The Jason-1 satellite design and development status.

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ABSTRACT: The Jason satellite is the first satellite based on the PROTEUS small satellite platform. The stated objectives of the PROTEUS product line are to reduce costs and development time, while maintaining a high level of performances for science missions.

The Jason mission is a follow-on cooperative effort between NASA and CNES for the continuous observation of the oceans. Jason will ensure ocean measurement survey until 2005, as a successor to the TOPEX-POSEIDON mission.

The JASON satellite carries on-board instrumentation unherited from the TOPEX program but at much less mass, power and cost. The satellite will be launched on-board a Delta 2 launcher in May 2000, from Vandenberg Air Force Base.

The JASON CDR has been held in July 98. Satellite elements are now in development. Platform and payload module integration will start by end of 98.

The Jason Mission

The JASON spacecraft main payload is a high-precision radar altimeter to take measurements of sea-surface height over 90% of the world's ice-free oceans. The satellite orbits at an altitude of 1336 kilometers above the earth at an inclination of 66 degrees. JASON measures the distance from the satellite to the sea surface to within approximately two and a half centimeter.

Scientists combine this measurement with precise orbit determination, allowing them to locate the spacecraft to within three or four centimeters. These measurements allow JASON to achieve its primary mission objective -- the production of accurate topographic maps of all the world's oceans.

The Jason Satellite

The Jason satellite uses the standard multi-purposes PROTEUS platform. A dedicated Payload Instrument Module (PIM) has been built for this mission in order to accommodate the instruments. The payload module has the same structural definition as the platform. Design is made such as to thermally decouple the payload from the platform.

The JASON satellite is a protoflight model. The Platform has already been successfully qualified on a structural mock-up (static, sine, acoustics, shocks) and a platform thermal mock-up will be fully tested by end of summer 98.

The JASON satellite is designed for 3 years lifetime but against a 5 years radiation environment (1336 kms orbit). Consumables are sized for a 5 years mission. The maximum power consumption is about 435 W. The overall satellite mass is less than 500 kgs with full loading of hydrazine (28 kgs) and it is about 3.4 m in height. Due to the high orbit nodal rate (2° per day), the satellite performs a yaw steering attitude control to provide solar array proper solar illumination. The payload science data rate of 25 kbps is continuously stored in the on-board mass-memory and is downloaded at each terminal visibility at 613 Kbits/s.

The Jason satellite is compatible with a Delta 2 dual-launch configuration.
The Mission Instruments

The payload is comprised of five instruments:

- The **POSEIDON-2**, low-power, low-mass solid-state altimeter derived from TOPEX Poseidon-1 altimeter, sends radar pulses at 2 frequencies (13.6 and 5.3 GHz), using a 1.2 meters antenna on the nadir side of the satellite. It is fully redundant.

- The **Jason Microwave Radiometer (JMR)** is a 3 frequencies sensor used to estimate the atmospheric water vapor content in the nadir column, in order to correct the radar altimetry measurement. The design is an improved heritage from the TOPEX radiometer. It is internally redundant.

- The **DORIS Receiver** is a radio tracking system developed by CNES, using the Doppler shift of ground beacons to provide an unprecedented precision orbit determination. The Jason DORIS receiver will be smaller than the actual Topex design. It is comprised of a Doppler receiver, an Ultra Stable Oscillator and the associated antenna. It is totally redundant.

- The **Turbo-Rogue Space Receiver (TRSR)** is a GPS receiver which allows to track up to 12 GPS satellites. With augmented ground processing, the satellite position can be determined to within 5 centimeters. This POD experiment complements the DORIS measurement. The instrument is fully redundant.

- The **Laser Retroreflector (LRA)** is a set of quartz corner-cubes monted on the nadir side of the spacecraft. This item is reflecting incoming laser beams from the ground and allows to calibrate the radial position of the satellite.

The Instruments are all accommodated inside the Payload Module. The Star Tracker is located on the Payload Module in order to minimize attitude errors.

