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Paper Session II-A - Iris-LAGEOS 2 Mission

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IRIS-LAGEOS 2 MISSION

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IRIS-LAGEOS 2 MISSION

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ABSTRACT

The developing and launching of LAGEOS 2 must be considered an important step in the evolution of Italian space and scientific activities. This paper will describe the scientific objectives of the IRIS-LAGEOS 2 mission, giving full details, characteristics and performances of the LAGEOS system and its launcher, IRIS:

- **LAGEOS 2** is a scientific satellite to be utilized for geodesy research being developed in Italy under a joint agreement between the Italian (ASI) and U.S. (NASA) Space Agencies.
- **IRIS (Italian Research Interim Stage)**, funded and managed by the Italian Space Agency, is a spinning, solid propellant upper stage system to be used in conjunction with the NASA Space Transportation System.

An overview of pre-launch ground activities and flight operations will be provided. The program status will be summarized. The industrial organization in charge of developing both systems will be, briefly, indicated.

1. SCIENTIFIC MISSION OBJECTIVES

LAGEOS 2, like its predecessor LAGEOS 1 launched by NASA in 1976, is a passive satellite dedicated exclusively to laser ranging technique (Fig. 1, page2). Its scientific objectives are centred around research in earth sciences made possible by very precise satellite geodesy. LAGEOS 2 is expected to improve by approximately a factor of two the accuracy of the geodetic quantities (e.g. point position and Earth orientation) produced by LAGEOS 1 alone.

LAGEOS 2 will be placed in a near-circular orbit at an altitude of 5900 km and an inclination of 52°.

LAGEOS 1 is in a similar orbit but with an inclination of 109.8°. Both LAGEOS satellites will be tracked by a global network of fixed and transportable lasers. The current precision of the laser systems varies from 15 cm to < 1 cm for single-shot range measurements. Further improvements will increase the precision of the majority of the laser systems to the 1 cm level by the time of the LAGEOS 2 launch.

Tracking of this satellite is expected to enhance research greatly in the following areas:
- regional crustal deformations and plate tectonics,
- geodetic reference datum and earth orientation,
- earth and ocean tides,
- temporal variations in the geopotential,
- satellite orbital perturbations.

1.1 Regional crustal deformation and plate tectonics

Emphasis is placed on the entire Mediterranean area which is one of the most tectonically active areas in the world. Tectonic processes in the Mediterranean are closely related to the collision between the African and Eurasian plates. However, great uncertainty surrounds the kinematic and dynamic pattern of the large-scale tectonic collision and the microplate kinematics between the two major blocks. Significant seismic gaps have been identified within the Mediterranean, most notably along the Hellenic arc, the North Anatolia and the Calabrian arc, creating a high level of concern about the hazard of earthquake in the region. Tracking of the two LAGEOS satellites provides an excellent opportunity for the development of techniques which can produce baseline recoveries of high temporal resolution.

From such baseline changes and through the use of ancillary data (local geodetic surveys, tide gauge analyses, seismologic data, geologic data, local gravity information, etc.) local kinematic models can be computed at relatively short time intervals. This last requirement is important for the Mediterranean region because of the complexity of its tectonics and the need to have as much information as possible preceding any further earthquake activity.

(*) ALENIA is the new Company resulting from the merger of Aeritalia and Selenia, taking over full responsibility for their functions, responsibilities and activities.

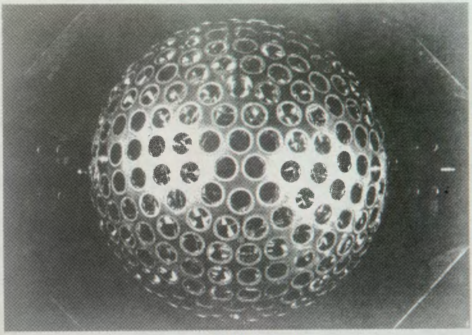

Fig. 1 - LAGEOS 2 Satellite

1.2. Geodetic reference datum and earth orientation

Emphasis is placed on the determination and analysis of high-precision (better than 2 milliarcseconds) and high temporal resolution (better than 2 days) polar motion and length-of-day values. Enhanced capabilities resulting from the tracking of the two LAGEOS satellites over those achieved from tracking a single satellite will permit the determination of universal time (UT 1), thereby separating it from gravity field variations; this is impossible to do with LAGEOS 1 alone. Areas of scientific investigation may include the study of the frequency structure of polar motion at Chandler, annual, semi-annual, diurnal, and other periods; the study of the nature of excitation of the Chandler component; the relationship between polar motion, earthquakes, and mass displacements in the Earth; the yielding of the Earth with movements of the rotation axis, the impact of atmospheric movements and mass transport on the orientation of the Earth; and the study of core/mantle coupling.

