INTRODUCTION TO THE INTERNATIONAL SCIENTIFIC SATELLITE ESRO II/IRIS

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IRIS! Is it a flower, a mythological Greek goddess or a term from the field of anatomy or photography? No, it is nothing more than the acronym for "International Radiation Investigation Satellite". This is its given name beginning from the instant of firing of its rocket carrying the first satellite, a product of European Cooperation in the scientific space field.

All those persons - and they amount to about a hundred in all - who played a direct role in the production and placing in orbit of this satellite know it under another name which was and always will be for them "ESRO II". The latter was one of the first scientific satellite projects placed on the program of the European Space Research Organization (Organization Europeene de Recherches Spatiales) in 1963, one year before this organization was officially created.

International Satellite

This satellite justifies especially well its International title. IRIS indeed has aboard in its trip around the Earth the scientific experiments of researcher groups belonging to 3 European countries (United Kingdom, Netherlands, France). It was designed then produced owing to the joint efforts of the industries of 4 European countries (Belgium, Switzerland, United Kingdom, France) and assisted in some cases by American advisors. It has been under the control of a team from the CERS/ESRO including chiefly the representatives from 5 European countries (Federal German Republic, France, United Kingdom, Netherlands, Italy). Finally, it should not be forgotten that IRIS was placed in orbit by an American

SCOUT rocket launched from the California base of South Vandenberg within the scope of the close cooperation with NASA (National Aeronautic and Space Administration).

Scientific Satellite

The reason for the existence of IRIS is the acquisition of new data concerning as yet unexplained or at least poorly understood phenomena connected with the Earth, the Earth's environment and more generally the galactic systems. In this project both solar astronomy and cosmic rays are the research fields forming the subject of the 7 experiments placed on board. There had originally been 9 candidates vying for the satellite payload. Two of these, however, had to be withdrawn from participation in this first European space round, owing to limitations of weight and of availability of on-board electric power. Two experiments are essentially concerned with certain particles making up the Van Allen radiation belts. The remaining five experiments measure certain components of cosmic radiation by different means. None of the experiments duplicates experiments already orbited by scientific groups involved in the same disciplines. Each one, on the contrary, may be attributed to the category of long-term research owing to the succession of several satellites. One of the experiments is completely new, practically justifying by itself the placing of the satellite in orbit. Doctor Page, the physician assigned to the IRIS project, provides details of the experimental goals in a special article.

For most of the engineers and technicians assigned to the project, these seven experiments represent a specific number of white, black or silvered boxes whose shapes may be peculiarly distorted or with almost too dry a geometrical purity. The contents of these boxes represent long months of mental effort, assemblies and testing. If these experiments had only been set up to carry out measurements in the laboratories which designed them, they would not be worth one line of comment for their design would stem directly from techniques in vogue already for more than ten years. These experiments, however, were supposed to be able to stand the harsh mechanical stresses from a thrustor vehicle, the contact with completely abrasive dust, the very special conditions of weightlessness, extreme vacuum as well as an environment hostile to the most inert matter owing to its unpredictable radiations and bombardments. The technological difficulties met during the design and the specification of the prototype and flight components of these experiments have left their mark, as much as lessons for the future as vivid memories of the past in the minds of those whose specified goal was to launch as soon as possible a satellite which was not only alive but "worked".

Two numbers give immediate cause for reflection concerning the many implications hidden underneath the laconic description of the seven experiments placed on board the IRIS satellite: 21.316 kilograms of scientific payload out of a total satellite weight of 74 kilograms. This has the same order of magnitude as the ratio of payload to total weight for a commercial aircraft. There is, however, in the case of the satellite neither engines, fuel nor wings. The difference between the total weight and payload represents everything necessary to make up from a non-uniform system of sensors of geophysical phenomena that uniform space vehicle capable not only of physically housing these sensors during orbit but also supplying them with power, culling from them the precious measurement magnitudes, processing them, recording them, passing them over a radio link to monitoring and tracking stations, and receiving from these same stations the control commands absolutely necessary for this embryo of space society, inanimate perhaps, but in spite of everything very complex.

