

Chapter 3: AIR Instrument Array

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AIR Instrument Array

Preface

The large number of radiation types composing the atmospheric radiation requires a complicated combination of instrument types to fully characterize the environment. A completely satisfactory combination has not as yet been flown and would require a large capital outlay to develop. In that the funds of the current project were limited to essential integration costs, an international collaboration was formed with partners from six countries and fourteen different institutions with their own financial support for their participation. Instruments were chosen to cover sensitivity to all radiation types with enough differential sensitivity to separate individual components. Some instruments were chosen as important to specify the physical field component and other instruments were chosen on the basis that they could be useful in dosimetric evaluation. In the present paper we will discuss the final experimental flight package for the ER-2 flight campaign.

Instruments Provided

The environment consists of various energies of photons, electrons, muons, light ions, high-energy heavy ions, target nuclear fragments, and neutrons. The main emphasis of this study was on the nature of the neutron spectrum especially above 10 MeV. Several instruments were considered but only the DOE Environmental Measurements Laboratories multisphere (Bonner sphere) neutron spectrometer with its ³-He proportional counters had sufficient dynamic range, had sufficient sensitivity to minimize spectral statistical uncertainty, and could operate in the ER-2 environment. In addition, a high pressure ion chamber, scintillation counters with varying sensitivity to ions, muons and electrons, gamma rays, and total high-energy neutron flux, bubble detectors, charged particle telescopes, plastic nuclear track detectors, thermoluminescence detectors (TLD), and tissue equivalent proportional counters made up the experimental instrumentation. No single instrument gave an exclusive measurement of any individual component and requires some correction from the components emphasized by the other instruments. Some of the instruments were chosen for their good resolution of the physical fields while others were chosen as candidate dosimetric methods.

The instruments of the AIR flight are listed in table 1. The DLR/Kiel particle telescope is limited in charged particle information and cannot clearly separate the electrons and muons from other charged ions. The DLR/Kiel plastic track detector is used to identify and count multiple charged ions. The University of San Francisco particle track detectors will record LET spectra of nuclear star events. The NRPB nuclear etch track dosimeters will record nuclear recoil events. The Yale/University of Pisa Bubble counter will record the rate of high LET events. The DREO TLD's will record the total ionization during the flight. The JSC particle telescope will allow identification of charge particle type. The RMC Bubble detector will record the total high LET events on each flight. The DREO and the Boeing tissue equivalent proportional counters (TEPCs) will record the lineal energy spectra allowing an evaluation of dose and estimation of dose equivalent rate during the flight. The PVAMU

Single Event Upset experiment will record the events seen in a digital memory device. The Boeing PDM-303 is a solid-state neutron dosimeter device carried by the pilot. The DOE multisphere neutron spectrometer is the primary instrument on the ER-2 flights. The ion chamber and scintillation counters will allow information of specific charged components to be collected to make corrections to the neutron spectrum. The instrumentation and their particle detection characteristics are given in Table 2. A plus sign in the table indicates the primary sensitivity of the specific instrument that was targeted by the measurement and the minus sign indicates a lessor-confounding factor of the primary measurement.

Description of the Flight Package

The ER-2 has four pressurized and heated payload areas available: 1) The nose, where instruments are mounted to a removable rack that slides into the aircraft nose section. The nose area can support a payload weight of 650 lbs (294 kg) maximum, with a volume of 47.8 cubic feet (1.35 cubic meters) maximum. 2) The equipment bay, or Q-bay as it is called, where instruments are also mounted to racks that are attached to the aircraft structure. The maximum weight capacity of the Q-bay is 1300 lbs (590 kg) minus the nose payload weight. The volume available in the Q-bay is 64.6 cubic feet (1.83 cubic meters). 3) The left superpod has a removable nose section and a midbody section under the wing. The payload weight capacity of a superpod is 650 lbs (294 kg), and the volume available is 86 cubic feet (2.43 cubic meters). 4) The right superpod is identical to the left superpod. Each payload area is pressurized to an altitude equivalent to about 30,000 ft (9.1 km) when the aircraft is at 65,000 ft (19.8 km). The actual payload area internal pressure is 3.88 psi greater than the external pressure when the aircraft is above 18,300 ft (5.6 km). The temperature in each payload area during flight depends on the instrument heat generated in that area, and may be supplemented by aircraft heater/fan units. The instruments had to be packaged within these confines and the associated environmental factors resolved.