1.3 Earth and ocean tides

The orbital inclinations of the two LAGEOS satellites differ sufficiently to allow for enhanced capabilities for the recovery of Earth and ocean tidal coefficients (below degree 6) for numerous ocean tide constituents (such ad M_2, N_2, S_2, K_2, O_1, P_1, K_1, Mm and Mf) and the frequency-dependent K_2, h_2 and l_2 Love numbers. Research emphasis will be placed on the development of techniques for the optimal incorporation of the satellite-derived ocean tide information into oceanographic tide models.

1.4 Temporal variations in the geopotential

The orbital inclinations of the two LAGEOS satellites differ sufficiently for their contributions to the study of the geopotential to be complementary. Continuous monitoring of the evolution of the orbits of the satellites will permit the observation of changes in the geopotential. Research areas may include studies of mass transport such as those caused by seasonal variations in the Earth's water distribution; studies of the Earth's rheology through observations of post-glacial responses; studies of mantle convection; and the determination and analysis of the rate of drift of the Earth's mean figure axis.

1.5 Satellite orbital perturbations

Investigation areas are the determination and analysis of conservative and non-conservative forces acting on the LAGEOS satellites. Emphasis is placed on further understanding the unexplained along-track acceleration of LAGEOS 1 by analysis of the combined LAGEOS 1/2 data.

Other research areas may include perturbations caused by the Earth's anisotropic reflection of sunlight; perturbations caused by oceanic circulation; and general studies of gravitational theories.

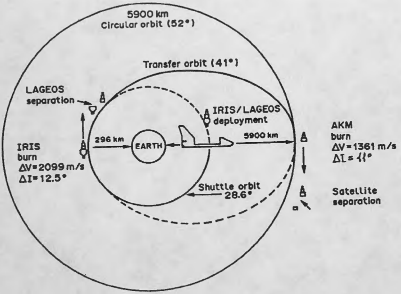

Fig. 2 - IRIS-LAGEOS 2 Mission

2. MISSION

The LAGEOS 2 satellite will be inserted into its orbit by the NASA STS and an Italian upper stage system, named IRIS (Italian Research Interim Stage). This will be the first IRIS mission and will qualify the use of IRIS as an STS upper stage.

IRIS will transfer the LAGEOS system from the Shuttle nominal parking orbit (296 km) up to an elliptical transfer orbit with apogee at 5900 km and an inclination of 41° (from the 28.5° of the initial orbit) using the increment of velocity provided by the IRIS solid propellant rocket motor; the LAGEOS system will circularize this orbit, changing the inclination to 52°, using a Mage 1SC on-board apogee kick motor. The overall mission is depicted in Fig. 2.

3. LAGEOS SYSTEM

The LAGEOS system (Fig. 3, page 4) consists of:

- The LAS (LAGEOS apogee stage) which represents the primary structure with all the subsystems necessary for mission implementation, and which supports the AKM Mage 1SC (solid propellant rocket motor for orbit circularization)
- The LAGEOS 2 scientific satellite to be deployed

The LAGEOS 2 satellite is a spherical body covered by 426 cubic corner retroreflectors (CCR), which are prisms of a special shape able to reflect laser beams under a wide range of incidence angles. All but four of these prisms are made from a special fused silica glass named "suprasil". The remainder are made of germanium for measurements in the infrared region.

The satellite has a mass of about 400 kg, concentrated as much as possible at the centre of gravity to minimize natural perturbations of the orbit and satellite position caused by such things as aerodynamic drag, magnetic field anomalies, solar radiation pressure etc.

The LAS structure interfaces with IRIS (Fig. 4, page 5) and supports the AKM, it is spin stabilized at 64 rpm by means of the IRIS spin table subsystem.

LAS subsystem operations are coordinated by an electronic sequencing subsystem, powered by two batteries, that controls the LAGEOS active nutation damper (LAND) and telemetry equipment, as well as commanding stage separation, yo-tumbling and AKM burning.