The Structure

A physical support in an environment as mechanically calm and chemically inert such as extra-terrestrial space included between 350 and 1,100 kilometers of altitude (the IRIS maneuver zone) could be a priori reduced to very little at all. Nevertheless, this support must successfully carry its precious payloads through the violent stresses associated with the combustion of the four carrier rocket stages. The key quality of this support, lightness, cannot be obtained without disregarding the solidity and flexibility which are absolutely necessary. Only advanced manufacturing techniques calling upon modern materials (honeycomb, extruded magnesium alloys) allow reaching the difficult compromise successfully arrived at after a long and arduous test series. Other constraints are also imposed on the design of this support. These are the constraints of size and shape which are imposed by the standard fairing of the carrier vehicle. There are in addition constraints of moment of inertia imposed by the stability of rotation of the satellite on its axis as well as constraints of thermal flow imposed by the conditions of absorption of solar flux and radiation of the energy consumed by the on board equipments in the presence of the orbital vacuum. Finally, another requirement which can be disregarded beginning from the moment when the satellite is in orbit but basic during its "life" on the ground: it is necessary for this support to lend itself as conveniently as possible to the assembly and disassembly of all the principal components in order to allow performance of the many tests planned or not planned for, which lead to the satellite's qualification for flight.

The Energy Supply

The scientific experiments and other equipments carried by IRIS require electric power in order to operate. There is no other power source as cheap for long space missions as the Sun which, moreover, appears to be an inexhaustible reservoir. Now, it happens that IRIS, by the very mission assigned it, has a special affinity for the Sun. The orbit selected rotates around the Sun at the same velocity as does the Earth during its annual long and complicated journey around the Sun in order that by correctly selecting the launch time, the satellite can be placed in an orbit such that it remains permanently lit up by the Sun for more than 6 months. This peculiarity allows minimization of the operational importance, and hence the weight, of the in-flight batteries which are still, in spite of everything, absolutely necessary for launch operations and for transits in the Earth shadow. (These eclipse periods only account in the worst case for 37% of the orbital period). The silicon solar cells, responsible for converting solar energy into electrical energy, are arranged into panels making up a cylinder with a 12 sided uniform polygonal base and number 3,456 little 2 centimeter squares. This simple peripheral arrangement was only made possible because the rotation axis of the satellite had to be kept perpendicular to the Satellite/Sun vector.

Altitude Control

After the satellite has been separated from the fourth stage of the carrier rocket, it is necessary to adjust its altitude in order to cause its axis to become perpendicular to the solar vector and to subsequently maintain this position in spite of disturbing torques which are slight to be sure but for which the satellite constitutes an excellent integrator. First of all, the satellite has to be slowed down. The carrier rocket had passed on to the satellite, in order that a precise orbit be reached, a speed of rotation around its axis which was 4 times higher (approximately 150 rpm) than could be tolerated by the experiments and the data transmission system. This slowing down is produced by triggering the ejection of two weights, each one connected to a fine steel wire, unwound in a direction expedient to the satellite. These two weights now rotate in space around the IRIS trajectory and have taken with them the excess of kinetic moment which had been given to the IRIS satellite at the beginning of its active life.