Placement of the *AIR* instrument components in the ER-2 was determined primarily by the requirement to separate the EML detectors as much as possible, to place the largest Bonner sphere detectors in a payload area away from the smallest Bonner sphere detectors, and to not place detectors under the ER-2 wing where fuel is carried. Lockheed (ER-2) Engineering also required that any detector containing flammable materials be placed inside a sealed container. This requirement applied to all of the EML detectors. In addition, the RMC Bubble Detector instrument, the University of Pisa Bubble Counter instrument, and the JSC Particle Telescope were placed inside sealed containers because they were designed to operate at sealevel pressure. The use of sealed containers greatly increased the complexity of the instrument array design. In addition, the EML detector signals had to be carried by the existing aircraft wiring from the other payload areas to the right superpod midbody section, where the control and data storage electronic modules were located. The final component locations in the ER-2 for all of the *AIR* detectors are shown in Figure 1. The *AIR* array filled nearly all of the available payload areas. Only the left superpod midbody section under the wing was left empty. The total weight of the *AIR* package was about 1800 lbs (818 kg), well under the maximum ER-2 capacity of 2600 lbs (1180 kg).

Physically, the *AIR* flight hardware consists of five aircraft racks and three electronics modules. The racks are mounted in the ER-2 nose, the Q-bay, and the left and right superpod nose sections. The electronics modules are mounted in the left and right superpod midbody sections. The *AIR* nose rack is shown in Photograph 1, on a ground support stand. The *AIR* components are mounted to a standard aircraft nose rack. Six cylinders attached directly to the rack contain EML Bonner spheres #1, #2, #4, #6, #7, and #8. The Bonner spheres are arranged consecutively from the smallest to the largest, starting at the forward end (left in the photograph). These cylinders are sealed on the ground and maintain one atmosphere pressure inside during flight. At the aft end of the rack, the two large boxes mounted above the cylinders are a Power Supply and Distribution Unit and a Bonner sphere amplifier box. Aircraft ballast weights are attached to the forward end of the rack, ahead of the first Bonner sphere cylinder. The long box on the forward end of the rack, mounted above the cylinders, contains the NRPB dosimeters. It is sealed on the ground and maintains one atmosphere pressure inside during flight. Immediately aft of the NRPB dosimeter box are the cylindrical pressure vessel for the Yale/University of Pisa Bubble Counter, and the flat plate pressure vessel for the DLR/Kiel plastic nuclear track detectors (barely visible behind the Bubble Counter cylinder in the photograph). The smaller rectangular box aft of the Yale/University of Pisa Bubble Counter cylinder contains the DLR/Kiel DOSTEL telescope. Photograph 2 shows the nose rack installed into the ER-2 nose cone. The view is of the aft end of the nose cone looking forward. The Q-bay rack is shown in Photograph 3, on a ground support stand. The *AIR* components are mounted to a modified aircraft Q-bay rack. At the forward end of the rack (left in the photograph) are the cylindrical JSC Particle telescope pressure vessel and a Bonner sphere amplifier box. Just aft of the JSC Particle Telescope is the EML Ion Chamber sealed cylinder. The tall cylinder in the middle of the rack is the sealed container for an EML scintillation counter. The cylinder visible at the aft end of the rack is another sealed container for EML scintillation counters. The EML Bonner Sphere sealed cylinders for detectors #9 and #10 are located on the far side of the rack in this view, as is the RMC Bubble Detector sealed cylinder. The Power Supply and Distribution Unit for the rack is located under the JSC Particle Telescope. Photograph 4 shows a view of the Q-bay rack installed in the ER-2. The row of cylinders visible in the foreground are the sealed containers for EML Bonner Sphere #9 (far right), the RMC Bubble Detectors (center), and EML Bonner Sphere #10 (far left). The rack holding TEPC units from DREO and from Boeing is visible on the far left, attached to the aft bulkhead of the ER-2 Q-bay. Photograph 5 shows a view of the Q-bay rack from under the ER-2 Q-bay (forward is to the right). The cylinders visible are for the EML Bonner Spheres, the EML Ion Chamber, and the EML scintillation counters. The two superpod nose racks are identical, and one is shown in Photograph 6, on a ground support stand. These racks each contain two sealed cylinders for the larger EML Bonner Spheres (#11, #12, #13, and #14). Photograph 7 shows the left superpod nose rack installation. The Power Supply and Distribution Unit and the amplifier box for each pod nose rack are mounted in the front of the superpod midbody section, just behind the nose racks. The EML computer components and the EML NIM bin assemblies are mounted in the midbody section of the right superpod. Photograph 8 shows a front view of the right midbody section, containing the nose rack Power Supply and Distribution Unit, the Bonner Sphere amplifier box, and components of the EML computer assembly. The EML NIM bin assemblies are shown in Photograph 9 being installed into the center section of the right superpod midbody. The forward end of the midbody section is to the left in this view.

