiment telemetry readout. The MGS operates at UHF (with VHF and S-band as options). The MGS consists of an operator console, a transceiver unit and antenna group, and can be operated remotely.

Ground-based data acquisition by an experimenter would occur by modem access to the AmSpace secure, off-line hard drive on which downlinked data is stored after each pass over the ground station to be located in Florida, or possibly by direct downlink. Control of payloads is accommodated by the experimenter providing time-tagged command stacks to the ground station via modem which are verified for non-interference with spacecraft operations and then uplinked and executed or stored for later on-board execution.

Payload Processing Facility Element

The AmSpace Payload Processing Facility and the Mission Operations Center will be located near Kennedy Space Center, Florida, either at an industrial park near Titusville, Florida or the Cape Canaveral area. AmSpace intends to provide a first-rate building with the needed space for experiment checkout, RPC integration, operations, administration and expansion to meet projected demands for the next 15 to 20 years. AmSpace is currently investigating whether construction of a new facility, buying an existing building, or leasing a facility is the most cost effective approach.

Although other locations were considered, such as Los Angeles, Houston, and Huntsville, Alabama, selection of the Florida Space Coast included the following considerations:

- Proximity to the launch site
- Transportation cost and route access to the launch site
- Land, construction, and facility leasing cost
- Room and cost for expansion
- Material costs and availability
- Proximity to related businesses
- Labor pool availability, skills, and costs
- Local ordinances, licensing, and permit requirements
- Community and state positive attitudes towards space industry

The Payload Processing Facility includes offices, conference rooms, and the Mission Operations Center located at the front of the facility. Sufficient offices are provided to accommodate the AmSpace staff and provide limited office or experiment build-up space for RPC experimenters. The Mission Operations Center is located in the center of the building's office space to provide a degree of security. The two high bays, located in the rear of the facility, have 20-25 foot ceilings to permit lifting and loading or removing an RPC to or from a transportation container. Typical high bays have higher ceilings (30 feet or more), but AmSpace intends to perform limited lifting using floor-based lifters. The lower high bay ceilings will reduce the expense of maintaining environmental control of the high bay volume. Also, using floor-based lifters will preclude the expense of installing and maintaining overhead cranes. A clean room is provided primarily for customer use during experiment build-up and post-flight examination.

Initially, only one high bay will be outfitted. As the second RPC comes on-line, the second high bay will be activated. Access to the high bays are through walk-in airlocks, or the main airlock which is used for moving major equipment items. Sufficient high bay floor area is provided for moving the RPCs around. Simultaneous work on floor-accessible and upper portions of the RPC is facilitated by a work platform. A rotator hub rotates to provide access to other RPC locations. Various tools, electronic test equipment, racks, jacks, hoists, power outlet panels, gas distribution and air pallets are located within the high bays. A machine shop located outside the high bay will meet simple manufacturing needs.

Electric power to the MOC, selected offices, high bays and the clean room will be 120/240 volts AC power protected by an Uninterruptable Power Supply (UPS). Using a UPS will provide protection to delicate experiments and test equipment in the event of unannounced power outages or fluctuations. Electric power to most offices, and the machine shop, will not be UPS protected. The electrical system in the high bays, offices, and clean room will not be hazard proofed.

Inert gases, such as nitrogen, clean air, and helium, will be distributed to selected offices, high bays and the clean room using K-bottles. The equipment and system to vent inert gases to the outside atmosphere will also be provided. The use of other inert gases, such as argon, will require special arrangements and as with the above gases, will be vented outside the facility. Volatile gases, such as oxygen and hydrogen, will not be available at the processing facility.

All required safety and fire protection equipment will be provided in the facility. This includes eye washes, electrical safety equipment (shorting sticks, rubber electrician gloves, etc.) and emergency lighting. In addition, containers for the disposal of hazardous waste will be provided. Sufficient fire extinguishers will be available in the offices and work areas and a sprinkler system will be installed in the administrative work areas. A Halon Discharge System will be installed in the MOC, high bays and clean room.