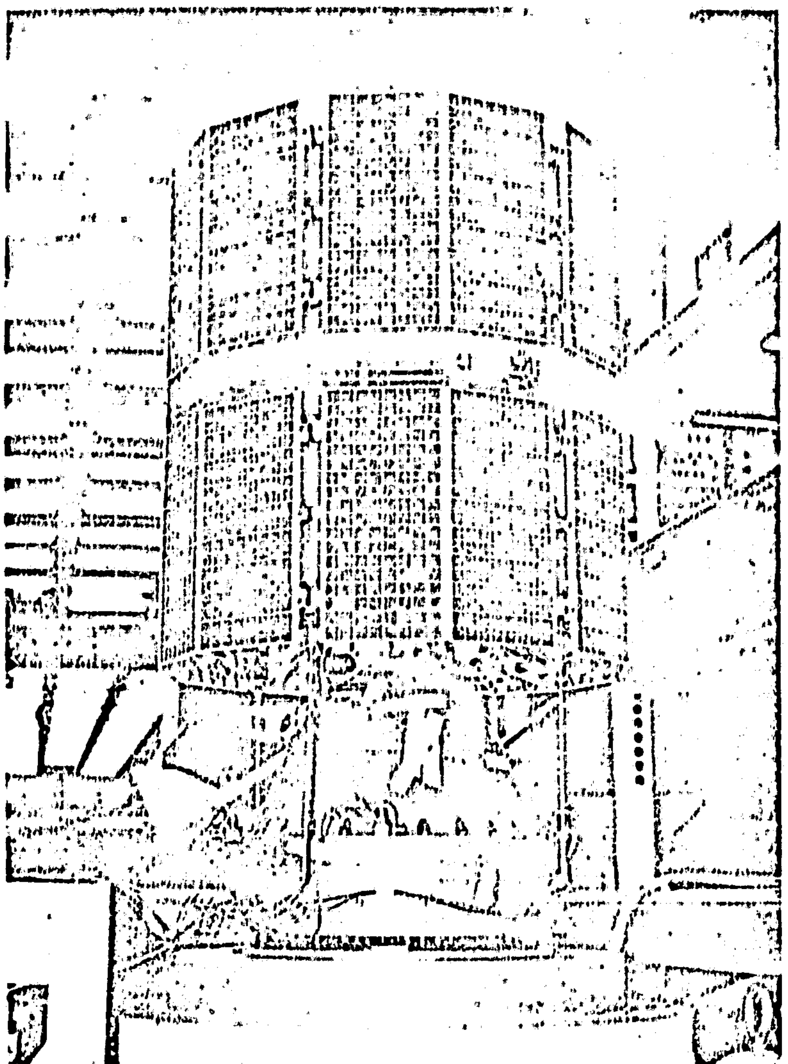
In order to control the attitude of the satellite in orbit, an electromagnetic solution, profiting from the terrestrial magnetic field at favorable portions of the trajectory, was chosen. This attitude control can be either automatic under control of data collected by solar attitude sensors and processed on board at the same time as the data coming from magnetometers, or controlled remotely from ground stations in the event of breakdown of the automatic system. Progressively, IRIS will slow down its rotation on its axis. This apparent fatigue will be due to the adverse effects of Foucauld currents, aerodynamic forces and hysteresis of ferromagnetic components used on board. If the rotational speed drops to 15 rpm, an acceleration system will be triggered in order to restore this speed to approximately 40 rpm. The acceleration system includes three bottles of compressed gas, electrovalves and a very small nozzle which can be seen at one point of the central strip of the satellite structure. In spite of all precautions taken, the satellite is not able to react in a perfectly symmetrical and balanced way to the multiple disturbing torques, whether natural or induced, affecting its attitude. It will tend to start a slow processing movement which a very simple damper (a mobile sphere in a tube with curvature desired) will be responsible for keeping within acceptable limits.