The electronic sequencing is derived from the one designed and developed for the IRIS system and is preprogrammed on the ground for the flight mission sequences. The LAND subsystem is responsible for correcting the LAS nutation by means of an inertial wheel, actuated by a brushless, battery-powered motor. The motor is driven by an electronic control unit elaborating input coming from an angular accelerometer.

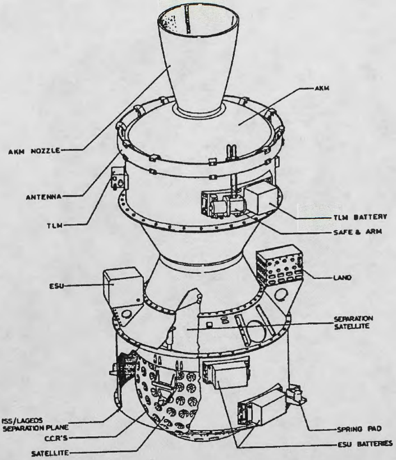

Fig. 3 - LAGEOS System

A separation subsystem will permit satellite deployment without contact with the LAS structure. Then, a yo-tumble will unbalance the LAS structure by means of a mass release to avoid recontact. Both functions are pyrotechnically actuated.

The telemetry and beacon subsystem is composed of a decoder, transmitter and related antenna for:

- tracking and acquisition of the LAS during transfer orbit and insertion into final orbit
- data acquisition of the LAS status during operations
- tracking of the LAS after satellite release

The on-board power is initially supplied by the IRIS system while LAGEOS is still in the Orbiter cargo bay. After separation from IRIS, power to LAGEOS is provided by 6 Ag-Zn 28-V batteries operating for a minimum of 90 minutes up to 4 days (telemetry batteries).

The solid propellant rocket motor is the Mage 1SC, qualified by the European Space Agency and successfully utilized as an apogee motor installed in many European satellites.

The Mage 1SC has a specific impulse of 290.4 s for a total energy of 11.7 x 10 E 5N in the case of maximum propellant loading. It can be off-loaded up to 20%, depending on mission requirements.

The LAGEOS system weighs 911 kg:

- 405 kg for the satellite
- 38.5 kg for on-board avionics (batteries included)
- 387.5 kg for the Mage motor
- 80 kg for the primary and secondary structures, separation subsystems, thermal control, harness and ballast masses.

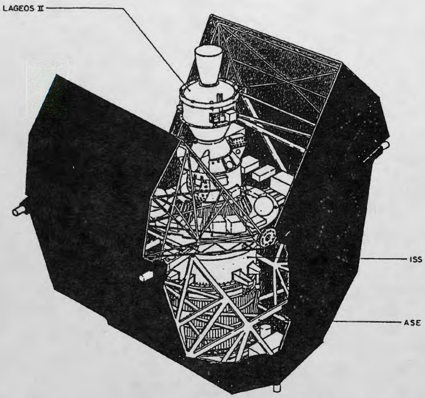

Fig. 4 - IRIS System

4. IRIS SYSTEM

The IRIS system is an upper stage for NASA's STS designed to inject a 600 to 900 kg mass payload into geostationary transfer orbit, starting from the STS nominal parking orbit.

Performance capabilities across the above-mentioned mass range are achieved by means of a solid rocket motor off-loading up to 25%.

The system (Fig. 4) consists of two main modules:

- **ASE MODULE** - The reusable set of structures, mechanisms and electronic/electric equipment required to support and control the ISS/Payload composite during mission phases up to the deployment from NSTS Orbiter.
- **ISS MODULE** - The spin stabilized, expendable stage that, after deployment from NSTS Orbiter, injects the payload into the required orbit.

4.1 Airborne Support Equipment (ASE) Module

The ASE (Fig. 5, page 6) gives structural support during launch to the ISS/payload composite by means of a truss structure that interfaces with the Orbiter cargo bay by means of four lateral attach fittings and one keel fitting.

The connection with the ISS is assured by a separation clamp band and two movable restraints (the grabbers) which are withdrawn just before the composite spin up.

Protection from the external space environment is provided by the ASE via passive thermal control based on multi-layered insulation blankets that completely enclose the cargo element, and on electrical heaters.

The upper part of the ASE insulation is supported by lightweight structures called sunshields. During the deployment sequence, the movable section of the clam-shell type sunshields is opened to allow ISS/Payload separation. The ASE also ensures monitoring and control of all mission operations up to deployment by means of a microcomputer-based data handling subsystem. This is completely automated, although it is under Orbiter crew supervision.

