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METEOROID AND DEBRIS INVESTIGATION ON EURECA

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ABSTRACT

The retrieval of EURECA, planned for May 1993, provides a unique opportunity for post flight investigation on a spacecraft that has spent considerable time in space. Besides technology investigations of in orbit anomalies, the European Space Agency has decided to carry out studies on material degradation and space debris & meteoroid impacts. The primary mission of EURECA is to conduct microgravity and science experiments: the carrier and some payloads have priority for post flight processing over the meteoroid and debris impact search. A condition which has to be taken into account during the post flight investigations is that EURECA must retain the capability to be quickly refurbished to refly. This requirement limits the kind of tests and inspections that can be planned on the spacecraft. This paper describes briefly the EURECA carrier, its mission, the spacecraft ground processing after landing, and the plans to conduct the post flight investigations with emphasis to the meteoroid and debris studies. A complete first optical survey of the spacecraft is foreseen right after the retrieval, while EURECA is still in the United States. More detailed impact feature analysis will be performed when the spacecraft is returned to Europe.

1. INTRODUCTION

Every spacecraft in orbit is exposed to a certain flux of impacting space debris and meteoroid particles. Space activities have led to large numbers of man-made objects in space, most of them being small fragments. Particle impacts and the resulting risks have to be considered for the planning and design of every space mission.

The knowledge of millimetre-and micron-size particles, which are the most abundant by far, is gained through dedicated experiments or through the analysis of materials returned from space. Already after a short exposure to the space environment, surfaces are normally covered with impacts from small-size debris and meteoroids.
EURECA, launched on July 31st, 1992 and to be retrieved in May 1993, has an area of exposed external surface of 145 square metre including 99 square metre of solar arrays (front and rear). EURECA, after nine months of in-orbit operation, will provide important information on the debris environment of the Earth through analysis of the impacts on its surfaces.

2. THE EURECA SPACECRAFT

EURECA is a space platform deployed and retrieved by the Space Shuttle. It provides accommodation and resources to payloads that needs a prolonged (from six to nine month) microgravity environment. EURECA is designed to be reflown with a different payload complement up to four times. Table 1 gives a summary of the EURECA capabilities and resources.
Figure 1 and Figure 2 show EURECA in its launch and flight configuration.

Most of the EURECA 1000 Kg payload complement is dedicated to microgravity research. The remaining instruments involve astronomical observation and technology research. Among the technology research instruments, the Timeband Capture Cell Experiment

(TICCE) is designed to study the microparticles population (typically Earth debris, meteoroids, and cometary dust) in the near Earth space. TICCE captures micro dimensioned particles in excess of 3 Km/s and stores the debris for retrieval and post mission analysis. Particles detected by the instrument pass through a front foil and into a debris collection substrate.

Lately it was recognized that additional debris collection techniques were more suitable to the particle sampling.
Therefore two additional arrays were added to the four containing the described capture cells. The additional arrays employ new techniques for impact debris collection, like silica aerogel materials and extremely thin aluminium foils, which have been developed by the lesson learned from the LDEF experience.

The EURECA spacecraft, having to support stringent requirements form a large payload complements, and being designed to refly for four mission, is a sophisticated space platform.
The structure of EURECA consists of a framework of high strength carbon fibre struts, joining at Titanium nodal points. The nodal points are designed either to carry directly the loads of heavy equipments, or to allow the mounting of aluminium plates used to place lighter boxes or instruments.
The power subsystem generates, stores, conditions, and distributes power to the EURECA system. The power distribution capability is about 2800 W, whose 1000 W is dedicated to payloads. The solar generators are two solar arrays wings composed of five panels each. The solar arrays are stowed during lift off and landing and have the capability to deploy and retract in orbit. During the sun-light phases part of the arrays provides power to the Nickel Cadmium batteries, which in turn will release the power to the system during the eclipse phase.

EURECA is also equipped with a data handling subsystem, an altitude control subsystem, and a communication subsystem. The thermal control of EURECA is accomplished using passive and active thermal control means. Passive control include Multi-Layer Insulation covering most of the external surfaces. A freon pumped cooling loop collects the heat and brings it to two radiators.