Table 1. Atmospheric Ionizing Radiation (AIR) Measurements

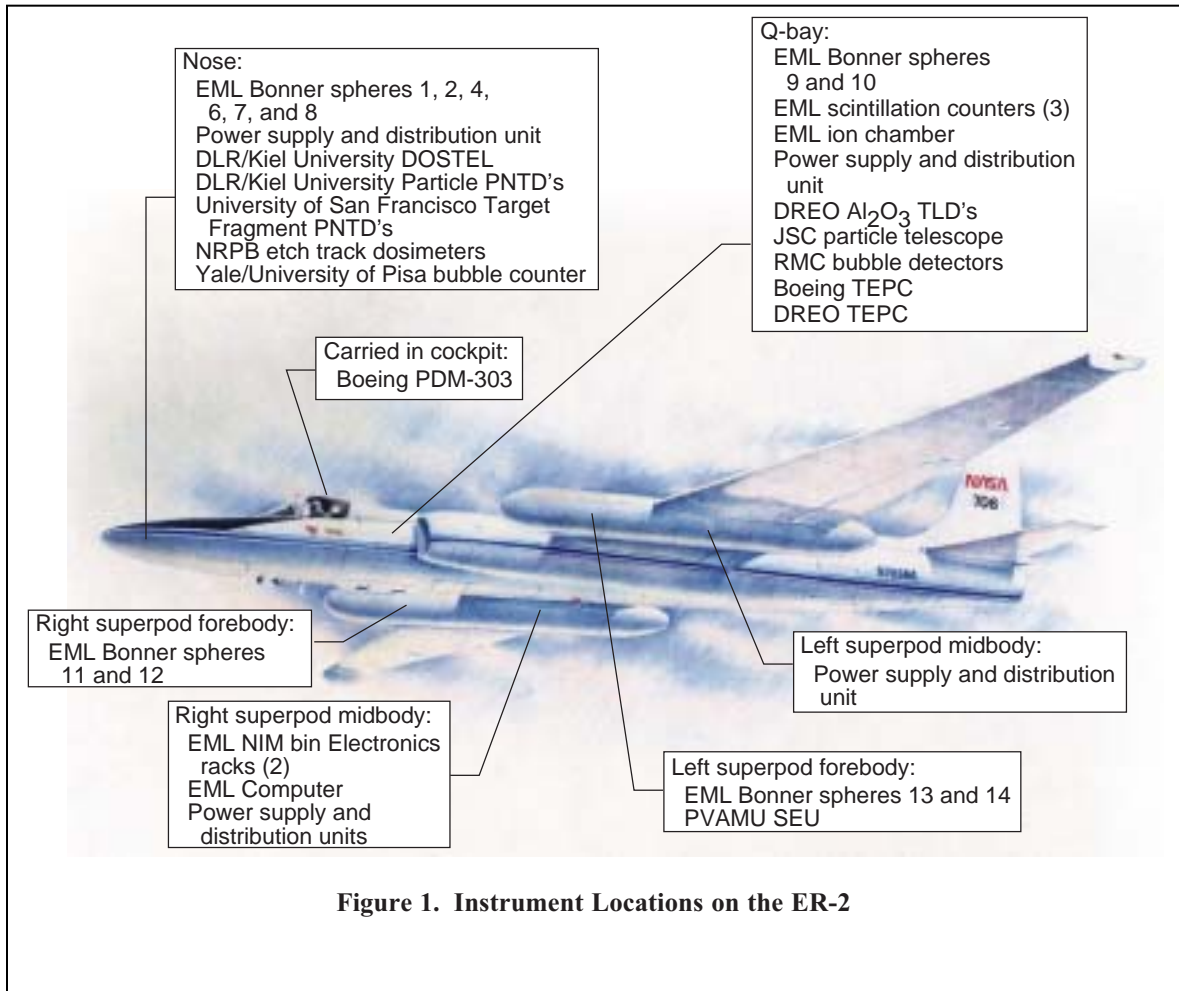
<u>Experiment</u>	<u>PI</u>	<u>Comments</u>
1. DLR/Kiel University DOSTEL [on nose rack]	Dr. Guenter Reitz Dr. Rudolf Beaujean	Size: 140mm x 240mm x 10mm thick mounting plate. Unit is 150mm above mounting plate top. Wt.: not specified (<5 lbs) Power: ±12VDC, 30 ma each leg; +5VDC, 15 ma Connectors: LaRC supplies two 6-pin connectors to terminate power & data cables.
2. DLR/Kiel University Particle PNTD's [on nose rack]	Dr. Guenter Reitz Dr. Rudolf Beaujean	Size: 416mm x 260mm x 19mm high Wt.: <1 kg Power: none required
3. University of San Francisco Target Fragment PNTD's [on nose rack]	Dr. Eugene Benton	Size: 2.5" x 2.5" x 2.5" Wt.: 0.4 lbs Power: none required Requires pressurized container.
4. NRPB Etch Track Dosimeters [on nose rack]	Dr. David Bartlett	Size: CR39's are 4cm x 4cm x 0.5cm each. TLD's are 5cm x 6cm x 1cm each. Wt.: very light, each unit Power: none required Want to fly as many of each type as possible - prefer 50 each.
5. Yale/University of Pisa Bubble Counter [on nose rack]	Dr. Francesco d'Errico	Size: 17 cm diam. x 16 cm tall cylinder Wt.: 3 kg Power: 10 watts peak, 28VDC (ER-2 power) Connectors: LaRC supplies U. of Pisa with an 8-10 pin connector to terminate power cable.
6. DREO Al ₂ O ₃ TLD's [on Q-bay lower rack]	Dr. Thomas Cousins	Size: few millimeters on a side for each TLD Wt.: <1 lb Power: none required Want to fly 6 TLD's. Mount near EML ion chamber.
7. JSC Particle Telescope [on Q-bay lower rack]	Dr. Gautam Badhwar	Size: 9.25" dia. x 21" high Wt.: 45 lbs Power: 28VDC, 45 watts (ER-2 power) Connector: PT07H-20-16P in base.
8. RMC Bubble Detectors [on Q-bay lower rack]	Dr. L.G.I. Bennett	Size: 8.5" dia. x 16.5" tall cylinder Wt.: 15 lbs Power: 20 watts, 115VAC, 400Hz (ER-2 power) Connector: MS3449H10C6P connector in base plate.