Data Transmission: Telemetry and Control Guidance

Let us now see how the experiments, suitably supported, powered and directed are going to be able to share their measurements with the impatient researchers waiting for them...on the Earth. The majority of the scientific data collected by IRIS are counts of particles and consequently lend themselves especially well to a digital treatment. Out of consideration for standardization and for a variety of other reasons forming the subject of a much more specialized separate article (cf. the article by Mr. J. Toussaint), even measurements of analog nature are put first of all in digital form and the system will then be seen, at the output of the telemetric encoder, as a succession of coded pulses at the rate of 128 signals/second, occupying only two amplitude levels (zero and one) and showing very special recurrence characteristics . These pulses are fed into a 200 milliwatt transmitter serving an antenna with as much omnidirectional coverage as possible and operating on 136 MHz. The large antennas of the monitoring stations are capable from a distance of several thousand kilometers of picking up these signals and thus allowing their recording and subsequent decoding. This permanently operating transmitter likewise is used as a beacon for the ground direction finding equipments which are responsible for measuring the instantaneous position of the satellite in the sky. It is not enough that the satellite transmits so as to ensure transferral of the data, it is also required that there be a station properly equipped to receive and record the signals. Now, the ESTRACK network which had been set up by the CERS/ESRO only includes 4 stations (Redu, Spitzberg, Fairbanks, Port Stanley) and even with the supplemental assistance of the CNES stations, a considerable quantity of information (more than 80%) would be lost if the satellite did not make a special effort to store up the data collected and to only release it during its transit above a region of the Earth covered by one of the stations. Such is the role which has been assigned to the on-board recorder which stores, on an endless magnetic tape having available a capacity slightly greater than the duration of one orbit (100 minutes), the same pulses as those transmitted by the 200 milliwatt transmitter. On command from the ground, the recorder abandons its recording function and passes over to the reproducing mode, at the same time multiplying its speed by a factor of 32. In this way, in a little more than 3 minutes, a whole orbit of data has been offered as input to a second transmitter. The latter, more powerful than the first transmitter, transmits the data toward the station ordering the replay. Mention has already been made of the existence of orders coming from the ground during transit. In order to make this possible, a receiver placed on board the satellite detects, under conditions characteristic of the IRIS satellite, a suitably formatted transmission in the form of one from among 36 orders possible. The precautions taken in the painstaking analysis of signals received by the receiver and the control guidance decoder may be explained by the fact that since IRIS maneuvers at high altitude it is capable of being reached by a considerable number of radioelectric transmissions within the frequency band which it is monitoring for signals coming from the Earth. The satellite must defend itself against signals which are not specifically addressed to it which may arrive either because there are poorly operating equipments on the ground, or because there are many other satellites in orbit at the same time.

