PRELIMINARY DESIGN AND OPERATIONS 
OF PALAMEDE MICROSATELLITE

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ABSTRACT

The current status of Palamede microsatellite is presented [1]. The satellite is designed by students of Politecnico di Milano. Following a general overview of the main subsystems, a detailed description of the electronic architecture and operations sequence will be presented. The satellite configuration should be frozen by September 2001, and launch is currently foreseen in year 2003.

1. PALAMEDE MISSION

The Microsatellite Palamede will be launched into a sun-synchronous Low Earth Orbit (LEO), with an altitude of 800 km and an inclination of 98.6 deg. It will be a secondary payload and, hence, its design is flexible enough to be flown on different orbits. The mission of Palamede has two aims: the scientific one is to use and test components not space qualified, the second one is to take photos of chosen areas of the Earth.

2. PALAMEDE LAYOUT

Palamede is parallelepiped-shaped with the square bases of 40 cm side and a height of 80 cm. Its structure, totally realised in aluminium alloy, is composed by four ‘L’ cross section beams at the corners and two machined plates, suitably stiffened with ribs. The electronic box is in central position and has a thickness of 10 mm to protect all the electronic boards from the effects of the space environment. The satellite electronics is powered by four solar arrays, placed on the lateral sides, when it is lightened by the Sun and by a Lithium battery, installed over the electronic box, when it is in eclipse. The CCD camera is on the lower plane as shown in Figure 1. The other payload is represented by the GPS system used for the attitude determination and to determine the orbit of the satellite.
A sun sensor, one three-axis magnetometer and three magneto torques with a momentum wheel constitute the ADCS. The electronic box contains all the electronic boards, based on the PC-104 standard, the radiomodem and GPS for an average power dissipation of 28.9 W.

![Figure 1. Layout of the Microsatellite PALAMEDE](image)

3. BREADBOARDING ACTIVITIES: STRUCTURE, PAYLOAD, GPS, POWER S/S

Some preliminary breadboarding tests were performed in the early design phases. These activities are described in [2,3] for what concern respectively the GPS-based attitude determination and the CCD camera performance evaluation. For the other components, an extensive test campaign has been carried on for the single items. For example, the performance in vacuum of the electronics (on board computer, data acquisition board, DC/DC converter, all based on the standard PC-104 and a radio modem) have been evaluated during dedicated test campaigns in a thermal vacuum chamber. A test campaign has been performed on the batteries as well, both on commercial Ni-Cd and Li-Ion cells, in order to define their efficiency and, hence, their thermal dissipation, and definitely to select the most effective one for the PALAMEDE mission.

3.1 Structure

A preliminary satellite structural/mechanical design has been made considering the need to accommodate components and requirements of ADCS subsystem as well as inertia characteristics. To evaluate strength and stiffness characteristics FEM analysis have been made. Software MSC-NASTRAN has been used for analysis and MSC-PATRAN to build the model, reported in figure 2, and for post processing.
Plates, stiffening ribs and angular bars have been modelled as plate elements (CQUAD4) that support forces also out of their plane.

Non structural parts (batteries, solar panels, magnetic coils, camera and boom) have been modelled as point mass elements and connected to the structure using rigid elements (RBE3). Launcher constraint has been modelled not allowing translations and rotations to the nodes positioned in launcher interface connecting points.

The following analyses have been made:

- Modal identification, to verify the first mode is above 50 Hz;
- Static analysis in which loads are quasi static accelerations during launch phases and static equivalent to random vibration loads.
- Random vibrations response to determine vibrations level acting on electronic cards.

After that, to evaluate the accuracy of FEM analyses; a satellite model was built, composed by two plates and by angular elements, namely the structural cell of PALAMEDE (see Fig. 3). The resonance frequencies have been compared with resonance frequencies of the corresponding FEM model.
Tests have been made exciting the structure in three orthogonal directions with loads checked by a load cell on the hammer used as actuator. With a set of accelerometers it has been found at what frequencies the acceleration imposed to the model were amplified by the structure. A free-free constraint was chosen for the tests. The model has been hanging using an elastic string. In this way pendulum and extension frequencies were two orders of magnitude lower than model proper frequencies. A maximum difference of 10% has been found between frequencies of real model and FEM model.

4. ELECTRONIC ARCHITECTURE

The electronic boards of Microsatellite Palamede are based on the industrial standard PC-104. The main characteristic of this solution is the possibility to connect more boards one above the other to form a so-called Biscuit PC. This allows mounting appropriately and without difficulties different boards, peripherals and devices necessary to the payload and to all the operations of the mission, as illustrated in figure 4.
The seven PC 104 boards used on Microsatellite PALAMEDE are the following:

- Power supply board;
- Main board;
- Data acquisition boards (2 items);
- Serial board (4 ports);
- Relay output board;
- Frame grabber.

