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# GALILEO ORBITER SPACECRAFT AND INSTRUMENTATION

**David Morrison**

*Office of Space Science*
*NASA Headquarters*
*Washington, DC 20546*

## ABSTRACT

The Galileo Jupiter orbiter and its science investigations are briefly described as a baseline design for a Saturn orbiter.

## INTRODUCTION

An essential element of the proposed SOP$^2$ mission is a long-lived Saturn orbiter. The orbiter spacecraft will release the atmosphere probes to both Saturn and Titan and will serve as the relay point for transmitting the probe data to Earth; it will then remain in orbit for two or more years investigating the planet, its rings and satellites, and its magnetosphere.

As presently envisioned, the SOP$^2$ orbiter is modeled closely on the Galileo Jupiter orbiter, just as the SOP$^2$ probes are expected to be derivatives of the Galileo probe (Colin, 1978). In this paper, I briefly describe the Galileo orbiter and its scientific investigations as examples of the type of spacecraft and associated science that could be launched to Saturn in the mid-1980's. It is important to note, however, that these Galileo designs are not fixed at the time of this writing (spring 1978), and that in any case signficant modifications, particularly in scientific experiments, could be accommodated for SOP$^2$.

## THE GALILEO SPACECRAFT

The Galileo orbiter is a new departure in planetary spacecraft. In the past, these spacecraft have been either three-axis stabilized (the Mariner/Voyager class) or spin stabilized (the Pioneer class). The Mariner vehicles are optimized for remote sensing, since they are highly stable platforms from which pointed experiments, such as those involving cameras and spectrometers, can be carried out. They are also capable of highly controlled maneuvers when necessary. The simple spinning spacecraft, in contrast, provide a superior base for particles and fields experiments, which need to scan many directions rapidly to characterize the space environment of the spacecraft. The Galileo orbiter is designed to incorporate both spinning and stable mounts for scientific experiments.

The bulk of the Galileo orbiter is designed to spin around an Earth-oriented axis at several rpm. Included in this spinning section are the large telemetry antenna, the selenide radioisotope power generators, the retropropulsion system, and most of the spacecraft structure and electronics. Attached to this spinning spacecraft is a despun platform for remote sensing instruments, with a connecting bearing across which power and telemetry signals can be transmitted During cruise or when the propulsion engines are being used, this despun section can be spun-up to rotate with the rest of the spacecraft.

The Galileo communication system makes use of an S-band (about 12 cm wavelength) uplink, or command system, and both S-band and X-band (about 3 cm wavelength) downlink capabilities. The bulk of the science data will be transmitted at X-band using an Earth-directed 4.8-meter antenna with a beam-width of less than a degree. The maximum data rate from Jupiter is 115.2 kilobits per second. With even modest improvements in transmitting and receiving capabilities over the next few years, at least a comparable data rate should be achieved by SOP$^2$ from Saturn.

The Galileo retropropulsion system used to insert the spacecraft in orbit and to modify the orbit subsequently is being provided by the Federal Republic of Germany. This engine has a thrust of 400 Newtons, and a substantial fraction of the orbiter mass consists of fuel for orbit insertion and navigation needed for close flybys of the Galilean satellites. If SOP$^2$ uses an ion drive engine, the burden on the chemical retropulsion system is somewhat decreased.

Science experiments are mounted on both the spinning and despun sections of the Galileo orbiter. The magnetometer and plasma wave experiments are on a long spinning boom, while other particles and fields experiments are mounted closer to the spin axis. On the despun section, a scan platform provides the base for the imaging camera and the other remote sensing telescopes that are bore-sighted with it. The expected absolute pointing accuracy is 0.2 degree, with short-term jitter of less than 0.1 degree.

## Galileo Scientific Investigations

A science payload for Galileo was tentatively selected in August 1977, with determination of the final selection scheduled for October of 1978. The description given here refers to the tentative selection and may not represent the final Galileo payload.

Seventeen investigations were selected for Galileo, sixteen involving instruments, and one dealing with the scientific capabilities of the radio-telemetry system. Six of these are probe investigations, as described in the companion paper by Colin (1978). The other ten are on the orbiter. These experiments are listed in Table 1 and briefly described below, beginning with those on the scan platform.

Table 1. Tentatively Selected Science Investigations for the Galileo Jupiter Orbiter

| PI | Investigation |
|---|---|
| M. Belton, Kitt Peak | Imaging (CCD, 1500-mm focal length) |
| R. Carlson, JPL | Near Infrared Mapping Spectrometer |
| C. Hord, U. Colorado | Ultraviolet Spectrometer |
| A. Lacis, Goddard Institute | Photopolarimeter/Radiometer |
| M. Kivelson, UCLA | Magnetometer |
| D. Gurnett, U. Iowa | Plasma Wave Spectrometer |
| L. Frank, U. Iowa | Plasma |
| D. Williams, NOAA | Energetic Particles |
| R. Grard, ESTEC | Electron Emitter |
| E. Gruen, MPI Kernphysik | Dust |

The Imaging Investigation is actually a series of related investigations being carried out by an Imaging Science Team consisting of thirteen individually selected scientists. The camera is provided by NASA. The optics, a 1500-mm focal length catadioptric telescope and 8-position filter wheel, are Voyager hardware. However, Galileo will be the first planetary spacecraft to use the new CCD (charge coupled device) detectors, with their high quantum efficiency, linearity, large dynamic range, and extended infrared responsivity. The Galileo camera will use an 800 × 800 pixel frame, with a resolution of 20 microradians per line pair.