3. THE EURECA MISSION

The EURECA mission started with the STS-46 Atlantis lift-off on July 31st 1992 at 13:56 GMT. The orbit achieved by the shuttle (inclination 28.5 and 425x424 Km altitude) was very close to nominal. EURECA was released from the orbiter on August 2nd, at 7:07 GMT. After an aborted attempt to bring EURECA to its operational altitude the spacecraft reached its operational orbit of 508 Km altitude with 0.0002 eccentricity. From this point until the descent orbit transfer manoeuvre foreseen in mid April, no orbit maintenance is performed. The orbit of EURECA is solely determined by the Earth gravity potential, atmospheric drag and other natural orbit perturbations. The decay of the semimajor axis is plotted in figure 3 versus Mission Elapsed Time (MET) in days. Figure 4 shows the evolution of the height of the perigee and apogee over the spherical Earth. The operational mode attitude of EURECA is inertial with the axis perpendicular to the solar arrays plane (+Z axis) pointing the sun, and the axis in the direction of the sill trunnion (Y axis) in the orbit plane. The X axis forms therefore an angle with orbit plane varying with the so called beta angle (angle between the orbit plane and the line joining the Sun with the centre of the Earth). The beta angle is a function of the orbit inclination (almost constant for EURECA at 28.45 degrees), the solar right ascension and declination (which depends on the time of the year), and the orbit Right Ascension of the Ascending node. The latter is changing due to the regression of the line of nodes caused by the oblateness of the Earth. For the EURECA orbit this regression is approximately 6.7 degrees per day.

Combining these effects, the beta angle varies during the mission covering all values between -52 degrees and 52 degrees. Consequently, the +/- X surfaces of the EURECA fly into the velocity vector with an angle between 90 and 90-beta with the X axis. Similar behaviour is followed by the +\- Z surfaces with an offset angle between 0 degree and beta degree. The +Y surfaces flies perpendicular to the velocity vector every orbit at midnight, while the -Y surfaces do it at orbital noon. These considerations are important to judge the predictions of the meteoroid and debris frontal impacts. Preliminary analysis shows that, in the most affected surfaces, it could be expected 150 impacts/m2 from micrometeoroid and up to 200 impacts/m2 from debris in the detectable range.

The descent orbit transfer manoeuvre will precede by three weeks the retrieval by the Shuttle mission STS-57. The rendez-vous phase is planned to take place after the third flight day of the shuttle, with the final approach conducted manually by the crew. After retraction of the appendages, EURECA will be grappled and stowed in the cargo bay. The Orbiter will continue its mission until four days later when it will deorbit and land in Kennedy Space Centre (KSC).

4. EURECA POST FLIGHT INVESTIGATIONS

ESA understands the value of EURECA as an engineering resource for post flight technology studies. Besides a comprehensive 1-meteoroid and debris investigation, ESA plans to conduct:

- materials degradation investigations
- inquiries into EURECA anomalies that are particularly relevant for future ESA missions
- basic technology studies.

The materials degradation investigation will be primarily conducted at KSC (OPF, VPF), and ASTROTECH. A team of the ESA Material & Processes Division will conduct visual inspections and record any interesting feature of the external surfaces of the spacecraft.
At ASTROTECH, as experiments are deintegrated, the ESA team will execute thermo-optical measurement of thermal control surfaces and take wipes for contamination analysis.

Concerning the anomalies that EURECA has experienced so far, ESA is planning to conduct special technology investigations on solar arrays partial loss of recharging capability, gyro failure, Ion thruster failure, AOCS sensors anomalies, payload control unit anomaly, and PCF pump failure.
ESA is evaluating additional 21 proposals that can be included in the group " basic technology ".
Among them there are investigations on the adhesive aging on struts, studies on mechanisms, hydrazine chemical analysis to detect possible contamination, etc. The merit of these proposals will be further evaluated to decide the ones that will be funded. One important point to consider in the selection of the candidate proposals, is that EURECA must retain the capability to be quickly refurbished and refly. This requirement limits the kind of tests that can be performed on the spacecraft. Except for the portion of the MLI that will not be reused for a reflight, requests to take samples from the spacecraft may not be satisfied.