CUSTOMER ACCOMMODATIONS

Experiment Build-up and RPC Integration

The Payload Processing Facility will provide sufficient space to allow experimenters to build-up and test their experiments before being integrated with the RPC. Customers will be assigned an area or office space to build-up their experiments, perform pre-installation checks and test their experiments. The facility will provide basic test equipment, tools, stabilized power, handling devices, and some administrative support, e.g. tables, chairs, telephones, desk, etc. Special test equipment, tools, computers or diagnostic equipment must be provided by the customer. The area assigned for experiment build-up and check-out can be secured. If special environmental controls are required, customers will be scheduled to use the facility clean room. Support requirements such as housing, transportation, and meals are the responsibility of the customer.

RPC Integration and Post-flight De-integration Scheduling

Detailed scheduling for all RPC integration and de-integration activities is planned. A 72 hour, 11 day schedule, similar to the Kennedy Space Center Integrated Control Schedule, will be published each work day. Integration/de-integration activities, facility maintenance, scheduled power outages, and any other planned activity which affects productive integration/de-integration time will be included in the 72 hour, 11 day schedule. RPC customers and the AmSpace staff will coordinate the preparation of all schedules. Also, long range schedules, up to five years, will be developed for long term planning purposes. AmSpace intends to develop facility use schedules which provide customers sufficient integration time and ensure cost-effective use of the processing facility.

AMSPACE SRM&QA PROGRAM

AmSpace plans to develop and implement a dynamic and comprehensive Safety, Reliability, Maintainability and Quality Assurance Program (SRM&QA). The AmSpace SRM&QA program will complement and in some cases exceed NASA SRM&QA requirements. All Occupational

Safety and Health Act (OSHA) Standards are to be rigorously applied at the AmSpace Payload Processing Facility. State of Florida safety regulations, occupational health criteria and environmental requirements will be strictly enforced by a staff of experienced SRM&QA professionals. However, the distinguishing characteristic of the AmSpace SRM&QA program is its customer orientation.

The AmSpace SRM&QA philosophy is to assist and advise customers and to provide a safe working environment for the integration and post-flight de-integration of their experiments. AmSpace's assistance should aid in lowering ground processing and launch costs, and facilitate experiment integration. With regard to a safe working environment, a first-rate facility with all required safety equipment will be provided. Furthermore, AmSpace intends to train and, if necessary, certify customer engineers and technicians on the operation of any system, equipment or devices they use in the build-up and integration of their experiment.

AmSpace is fully committed to the safe and successful integration, launch, mission operations, and de-integration of the RPC. SRM&QA criteria and standards cannot be compromised.

Customer Safety Implications

Before any payload is processed at the launch site and flies on the shuttle, stringent SRM&QA criteria must be met. The RPC must have formal NASA certification for launch site processing and flight. The RPC and customer payloads' construction, wiring, materials, and interfaces with the launch vehicle and other payloads must comply with exacting engineering standards. AmSpace, serving as a Payload Organization (PO), is responsible to ensure that the RPC and its payload complement complies with all applicable design, manufacturing and operations specifications. AmSpace must demonstrate to NASA, through engineering analyses and reviews, that the RPC and payloads comply with applicable engineering criteria and no hazards will be introduced, either during ground processing or flight, which endangers life, other payloads, or the shuttle.

The process of obtaining NASA certification, which allows a payload to be processed at the launch site and to eventually fly on the shuttle, is usually a lengthy process. Depending on the complexity of the payload, the certification process can take up to three to five years for the most complex experiments. Typical experiments may take six to eighteen months. A myriad of documents and engineering analyses must be submitted by AmSpace for NASA review and evaluation. In addition, AmSpace must make formal presentations to a NASA Ground Processing Safety Review Panel and a Flight Safety Review Panel at various stages of the experiments' or RPC's development to ensure compliance with NASA SRM&QA requirements.

The PO obtains NASA certification to proceed with launch site ground processing and fly a payload by participating in NASA's Payload Phased Safety Reviews. Phased reviews take place for both ground processing and flight and generally are conducted independently of each other. For both ground and flight, there are four Phased Safety Reviews, Phase 0 through Phase III. These reviews correlate with the milestones that occur during a typical program life-cycle: concept review (Phase 0); 30% design review (Phase I); 60% design review (Phase II); and 90% design review (Phase III). Normally, the Ground Phased Safety Reviews and the Flight Phased Safety Reviews occur at the same time in the life-cycle development of the payload.