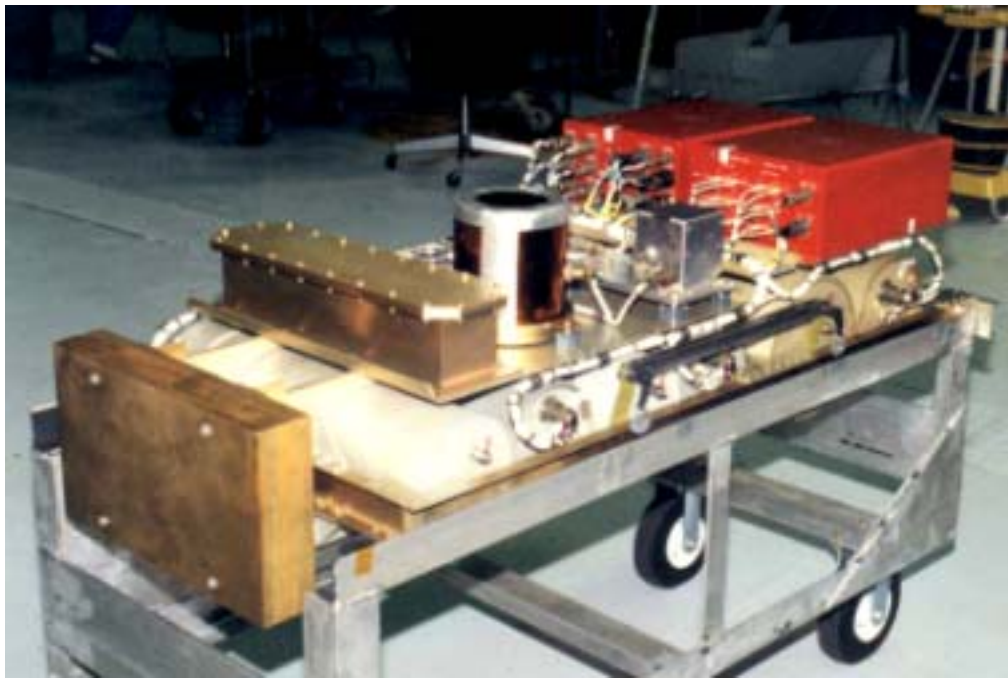
<u>Experiment</u>	<u>PI</u>	<u>Comments</u>
9. Boeing TEPC [on Q-bay vertical rack]	Dr. Alexander Chee	Size: 7.25" dia. x 20" long cylinder with 9" square top flange. Wt.: 22 lbs Power: 28VDC, max at startup 2 amps (ER-2 power) Connector: MS3449H10C6P connector in top flange.
10. DREO TEPC [on Q-bay vertical rack]	Dr. Thomas Cousins	Size: 7.25" dia. x 20" long cylinder with 9" square top flange. Wt.: 22 lbs Power: 28VDC, max at startup 2 amps (ER-2 power) Connector: MS3449H10C6P connector in top flange.
11. Single event upset [on left superpod rack]	Dr. Tom Fogarty	Size: 17" x 17" x 6" high Wt.: unspecified, approx. 15 lbs Power: 115VAC, 400Hz, 1 amp (ER-2 power) LaRC supply external box & connectors. PVAMU supply internal hardware.
12. Boeing PDM-303 [carried in cockpit]	Dr. Eugene Normand	Size: 5" x 0.38" x 1" Wt.: few oz. Power: none required
13. DOE Multisphere Neutron Spectrometer [various locations]	Dr. Paul Goldhagen	Size: various (14) spheres 1.3" to 15" diameter Wt.: 1190 lbs Power: 500 watts
14. DOE Ionization Chamber [on Q-bay rack]	Dr. Paul Goldhagen	Size: 12" x 12" x 17" Wt.: 30 lbs Power:
15. DOE BGO/Plastic Scintillation Counters [on Q-bay rack]	Dr. Paul Goldhagen	Size: 20" x 10" x 29" Wt.: 30 lbs Power:
16. DOE NaI Scintillation Counter [on Q-bay rack]	Dr. Paul Goldhagen	Size: 20" x 10" x 29" Wt.: 30 lbs Power:

Table 2. AIR Instrument Array and Sensitivity to Environmental Components

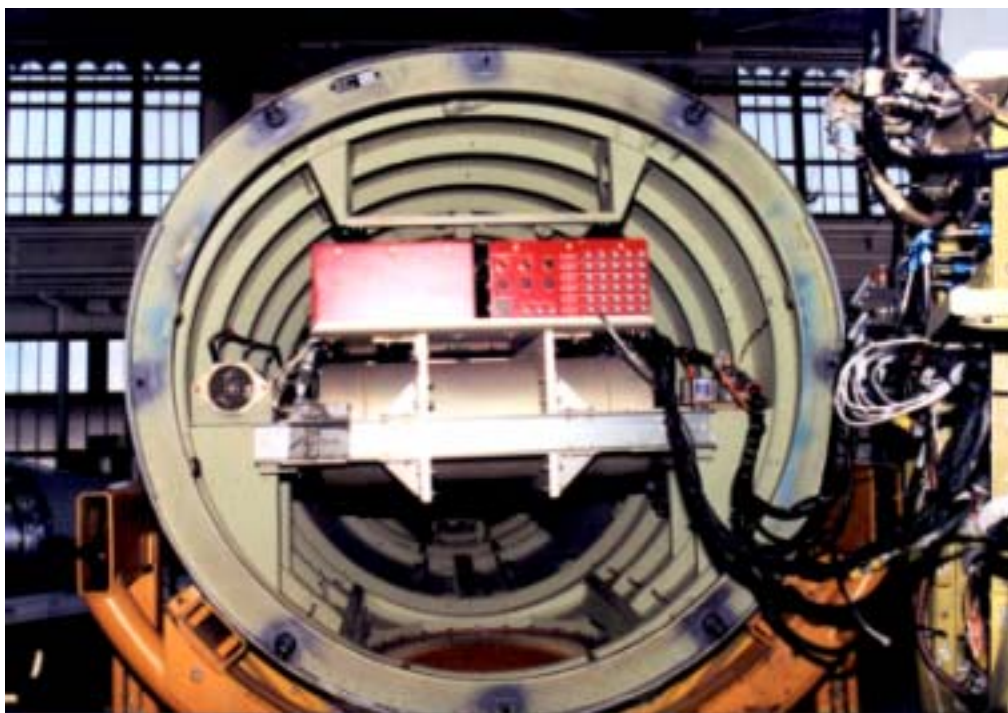
Instrument	Photons	Leptons	Neutrons	Light ions	HZE ions	Target fragments
Bonner spheres			+	-	-	
Ion telescope		-		+	+	
Neutron telescope			+			
Ion chamber	+	+		+	+	+
TEPC	+	+	+	+	+	+
PNTD			+	-	+	+
BGO scintillator	-	-	+	-	-	-
NaI scintillator	+	+		+	+	-
Organic scintillator	-	+	-	+	+	-
Bubble detectors			+		-	-

+ indicates prime measurement, - indicates confounding factor





Photograph 1. Nose Rack on Ground Support Stand



Photograph 2. Nose Rack Installed in the ER-2



Photograph 3. Q-Bay Rack on Ground Support Stand



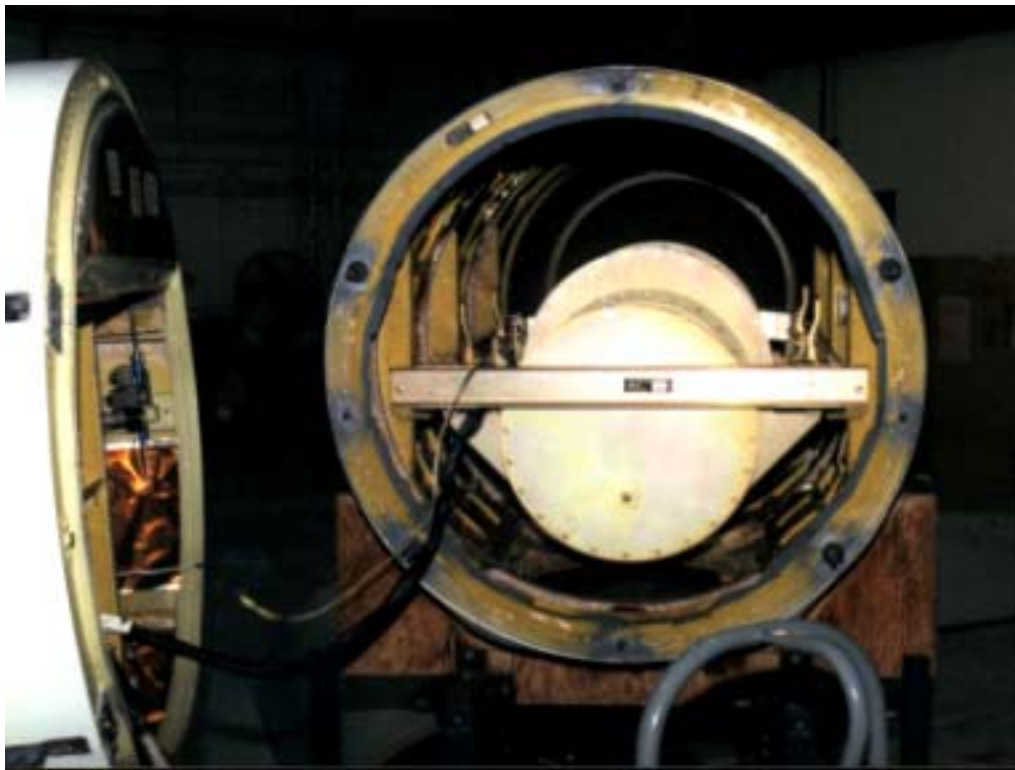
Photograph 4. Q-Bay Rack Installed in the ER-2 (Top View)