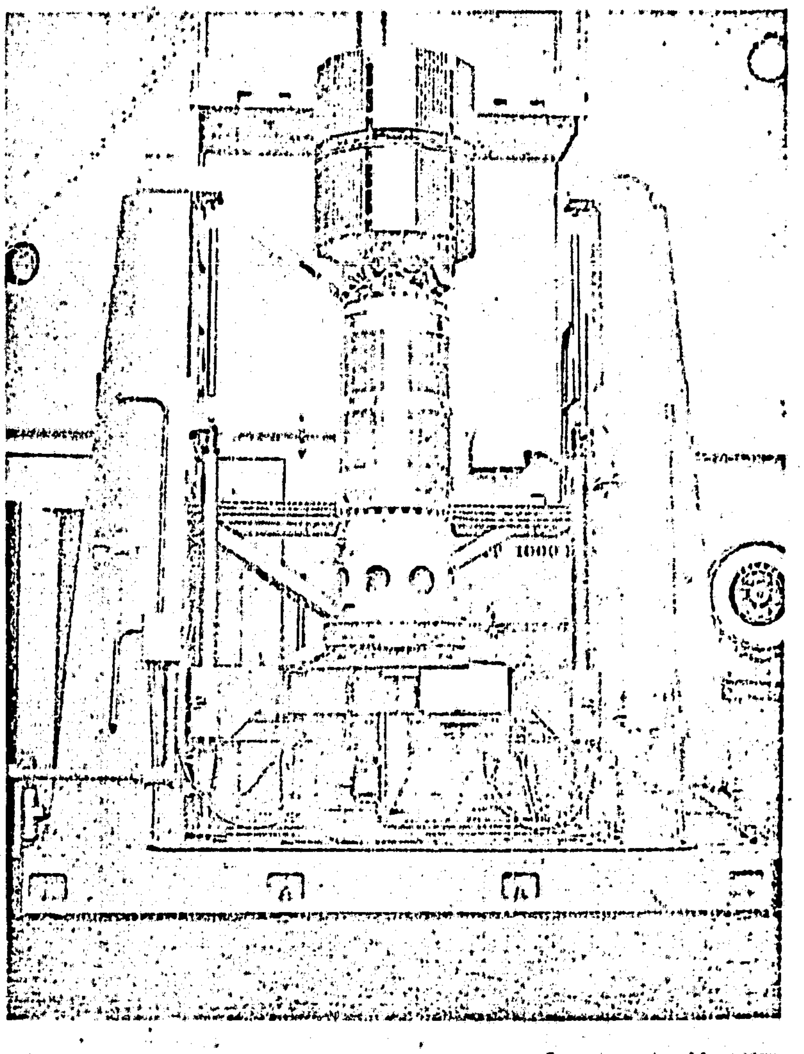
IRIS was launched 17 May 1968 at 0306 hours European time. It is the second flight model of this satellite to try the great adventure. Indeed, on 29 May, 1967, the first flight model of the same satellite passed its qualification trials successfully and ended up at the top of the 24 meter SCOUT rocket, ready to perform its orbital task as collector of measurements. The rocket, however, did not fulfill its part of the bargain. Owing to an anomaly in the operation of the third stage, the first flight model dove hopelessly towards the Pacific, at the same time passing on to the very last second strong, completely normal telemetry signals. From the beginning of the industrial production phase of this satellite (25 November 1964), two flight models were planned for just precisely for the purpose of compensating for such an accident. There were, however, in all 8 models of various types which were constructed from the very first vibration model, the thermal model, the electrical integration model, the prototype model P1, the prototype model P2 up to the 2 flight models F1 and F2. In addition to the specific goal of each one of these models, their elaboration has kept pace with the complex requirements of scheduling and availability in time and space of the specialized means of measurement: test stands for vibration, thermal vacuum chamber, solar simulation chamber, measurement stand for balance and moment of inertia, rotation table, ground stations for the verification of radioelectrical accounting before placing in orbit. Electronic equipments, whose character was special but did not include a universal computer capable of high-speed performance and transcription of a great many electrical tests, accompanied the difference prototypes and flight models in the testing and preparatory sites. To ensure a proper and efficient order of all operations, from design to launch, this was the difficult task assigned to specialized teams both with the contractors as well as in the heart of ESRO itself.

It would be useless to try and pretend that during all this effort there were no conflicts arising between members of the teams harnassed to this work. Such conflicts were born of the impatience and determination on the part of certain temperaments to reach the specified goal by paths which could sometimes be different from each other. It would be ridiculous to claim that there were no serious technical difficulties. These were, however, overcome by a methodical analysis of their causes. On the other hand it was highly encouraging to watch the continuous progress toward concretization of a basic concept which bordered the limit of the theoretical and practical means available at the beginning of the project and see it arrive at a disciplined living production corresponding to a precise goal. IRIS is in orbit. It works constantly and functions well. It occasionally still reveals some of those rare mysteries. When it ceases to operate it will always be present and alive in the minds of those who devoted so much effort and attention to it.