A power supply subsystem controls the electrical power provided by the STS fuel cells and distributes it to the various IRIS elements.

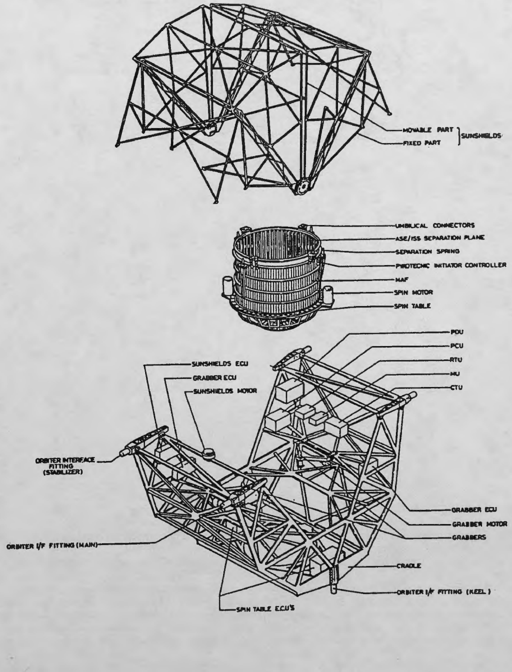

Fig. 5 - ASE Module

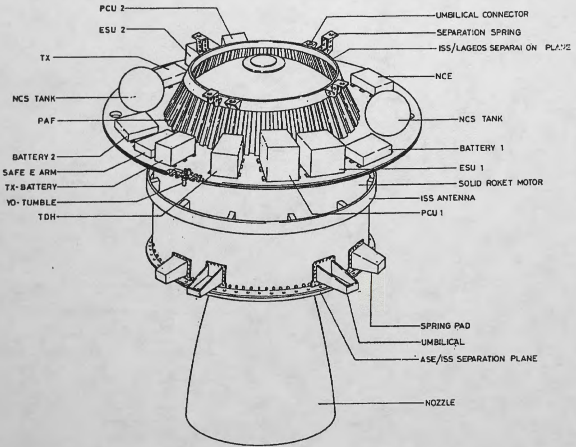

Fig. 6 - ISS Module

4.2 IRIS Spinning Stage (ISS) Module

The ISS (Fig. 6) consists of a high performance HTPB (hydroxyl terminated polybutadiene) solid rocket motor with a Kevlar case and carbon phenolic nozzle.

On top of the motor, an aluminium corrugated adaptor supports a platform with all stage subsystems such as avionics and telemetry data handler. Power is supplied by batteries when the spinning stage is deployed. A nutation control subsystem uses nitrogen gas for controlling the coning of the payload and ISS during the coasting phase.

All operations of the IRIS spinning stage in the coasting phase are commanded and controlled by the electrical sequencing subsystem (two redundant units) that perform the preprogrammed mission sequence until the final payload separation. The last command after separation is for the yo-tumble subsystem. This subsystem releases a mass to unbalance the empty stage in order to avoid eventual recontact with the separated payload due to residual thrust of the motor.

A telemetry subsystem is also foreseen in order to retrieve all available information to assess in flight qualification.

The performance or the IRIS spinning stage in terms of velocity increment vs payload mass is shown in Fig. 7, page 8.

For a nominal mission with a 900 kg payload, an elliptical geostationary transfer orbit can be attained from a STS circular low orbit (296 km, 28.5° inclination) with a velocity increment of 2427 m/s.

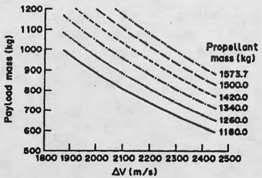

Fig. 7 - IRIS System Performance

5. IRIS-LAGEOS COMPLEX

The overall system mass in launch configuration is 3448 kg:

- 911 kg for LAGEOS system
- 1534 kg for IRIS-ISS
- 1003 kg for IRIS-ASE.

In the specific case of the LAGEOS mission, the IRIS solid rocket motor is loaded with 1270 kg of propellant instead of 1574 kg, which is the maximum load for inserting a 900 kg mass satellite into geostationary orbit. The power budget is 1250 W from the Orbiter (nominal mission).

The overall system reliability is estimated at 0.93. The IRIS/LAGEOS system accuracy for LAGEOS at a 5900 km high and 52° inclination orbit has been analysed using an error propagation method with Monte Carlo techniques and has been estimated at ± 250 km in height and ± 1.0° in inclination at 3 σ.