The phased reviews are scheduled by the PO, with NASA concurrence. A Phased Safety Data Package for each Flight and Ground Phased Safety Review is submitted to the applicable NASA Center Safety Office no later than 45 days before the agreed upon meeting date. Ordinarily, Flight Phased Safety Reviews are held at Johnson Space Center, Texas, while Ground Phased Safety Reviews are held at Kennedy Space Center, Florida. The safety data packages, for both flight and ground processing, contain an explanation of the payload's mission, description of the payload and vital background data. Most importantly, the safety data packages contain Hazard Reports (HRs). For every hazard that the PO expects will occur or is introduced by the payload, during either ground processing or flight, an individual HR is prepared. Since the phased safety review process is an iterative process, the Phase 0 HR usually identifies the hazard and minimal information is provided regarding control or abatement of the hazard. During the subsequent submission of the HR, in the Phase I through III data packages, detailed explanation is provided on how the hazard is either eliminated or is controlled by design improvements, procedures or warning devices. The PO must submit supporting engineering data and drawings with each HR to support engineering assessment. Upon submission of the phased safety data packages, selected NASA engineers, at the launch site for ground processing packages and JSC for flight packages, perform an exacting engineering review of each HR. This NASA review is to ensure the PO has sufficiently and accurately identified, considered, and assessed all possible hazards.

The Phased Safety Reviews, for each phase level, are scheduled presentations during which the PO provides a briefing on the payload and discusses in detail each HR. Any questions and issues are resolved during the presentation. If there are any concerns that require additional research, action items with suspense dates are assigned. If there are no problems, individual HRs are signed by both the PO and the Chairman of the Phased Safety Review Panel to indicate the HR has been approved for the applicable phase review.

To facilitate this phased safety review process, lower processing costs, and lessen the burden on prospective experimenters of the preparation of SRM&QA documentation, AmSpace intends to serve as a focal-point and prepare all required phased safety data packages. AmSpace plans to begin an early dialogue with potential experimenters so they will be aware, in the conceptual phase of their experiment, of the NASA SRM&QA requirements for ground processing and flight. This early dialogue not only serves to make AmSpace's job of preparing the phased safety data packages easier, but it will hopefully aid experimenters in the design, development, and manufacturing of their experiments.

With the experimenter's decision to fly on the RPC, AmSpace intends to provide a tutorial and detailed written instructions on the steps and procedures necessary to obtain NASA safety certification to process and launch the experiment on the RPC. Depending on the complexity of the experiment, this initial briefing can be accomplished either at the experimenter's offices, or at the AmSpace Payload Processing Facility. For less complicated experiments, the initial SRM&QA briefing can be conducted by teleconference. The purpose of this introductory tutorial is to acquaint prospective experimenters with the documentation required by NASA. Furthermore, it acquaints experimenters with the list of regulations, directives, codes, standards, and specifications which must be met in the design, development, construction, transportation, ground processing and eventual flight of an experiment. Also, AmSpace's early contact with potential customers fosters cooperation and contributes to a team approach in the integration of the RPC.

AmSpace will necessarily rely on the basic engineering data and information provided by prospective experimenters in order to prepare engineering assessments and the ground and flight safety data packages. The AmSpace SRM&QA staff expects to have continuing discussions with experimenters. Questions regarding design and construction of an experiment will be encouraged. AmSpace's policy will be to expedite answers to questions from our customers. Furthermore, the AmSpace SRM&QA and engineering staff intends to make informed suggestions to prospective customers regarding the experiment design and construction, which should facilitate NASA approval to process and fly on the RPC.

Another related service, which the AmSpace SRM&QA Office intends to provide, is to act as an intermediary between customers and appropriate NASA offices. Since the members of the AmSpace SRM&QA staff will possess previous experience working with numerous NASA offices and managers at both KSC and JSC, AmSpace will represent RPC experimenters at technical interchange meetings, scheduling meetings, safety reviews, and support requirements meetings, reducing the experimenters travel expenses. The AmSpace Payload Processing Facility will be near KSC so interfacing with NASA managers at the launch site is expected to be on a day-to-day and face-to-face basis.