5. OBJECTIVES AND OVERVIEW OF THE EURECA SPACE DEBRIS AND METEOROID POST FLIGHT ANALYSIS

The main objectives of the EURECA space debris and meteoroids post flight investigations are:

- to document the cratering and impact features
- to analyse the impacts and assess potential damage by space debris and meteoroids
- to validate and improve the current meteoroid and debris models in low Earth orbit.

Tables 2 and 3 give an overview of the planned meteoroid and debris investigations.

For LDEF, a detailed photographic survey of the external surfaces began already in-orbit. For EURECA it will not be possible to deviate from the nominal retrieval operation sequence to survey the spacecraft. During retrieval, the solar arrays of EURECA are stowed. The power subsystem of the spacecraft relies on batteries until EURECA is recovered in the Orbiter cargo bay and connected to an umbilical power supply. During retrieval, the crew will take "pictures of opportunity" of EURECA from the aft flight deck using high resolution equipment.
During approach and retrieval operation, thruster firing toward EURECA could damage or contaminate the spacecraft external surfaces. To minimize the possibility of contamination, the retrieval scenario foresee a transition of the Orbiter Primary Reaction Control System (PRSC) to a low thrust mode (LOWZ) at 400 ft from EURECA.

In the Orbiter cargo bay, EURECA will be placed behind SPACEHAB, out of the field of view of the aft flight deck windows. At this point it would be possible to conduct further photographic survey with the low resolution camera of the Remote Manipulator System (RMS). It is questionable whether the data obtained with the RMS camera can be of any use for a meteoroid & debris survey. Figure 5 shows EURECA, when retrieved, in the Orbiter cargo bay.
The primary landing site of STS-57 is Kennedy Space Center (KSC). One day after landing, the Orbiter is towed in the Orbiter Processing Facility (OPF) were it will stay for 5 days. Access to EURECA to service the Protein Crystallization Facility (PCF) is limited to eight hours.
Servicing to PCF is the first opportunity to conduct a photographic survey of EURECA.
To have access to PCF it will be necessary to remove the MLI around the payload. Existing procedures will be reviewed and commented to minimize the destruction of evidences of impacts. ESA is planning a photographic survey with an high resolution camera of all EURECA surfaces that are accessible (EURECA is still in the cargo bay of the Orbiter). Figure 6 shows the possibility to access EURECA at OPF to take photographic records.
At KSC there will be other opportunities to complete the hight resolution photographic survey before EURECA is placed in its trolley to be transported to ASTROTECH.

The main photographic survey to document the debris and meteoroid impacts will take place in the High Bay at ASTROTECH. A systematic optical survey for impact features will be performed for all external surfaces of EURECA. Localized effects due to failures and surface modification phenomena will be identified and recorded. The optical survey will be carried out with the use of a new digital imaging system recently developed for similar work on the Space Shuttle Orbiters. Here, as with the NASA programme, time is essential. It is expected that the general and specific surveys will be completed in six weeks. This operational constrain has led to the incorporation of a high resolution, low noise CCD as a detector in a variable magnification optical rig capable of reproducible scanning. A mechanical articulated head allows the scanning motion in close proximity to the surface to be imaged without contact. The equipment carries out a rectilinear scan several times, achieving improved spatial resolution at specific impact sites located in the previous scan. In this way all sites larger than some tens of microns in diameter will be imaged in a few hours for an area of one square metre, based on average expected fluxes. Digital image processing is involved both in site location and documentation. Achieving of images and associated files will use optical disc technology.

Besides the recording activities described so far, in a second phase of

the post flight analysis, ESA plans to carry out studies on craters morphology and chemical compositions of residues (to distinguish between man made and natural particles). Eventually these data will be incorporated in the digital database initially set up just to record the impacts. A correlation of the TICCE data with results of the EURECA survey will be attempted too.
The results of the EURECA survey will be compared with the prediction of the existing reference flux models. If necessary, these flux models will be updated based on EURECA data.