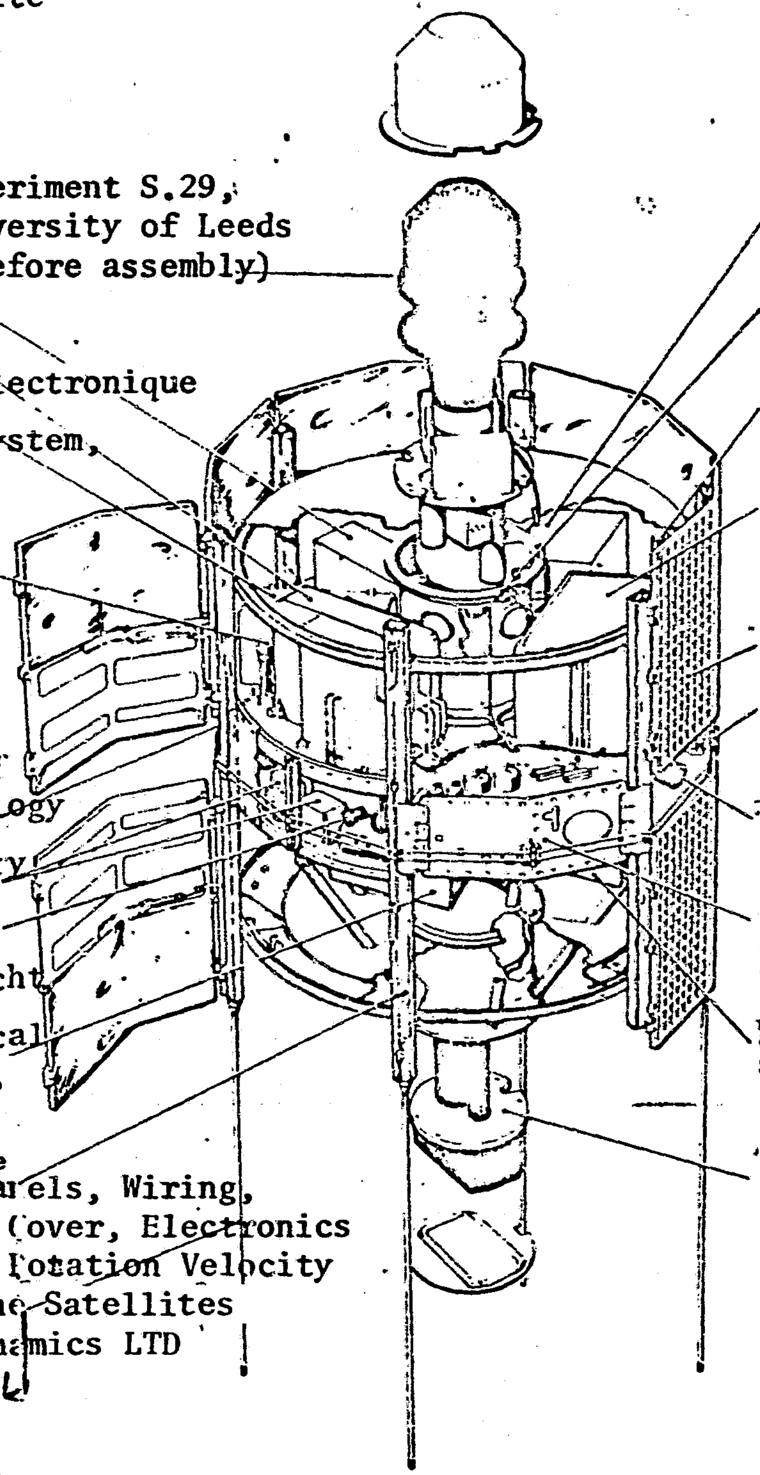


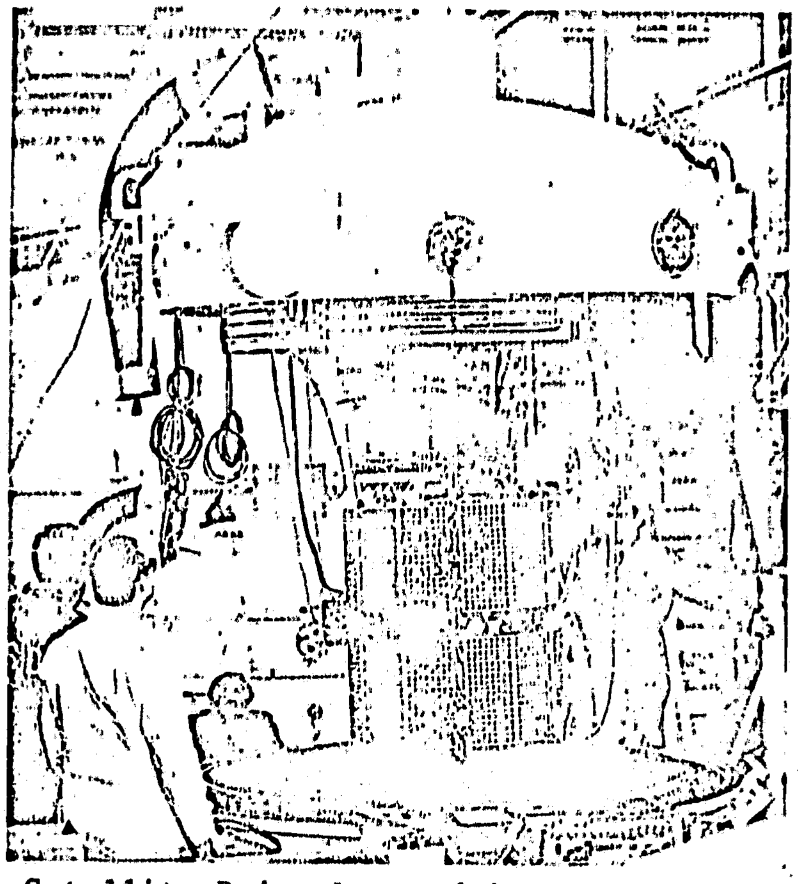
General View of Satellite
on Vibration Test Machine

Test of Dynamic
Equilibrium on the Firing Range