Also on the scan platform is the NIMS, or Near-Infrared Mapping Spectrometer. This instrument is designed primarily to identify and map mineralogical units on the Galilean satellites, but it will also be used for cloud studies and temperature sounding of the Jovian atmosphere. Its spectral sensitivity covers most of the infrared reflectance region where diagnostic spectral features of ices and silicate minerals appear. The spectral resolving power is about 100 and the angular resolution is 0.5 milliradians. Galileo is the first spacecraft to carry a NIMS-type instrument.

A Fastie-Ebert ultraviolet spectrometer (UVS) is bore-sighted with the imaging and NIMS telescopes. This UVS is designed primarily to study the composition and structure of the upper atmosphere of Jupiter and the tenuous atmospheres of the satellites. The wavelength range is from 110 to 430 nm, with spectral resolution of about 1 nm. Similar spectrometers have been flown before on Pioneer Venus and Voyager.

The final scan-platform instrument is a photopolarimeter/radiometer, designed primarily for study of cloud and haze properties on Jupiter. A 10-cm telescope and 16-position filter wheel allow measurements in a number of spectral bands in the visible and near-IR. A similar instrument is on Pioneer Venus, while other photopolarimeters have flown to the outer planets on Pioneers 10 and 11 and Voyager.

The next four instruments in Table 1 obtain coordinated data aimed at understanding the physical dynamics of the Jovian magnetosphere and the plasma processes that affect it. All have major inheritance from Voyager, Pioneer Venus, and other planetary and Earth-orbiting spacecraft. First of these is the Magnetometer, mounted on a boom on the spinning part of the spacecraft. Dual triaxial fluxgate magnetometers are used, sensitive to magnetic fields over the dynamic range from near 1 milligamma to as high as 16 kilogamma.

Also mounted on the magnetometer boom are the antennas for the Plasma Wave Spectrometer, which directly measures the varying electric and magnetic fields in the Jovian plasma. Frequency range is from 6 Hz to 300 kHz.

The Plasma investigation will measure both positive ions and electrons in the plasma over an energy range from 1 eV to 50 keV. Energy spectra will be determined as a function of direction over essentially the entire celestial sphere. Miniature mass spectrometers will also identify several major ionic species, including several components of the extended atmosphere of Io.

An Energetic Particles experiment, also mounted on the spinning section of the Galileo orbiter, consists of a series of particle telescopes to determine the energy and angular distribution of protons, electrons, and ions trapped in the Jovian magnetosphere. The energy ranges up to 11 MeV for electrons and 55 MeV per nucleon for ions. This experiment can also measure the composition of the trapped ions from He through Fe.

The final two experiments are also mounted on the spinning part of the orbiter. The Electron Emitter is designed to clamp the spacecraft potential to that of the surrounding plasma. The Dust investigation has the goal of determining the physical and dynamical properties of small dust particles or micrometeorites in the Jovian environment. Mass, velocity, and charge can be determined over the mass range from $10^{-10}$ to $10^{-6}$ gram. This is a much higher sensitivity than has been achieved in past experiments to measure dust in the outer solar system.

## Possible Modifications for Saturn

If the Galileo spacecraft proves satisfactory for the Jupiter mission, it will probably need only slight modifications for Saturn. The interfaces will need substantial alteration to accommodate the ion drive propulsion system and the second probe, but the basic spacecraft need not change significantly. Less radiation shielding will be required, but the spacecraft power sources and telemetry rate may need enhancement if the performance at Saturn is to equal that expected of Galileo at Jupiter.

More substantial changes may be needed in the scientific payload. On Galileo, there is a heavy emphasis on particles and fields measurements: we do not yet know if Saturn has a substantial magnetosphere, and it is possible that after the Pioneer 11 and Voyager flyoys we will not conclude that a similar emphasis in this area is needed for a Saturn orbiter.

In the remote sensing area, however, our present limited knowledge suggests two additions to the payload. Interest in atmospheric dynamics on Saturn and perhaps also on Titan argues for the addition of a second, wide-angle CCD camera to obtain synoptic global-scale images. Such coverage will be very limited on Galileo, but in the case of Jupiter many goals in atmospheric dynamics can perhaps be carried out by the Space Telescope. For Saturn, in contrast, imaging from an orbiter seems to be required. The second new instrument suggested by discussions at this workshop is a submillimeter radiometer for studies of the rings. A great deal of information on particle sizes and bulk composition may reside in radiation emitted at wavelengths from 100 $\mu$m to 1 mm, and no existing spacecraft instrument operates in this area.

At present, of course, all of these suggestions concerning the detailed spacecraft design and science payload of a SOP$^2$ mission are highly speculative. Only after the Pioneer 11 and Voyager flybys will we have the information needed to assess these issues properly. The purpose of the present exercise is to show that even the unmodified Galileo orbiter and science instruments are reasonably well suited to a Saturn mission.

## REFERENCES

Colin, L. (1978). Outer Planet Probe Missions, Designs, and Science. In this volume.