6. SOLAR ARRAY INVESTIGATIONS

As for the Hubble Space Telescope HST arrays, it is of great importance to the Agency to study the EURECA solar arrays after retrieval. Compared to the HST arrays, EURECA stays a relatively short period in LEO (almost four years against nine months). Effects like darkening or brittlement of silicone adhesive due to UV radiation are not expected to have a dominant effect. However it might be possible to discover other effects that are particularly active in the initial part of the array exposure to space. The EURECA solar arrays will be studied for meteoroid and debris impact in the same fashion as the rest of the spacecraft. It is expected that particles can be recovered for chemical analysis without the need to destroy the panel. Besides meteoroids and debris investigations, material investigations, and inspections on the deployment mechanism, a main task of the solar array investigation will be to identify and fully understand the in-orbit anomalies of the electrical power generation.
The power degradation was much higher than expected. During the first month in orbit 11 solar cell charge strings were lost and the load array suffered from losses of strings. So far, it has not been a problem to satisfy the power requirements of the payloads, but to be ready for a reflight the EURECA arrays will have to be refurbished.

7. CONCLUSION

ESA understands the importance of the data that can be gathered with technology studies from EURECA after retrieval. Yet, EURECA has been designed to conduct microgravity and science experiments. Then the spacecraft must be kept in a status that can be reflown again. The post flight analysis has to be performed respecting these constrains and according to the sequence of activities and locations dictated by the EURECA schedule.

8. REFERENCES

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MASS	TOTAL	**4500 Kg**
	FUEL LOADING	**750 Kg**
	AVAILABLE TO PAYLOAD	**1000 Kg**
VOLUME	AVAILABLE TO PAYLOAD	**85 m3**
POWER	SOLAR ARRAY OUTPUT	**5000 W**
	AVAILABLE TO PAYLOAD	**1000 W**
THERMAL CONTROL	LIQUID FREON LOOP AND MLI	**1200 W**
DATA MANAGEMENT	HIGH SPEED	**256 kbps down link S-band**
	LOW SPEED	**2 kbps up link S-band**
	MEMORY CAPACITY	**128 Mbits**
	AVERAGE P/L BUS CAPABILITY	**1.5 kbps**
ATTITUDE POINTING ACCURACY		**+/- 1 degree (3 sigma)**
MICROGRAVITY		10E-5g < 1 Hz 10E-3g > 100 Hz
NOMINAL ORBIT		525 km at 28.5 degree
MISSION DURATION		6 months operational and 3 months dormant
DESIGN LIFE		5 missions in 10 years
TURN AROUND BASELINE TIME		2 years between retrieval and next launch