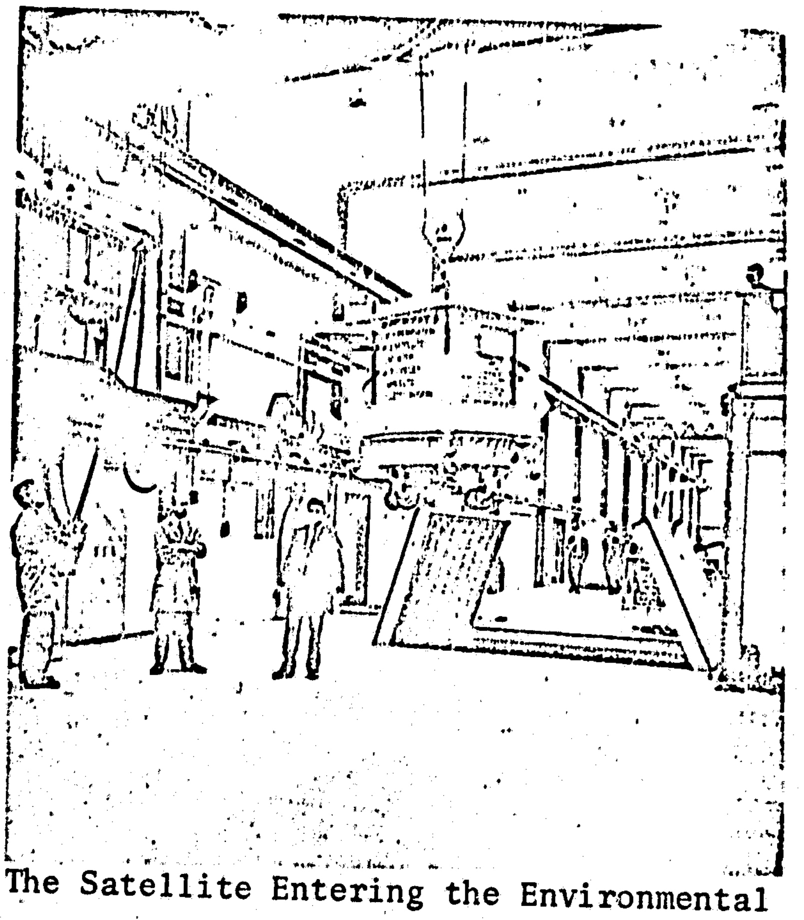


Internal Arrangement of the ESRO-II
International Satellite





Satellite Being Lowered into the Thermal Vacuum Chamber



The Satellite Entering the Environmental Testing Hall.