In summary, AmSpace intends to establish a customer-oriented SRM&QA program. The company will serve as a focal point in the preparation of Phased Safety Data Packages, as well as other required SRM&QA documents. The intention is to provide an SRM&QA expertise to customers and assist experimenters in the preparation of safety, quality assurance, reliability and maintainability data. In addition, AmSpace intends to provide customers with a safe processing facility for the build-up, testing, integration, and de-integration of their experiments.

TEAM ELEMENT

Of the four RPC Program elements, the team is the most important because it is the one which implements the remaining elements. The following discussion outlines the innovative approach to be taken in ensuring that the best possible services are provided to customers. The AmSpace strategic human resources (HR) plan integrates business-level strategy and career management. AmSpace has adopted a "team member" approach as opposed to the traditional "employee" approach to staffing. Technical quality management techniques are employed. A mentor-protege relationship has been formalized to reduce the learning curve and preclude haphazard time-consuming trial and error methods of accomplishing tasks. Training and development are provided on-site and off-site (possibly at KSC). The "defender" and "prospector" approaches are combined, where a defender is focused on efficiency/doing things right/problem solving, and a prospector is concerned with effectiveness/doing the right things/problem finding.

Finally, a direct link between company success and paycheck size will be emphasized. The HR plan has "hooks" and "scars" into customer requirements and results in the greatest possible satisfaction of customer needs.

CURRENT STATUS

Contact with NASA on this program was initiated in 1988. A draft Joint Endeavor Agreement (JEA) was completed by NASA and AmSpace in February 1992 in anticipation of approval of the RPC Program business plan. In March 1992, an extensive RPC Program business plan was submitted by AmSpace to NASA and is still under review. The business plan must be approved before the JEA can be circulated through NASA for approval. JEA terms and conditions are currently proprietary pending finalization and NASA approval, but are generally similar to earlier JEAs. Customer flights under this JEA are particularly favorable in an economic sense. The JEA is a tool NASA has at its disposal to assist industry in demonstrating a new space capability with commercial promise. As of the completion of this paper in November 1992, major reorganizations of NASA offices interacting with AmSpace are continuing, inauguration of a new president is imminent, and the RPC Program is still awaiting approval. Government, industry, university, and international customers continue to express strong interest in flying payloads on the RPC via numerous letters of interest. Materials exposure, environment characterization, life sciences, and technology demonstration experiments dominate current customer interest. Investors await NASA decisions and customer commitments. The RPC spacecraft is anticipated to be available for launch as early as 24 months after capitalization.

REFERENCE

1. "Retrievable Payload Carrier (RPC)-Next Generation Long Duration Exposure Facility," Arthur T. Perry, NASA CP-3134, First LDEF Post-flight Symposium, Orlando, FL, June 4, 1991.