Table 1

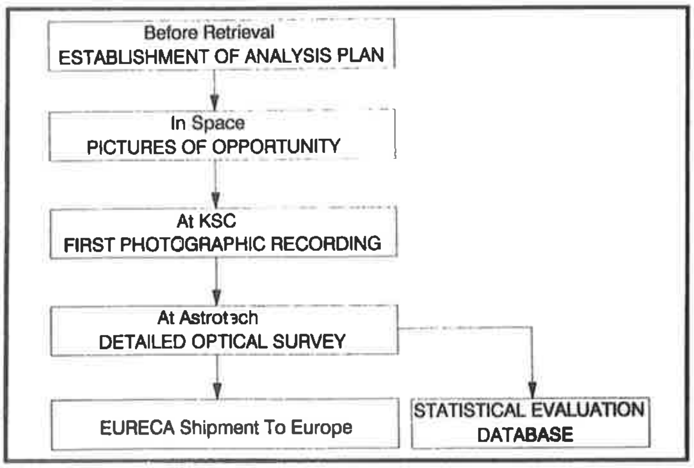

Table 2

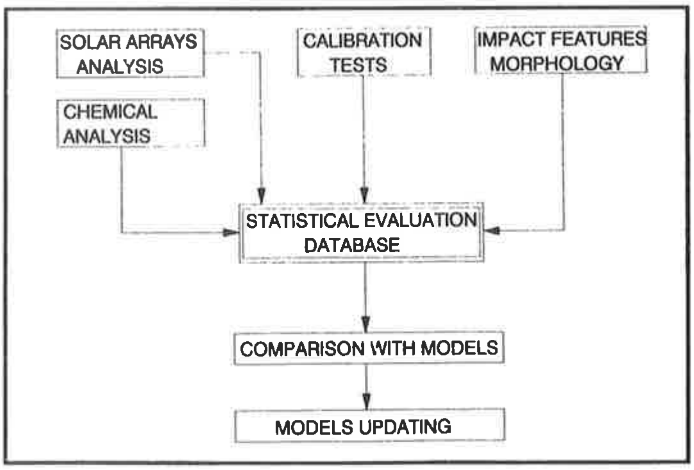

Table 3

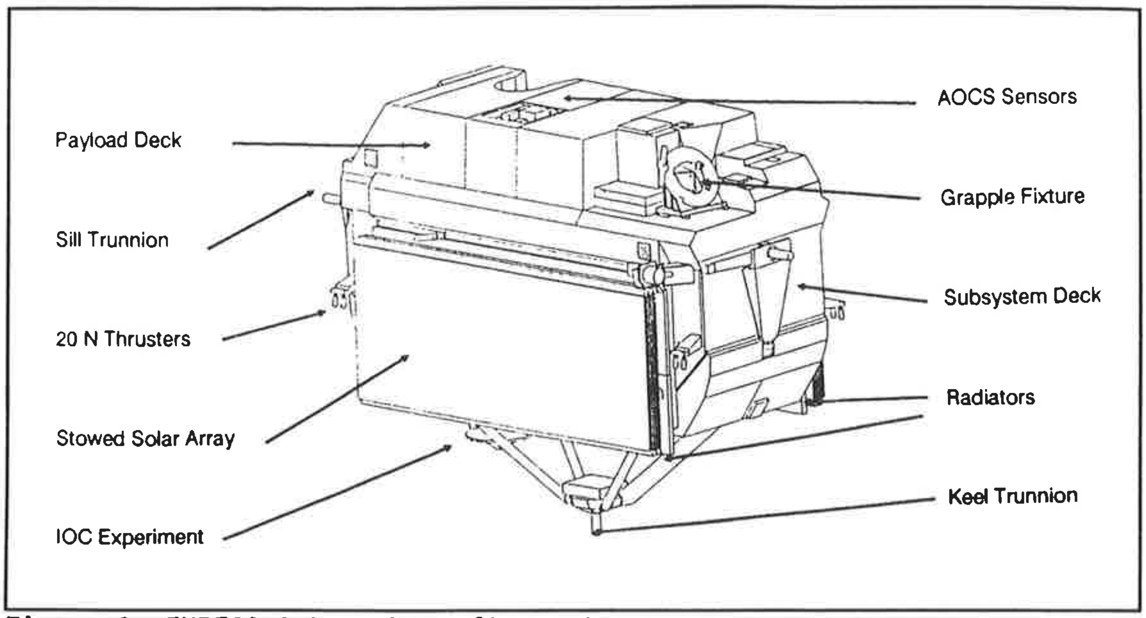

Figure 1: EURECA-1 Launch Configuration

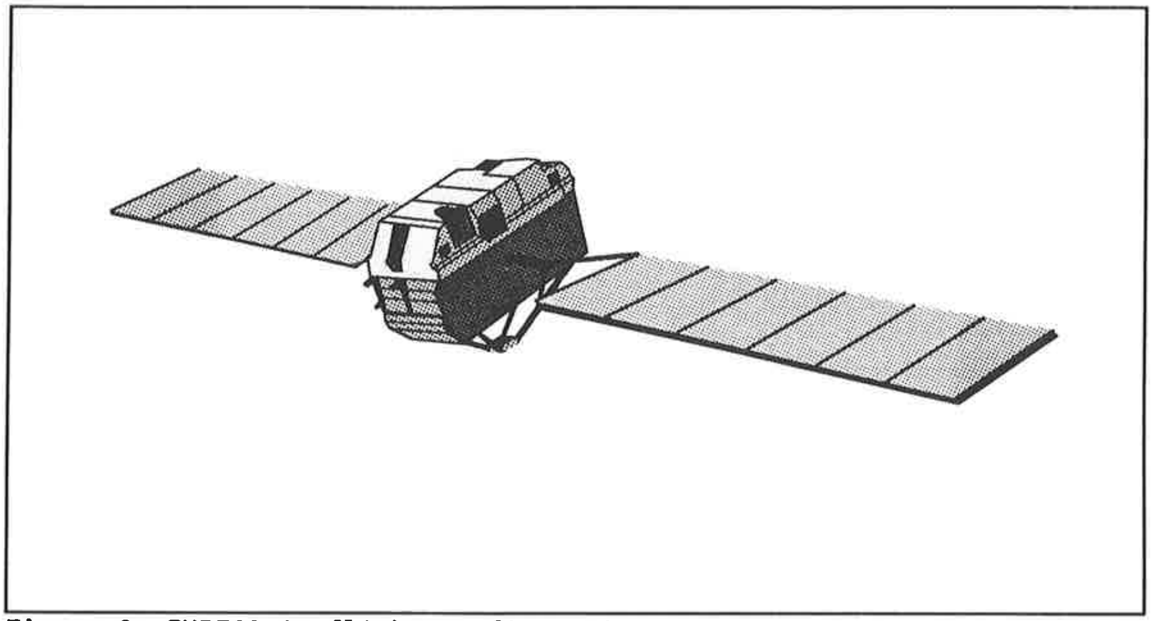