The instruments are connected to the platform Electrical system via the standard harness interface comprised of power lines, discrete commands and acquisitions, and 1553 data bus for telecommand and scientific data transmission.
Fig.2 The Payload Instrument module

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Mass (kg)</th>
<th>Power (W)</th>
<th>Data Rate (Kbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>POSEIDON-2</td>
<td>55</td>
<td>78</td>
<td>23</td>
</tr>
<tr>
<td>JMR</td>
<td>27</td>
<td>24</td>
<td>1</td>
</tr>
<tr>
<td>TRSR</td>
<td>8.3</td>
<td>17.5</td>
<td>0.6</td>
</tr>
<tr>
<td>DORIS</td>
<td>28</td>
<td>28</td>
<td>0.35</td>
</tr>
<tr>
<td>LRA</td>
<td>2.2</td>
<td>N.A</td>
<td>N.A</td>
</tr>
</tbody>
</table>

The PROTEUS Platform

The PROTEUS platform has been designed according to a set of potential missions ranging from astronomy, earth observations to telecommunications constellations.

Classical subsystem breakdown has been replaced by a functional chain breakdown, aiming at suppressing an intermediate layer between the prime and the equipment supplier. The functional chains are:

- Command/Control
- Mechanical/Structural
- Electrical
- Attitude and Orbit Control
- Thermal

- Payload

This allows for a more efficient coordination of the main functions to achieve at system level, each functional chain being managed by a dedicated architect, and overall synthesis performed by the system manager.

The platform mixes new technologies and off-the-shelf equipment. New major development are:

- The Data Handling Unit,
- The Star Tracker,

Technically, the Jason satellite will use the generic platform architecture. Adaptations are limited to relatively minor changes (electrical interfaces, application software modules).

Platform description

A complex structural mechanical adapter has been built to provide a load path from the cylindrical launcher adapter to the cubic structure (1m size). The panels making the box have both functions of providing structural strength as well as surfaces to accommodate the equipment. Lateral panels provide also heat rejection surfaces for thermal control (Second Surface Mirror). It is basically the same design for the Payload Instrument Module.

The platform accommodates in the lower part mono-propellant hydrazine propulsion with a 40 liters tank (28 kgs of hydrazine, but only 9 Kgs are strictly necessary for the Jason Mission), valves, tubing and four 1N thrusters. The propulsion is not used for attitude control but only for orbit acquisition and maintenance. The upper panel offers a simple mechanical interface for the Payload module fixation, through four attachment points, thermally decoupling the payload from the platform.

Two solar wings (Silicon cells) are attached near to the satellite center of mass with two one axis stepping motor mechanisms. Platform attitude control provides a second rotation axis (yaw steering) allowing 90% recovery of sunlight in the case of the JASON orbit.
The normal in-orbit satellite Attitude Control is based on a GPS/ Gyro-stellar concept. The platform GPS (Distinct from the Payload GPS) provides satellite position information for accurate orbit ephemeris determination and accurate on-board time delivery. Accurate gyrometers are used for stability requirements, attitude propagation and to allow low frequency attitude updating using a low-cost, simple wide field of view star-tracker. Four small reaction wheels will generate correcting torques for attitude command and are desaturated using magneto-torquers.

Satellite power is distributed by means of a single non-regulated primary electrical bus (23-36 volts), using a single recurrent, 40 A-h NiCd battery (SPOT 4 design), connected to 8 (1.5 x 0.8 m) Silicon cells solar panels.

The system Command-Control architecture is based on a simple redunded architecture shared in two half satellites, each under the control of one side of the Data Handling Unit. Units that cannot be redunded or are critical for the mission are shared between the two processors modules of the DHU. Platform and payload electrical interfaces, power distribution, data handling and storage are managed by the Data Handling Unit, using a 31750 rad-hardened processor. Operational communication between the payload and the data handling unit is ensured by a 1553 bus.

The on-board storage capacity is about 2 Gbits End Of Life. A 613 Kbps S-band QPSK is available for telemetry. A telecommand capacity is provided by a 4 kbps S-Band up-link. The communication protocol uses the CCDS standard.

**Satellite operation**

The Jason satellite will use the standard operating modes of the PROTEUS platform which are designed to suit a wide variety of missions.