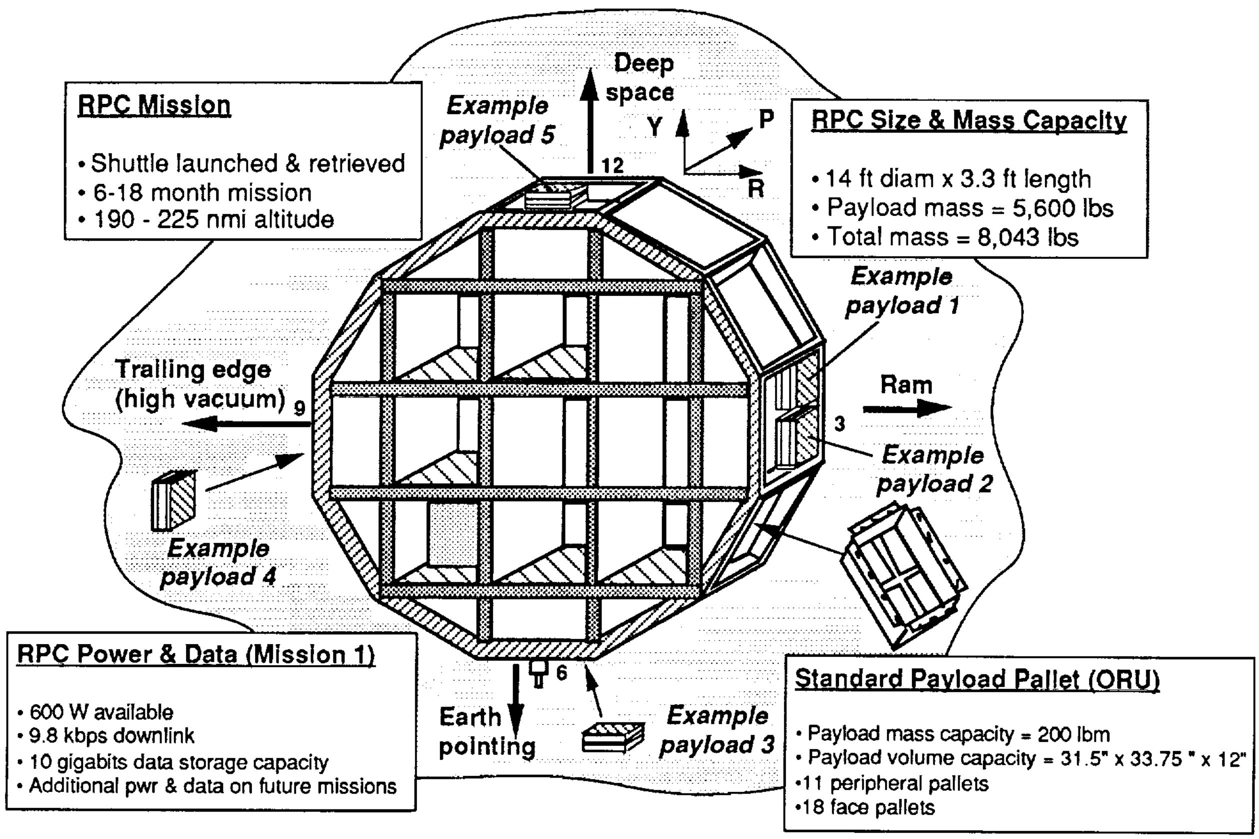

Figure 1. RPC Configuration and Duplicate Experiment Location Options

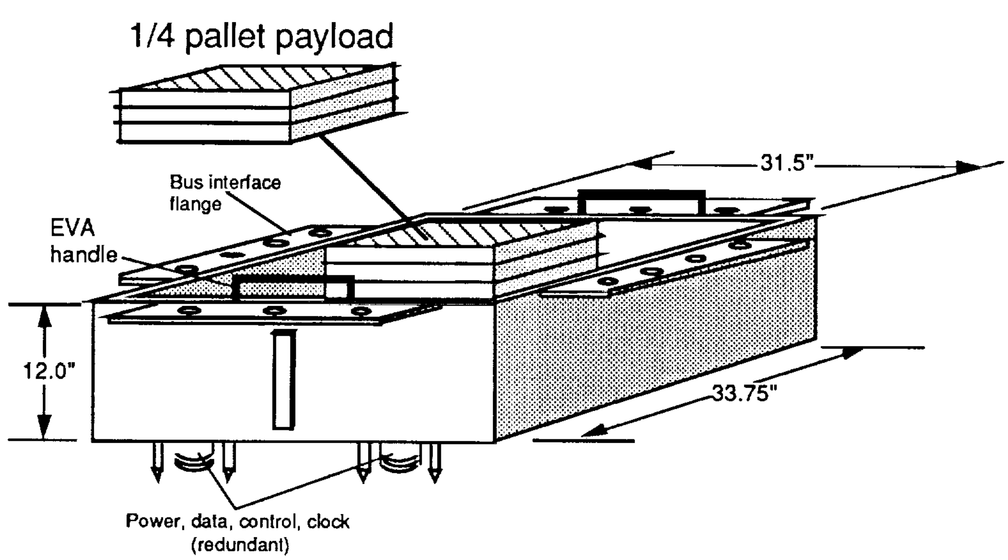

Figure 2. RPC Standard Payload Pallet (Orbital Replacement Unit-ORU)