Figure 2: EURECA in flight configuration

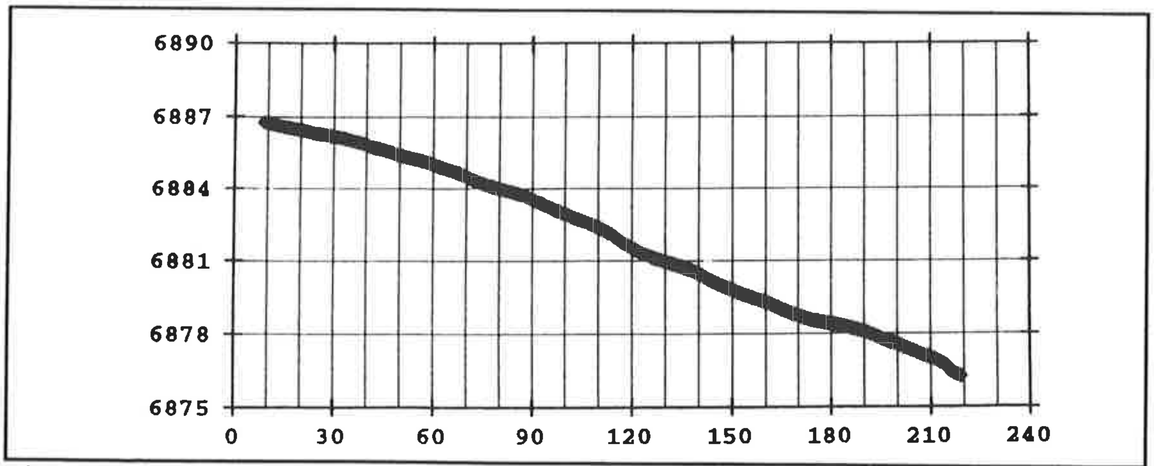

Figure 3: Arithmetic mean semi-major axis (KM)

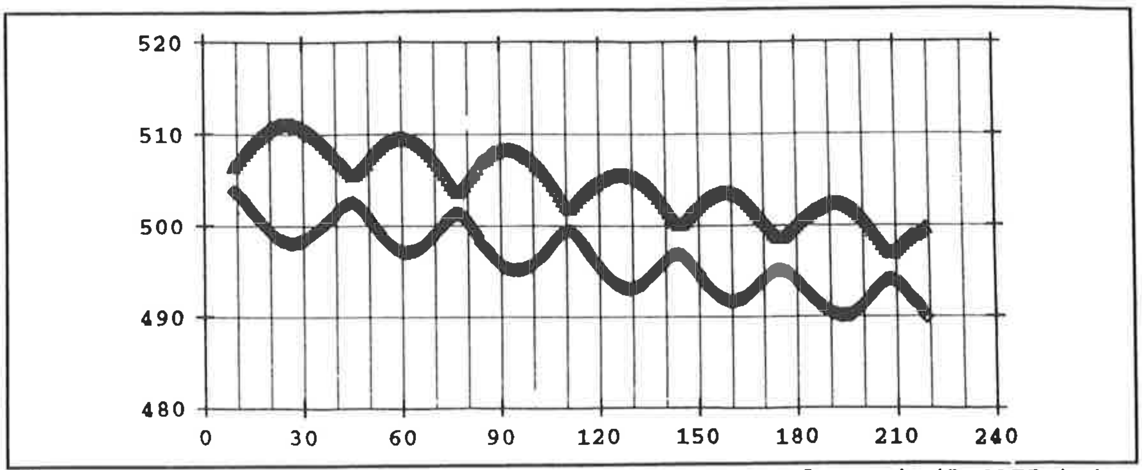

Figure 4: Minimum and maximum height over spherical earth (R=6375 km)