The satellite is set off during launch except TC decoder, mass memory and Reconfiguration Module (start-up mode). At launcher separation, breakwires separation in the umbilical are used to engage the initialization sequence: the processor module is set on, the OBS (On-Board Software) is loaded from EEPROM into the RAM, and initiates the deployment sequence. After deployment, the satellite will enter nominally into Safe Hold Mode (SHM) as a stable and robust mode prior to engage the nominal attitude acquisition sequence. SHM brings the satellite launcher interface side perpendicular to the sun-line with the Solar Array in canonical position (S.A perpendicular to satellite main axis). Reaction wheels are set at constant speed to provide gyroscopic stiffness around X axis. Magnetotorquers actuation together with gyroscopic stiffness hold the satellite in the sun direction.

Transition from Safe Mode to Nominal Operation is commanded by the ground. Nominally, the Platform is designed to be controlled by a single ground station. For Jason, there will be 2 ground stations available, according to the data latency requirement at mission level.

If a failure occurs on board, automatisms are in charge of the decision to switch the satellite into Safe Hold Mode. No failure isolation is performed on-board. Redundancy switching is always managed by the ground. Satellite commandability is maintained as simple as possible.

**Jason performances summary**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite mass:</td>
<td>500 kg</td>
</tr>
<tr>
<td>Satellite power:</td>
<td>435 W</td>
</tr>
<tr>
<td>Lifetime:</td>
<td>Up to 5 years</td>
</tr>
<tr>
<td>Bus dry mass:</td>
<td>271 kg</td>
</tr>
<tr>
<td>Bus consumption:</td>
<td>280 W max.</td>
</tr>
<tr>
<td>Bus size (mm):</td>
<td>954 x 954 x 1000</td>
</tr>
<tr>
<td>Payload module size (mm):</td>
<td>954 x 954 x 1218</td>
</tr>
<tr>
<td>Storage capacity:</td>
<td>2 Gbits (EOL)</td>
</tr>
<tr>
<td>Downlink capacity:</td>
<td>650 kbps</td>
</tr>
<tr>
<td>Uplink capacity:</td>
<td>4 kbps</td>
</tr>
<tr>
<td>Pointing accuracy:</td>
<td>0.035°</td>
</tr>
<tr>
<td>ΔV capacity:</td>
<td>Up to 120 m/s</td>
</tr>
</tbody>
</table>

**Satellite development status**

The satellite Critical Design Review has been held end of June 98. No showstoppers or critical items were raised. Despite a high pressure schedule environment, activities are progressing satisfactorily. Mechanical qualification of the platform is now achieved, and the thermal qualification should be done by the end of summer 98.
Payload instrument Engineering Models are currently built and are under testing. Instrument flight hardware delivery shall take place at the end of 98.

Satellite electrical, functional and software validation is achieved through the implementation of a System Validation Bench on which the mission software and electrical interfaces can be validated.

The first version of the bench is purely a software validation bench, with all Instruments and platform equipment numerically simulated. On-board software validation shall start end of 98. Functional validation is performed with real equipment (engineering models) representing all critical functions of the satellite (ACS, Power, Coms...) and the payload instruments, on a dedicated bench with a representative Data Handling Unit. System Functional tests shall start beginning of 99.

The beginning of platform flight model mechanical integration is scheduled in November 98, with payload module integration in parallel. After mating of the payload on the platform, the satellite integration and qualification campaign shall last approximately 6 months.

The launcher

JASON is scheduled on a Delta 2 dual launch in May 2000. In order to decrease the cost of launching scientific missions, NASA has planned to share the JASON launch with another small mission called TIMED. This dual launch will be one of the first to use the new Dual Payload Attach Fitting developed by Boeing in order to accommodate two satellites inside the same fairing (see fig.4).

Thanks to Delta 2 performances resources, the launcher can accommodate those 2 complex missions despite significant differences of altitude and inclinations. The dual launch configuration has nearly no impacts with respect to a standard single satellite mission.

Conclusion

The development status of Jason is satisfactory, despite a strong schedule pressure environment. The satellite development enters now a critical step with the functional validation on the system test benches, with representative hardware.

The close cooperation between the customer (CNES) and the prime (ALCATEL SPACE) during the design phase and all along the validation phase is a key factor for keeping up with the new « faster, better, cheaper » paradigm.
Fig. 4. Jason launch configuration (courtesy of BOEING Co.)
Fig. 5. Jason shortly after separation from Delta 2 second stage.