6. MISSION OPERATION

The launch campaign consists of three main phases:

- Launch preparation
- Flight operations
- Post-landing activities

- The launch preparation includes at KSC (Kennedy Space Center):
  - reintegration and check of IRIS and LAGEOS systems which have been disassembled for transportation from Italy to the United States
  - installation of IRIS/LAGEOS in the Shuttle cargo bay in the launch complex
    and at JSC:
  - preparation of POCC
- The flight operations can be subdivided into the following mission phases (Fig. 8, page 9):
  - Lift-off and On-Orbit Quiescent Phase
  - On-orbit active phase, that includes:
    - ASE DH Power-on and IRIS/LAGEOS system check-out
    - Deployment Sequence
    - ISS Postdeployment timing and ISS SRM burn-out
    - LAGEOS Transfer Orbit phase
    - LAGEOS Operative Orbit phase (LAGEOS Satellite only)
    - Abort Sequence (in case of contingencies)
    - Emergency (Back-up) Deployment (in case of emergencies)
  - IRIS ASE Post-Deployment On-Orbit Quiescent and Reentry Phase.
- The post-landing activities include:
  - ASE removal from Orbiter
  - ASE checkout and preparation for the next mission or storage.

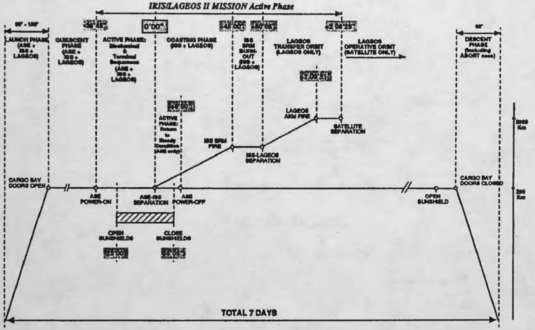

Fig. 8 - IRIS/LAGEOS Mission Profile

7. PROGRAM STATUS

The flight unit of the LAGEOS system has been completed. It has been subjected to the qualification/acceptance test program including a series of tests, such as vibration, thermal vacuum, electromagnetic compatibility and integrated avionics in addition to optical tests at NASA Goddard Space Flight Center for final verification of the performance of the laser retroreflectors.

The IRIS system has completed the qualification phase consisting of a series of tests conducted on a structural/thermal model and on an electrical/avionics model. This phase has included also the three qualification firings of the solid rocket motor which followed a parallel qualification test sequence.

Completion of the test campaign to verify the electrical, functional and mechanical characteristics of the IRIS system, after modifications introduced to satisfy the new NASA Safety requirements, is foreseen for the second quarter of 1991.

The delivery to ASI of both the IRIS and LAGEOS flight units is foreseen by mid 1991.

The flight date is subject to Shuttle mission planning. At the moment, the NSTS manifest foresees IRIS/LAGEOS 2 Launch in October 1992.

8. INDUSTRIAL ORGANIZATION

Both the IRIS and LAGEOS programs are funded by the Italian Governement and managed by ASI (Agenzia Spaziale Italiana).

For IRIS, ALENIA is the prime contractor leading a group of Italian aerospace industries with BPD as associate contractor and FIAR, LABEN and Microtecnica as main subcontractors.

ALENIA is responsible for the design, development and qualification of the overall system. Further, it is responsible for construction of the ASE module, mechanical and electrical ground support equipment, and the assembly, integration and verification of the entire IRIS system. BPD is responsible for the design, development and qualification of the ISS module, specifically of the solid propellant rocket motor which is the main component of the propulsive stage.

ALENIA is also prime contractor for the LAGEOS system and leads a group of aerospace industries composed of LABEN, Microtecnica, McDonnell Douglas and ZYGO.

The AKM is provided by the BPD/SEP/MAN consortium.

The LAND subsystem is provided directly by NASA Goddard Space Flight Center.

ALENIA will also be responsible for the IRIS-LAGEOS launch campaign.

ACRONYMS

NASA	National Aeronautics and Space Administration
STS	Space Transportation System
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
IRIS	Italian research interim stage
LAGEOS	Laser geodynamic satellite
LAS	LAGEOS apogee stage
AKM	Apogee kick motor
CCR	Cubic corner retroreflector
LAND	LAGEOS active nutation damper
ASE	Airborne support equipment
ISS	IRIS spinning stage
PAF	Payload attach fitting.
SRM	Solid rocket motor
DH	Data handling