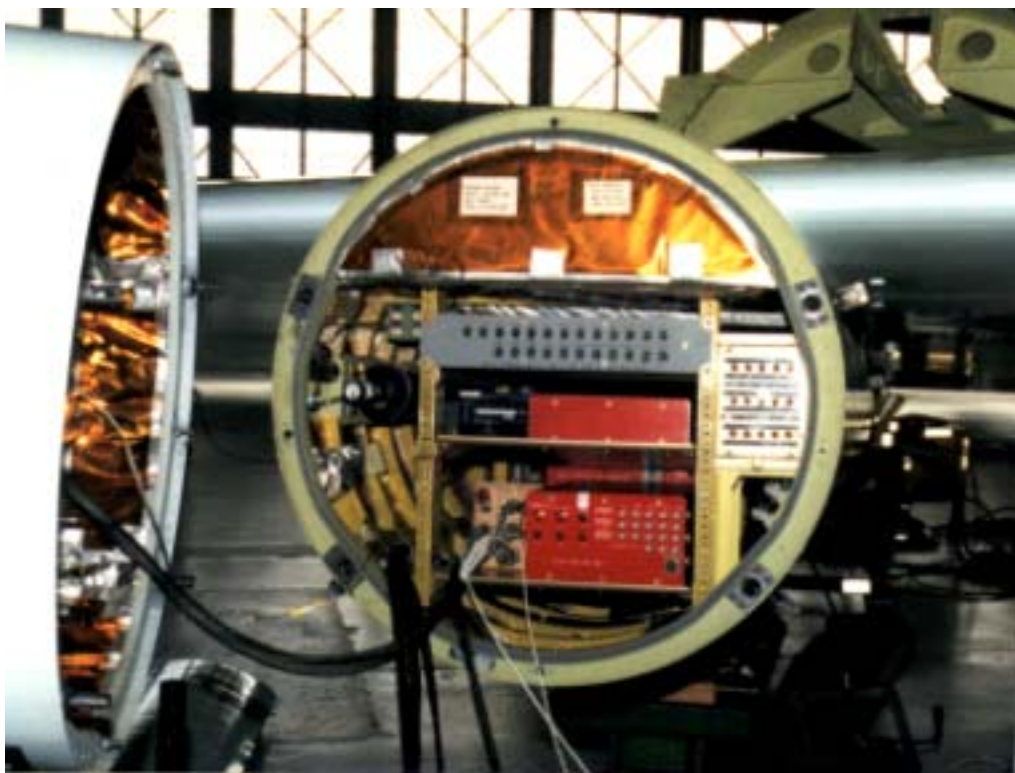
Photograph 5. Q-Bay Rack Installed in the ER-2 (Bottom View)



Photograph 6. Pod Rack on Ground Support Stand



Photograph 7. Pod Rack Installed in the ER-2



Photograph 8. Pod Rack Electronics Installed in the ER-2



Photograph 9. Right Pod Mid-Body Electronics Installed in the ER-2