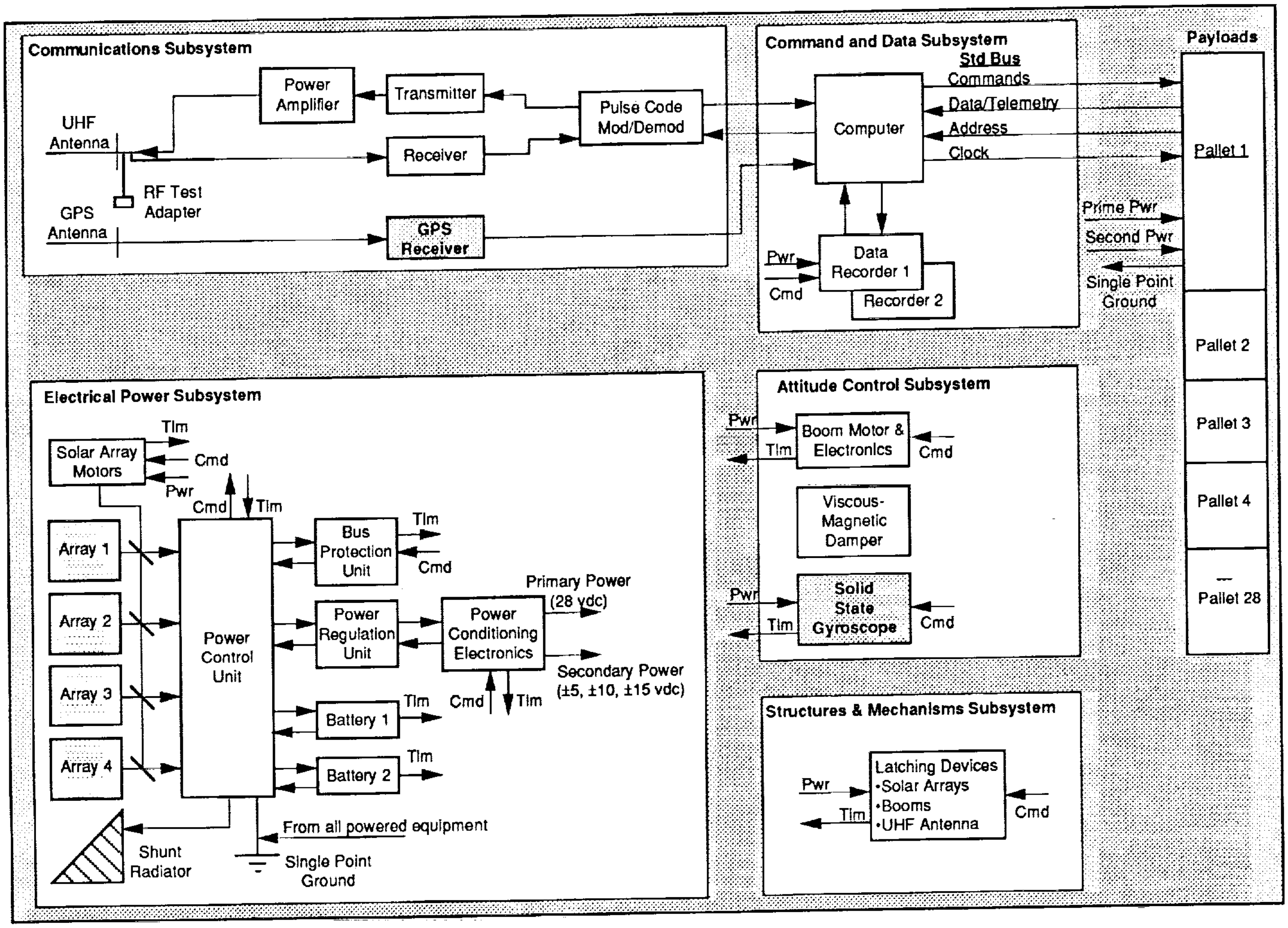

Figure 3. RPC Functional Block Diagram