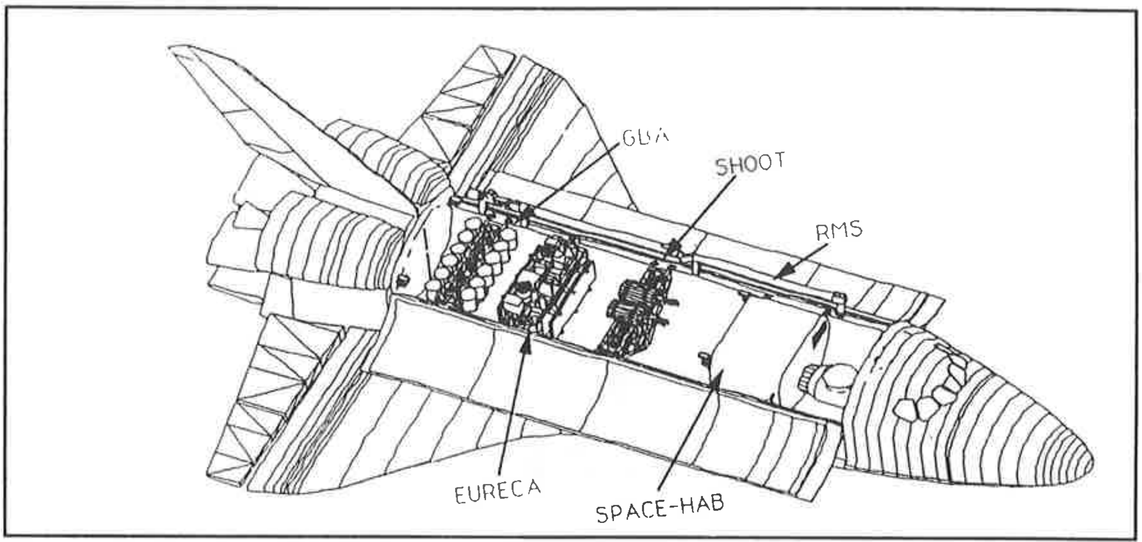

Figure 5 Bird's eye view

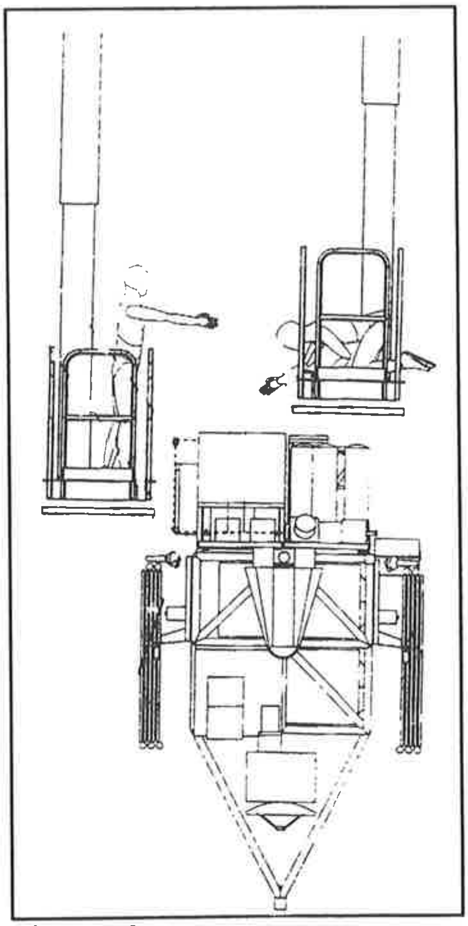

Figure 6