All these boards are placed in the electronic box. However, they are not all positioned one on the other for two reasons: the first is the reduction of the dimensions of the box, the second is to comply with the thermal analysis that suggests to stack only a few boards with a very low power dissipation to be able to cool them. For these reasons the boards are mounted in two stacks with a suitable connection board. The electronic box will have the dimensions of 40x40x7 cm.

The main bus of the Microsatellite is at 28 V and it supplies directly the magnetometer and the DC/DC converter. This DC/DC converter is a PC-104 board and it has two outputs: the first at 5 V and the second at 12 V. Therefore, as we see in Table 1, it is able to supply all the
PC-104 boards and all the other peripherals. Beside that, the main bus is semi-regulated, so that its voltage can vary about from 26 V to 29 V when the satellite is supplied by the battery. This is not a problem because the DC/DC converter has a wide range of input voltage.

<table>
<thead>
<tr>
<th>Component</th>
<th>Supply Voltage</th>
<th>Nominal Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC/DC converter</td>
<td>6 - 40 V</td>
<td>28 V (Main Bus)</td>
</tr>
<tr>
<td>Main board</td>
<td>PC-104</td>
<td>5 V</td>
</tr>
<tr>
<td>Relay board</td>
<td>PC-104</td>
<td>5 V</td>
</tr>
<tr>
<td>Data acquisition board</td>
<td>PC-104</td>
<td>5 V</td>
</tr>
<tr>
<td>Serial ports board</td>
<td>PC-104</td>
<td>5 V</td>
</tr>
<tr>
<td>Frame grabber</td>
<td>PC-104</td>
<td>5 V</td>
</tr>
<tr>
<td>GPS receiver</td>
<td>5 V</td>
<td>5 V</td>
</tr>
<tr>
<td>GPS Splitter</td>
<td>12 V</td>
<td>12 V</td>
</tr>
<tr>
<td>Radiomodem</td>
<td>12 V</td>
<td>12 V</td>
</tr>
<tr>
<td>CCD camera</td>
<td>12 V</td>
<td>12 V</td>
</tr>
<tr>
<td>Magnetic torques</td>
<td>10,5 ÷ 14 V</td>
<td>12 V</td>
</tr>
<tr>
<td>Momentum wheel</td>
<td>14 ± 3 V</td>
<td>12 V</td>
</tr>
<tr>
<td>Magnetometer</td>
<td>14 - 45 V</td>
<td>28 V</td>
</tr>
</tbody>
</table>

Table 1. Power supply of the components of Microsatellite Palamede.

The heart of all the operations on board is the main board with a 80386 Intel processor and a Solid State Disk as mass memory. It checks all the functions of the satellite, acquires data and images from the data acquisition boards and from the frame grabber and controls the relay boards.

The relay board has 8 opto isolated inputs commanded by the computer and 8 outputs that allow switching on/off all the peripherals, such as the radio modem, the GPS receiver, the GPS splitter, the CCD camera and the actuators of the ADCS. In this way we can act on each component of the satellite to turn them on following a precise sequence and to turn them off in case of emergency or of bad working.

A schematic layout of the electrical connections is presented in figure 5.

5. ON ORBIT OPERATIONS

Once the design of the microsatellite Palamede has been completed in its first iteration, we have analysed the operations from the moment in which the satellite is released by the launcher till all the subsystems are correctly operating.

The sequence of these operations is presented in figure 6.

We briefly analyse each phase of the operations of the mission of Microsatellite Palamede:

- **Phase 1: Start**
  The satellite, once released by the launcher, is automatically switch on, with some switches that are turned on at the moment of satellite release;

- **Phase 2: Supply Main bus**
  The battery is charged and begins to supply the main bus and all the components directly connected at it, the DC/DC converter, the beacon and the magnetometer;

- **Phase 3: Switch on of the computer and of the PC-104 boards**
  Simultaneously with the phase 2 the computer and all the other PC-104 boards switch on too. The data acquisition boards begin to acquire the measured parameters to examine the health of the subsystems of the satellite;
Phase 4: Switch on of the ADCS

The detumbling algorithm of the attitude determination is started, the actuators of the ADCS are activated: magnetic torques and the momentum wheel, controlled by the relay PC-104 board;
- **Phase 5: Switch on the radio modem**
The turn on of the radio modem is controlled by the relay board and takes place when the satellite is in nominal attitude and close to a ground station;

- **Phase 6: Switch on of the CCD Camera**
The CCD camera is turned on by the relay board and is activated when the satellite has reached its nominal attitude, provided illumination condition are suitable [3];

- **Phase 7: Switch on the GPS system**
The turn on of the GPS system consists in the activation of two components: the GPS receiver and the splitter. It is controlled by the relay board too and it is turned on when the satellite is in nominal attitude.

The nominal attitude of the satellite is reached when the CCD camera is pointed to the Earth and the satellite has an angular rate lower than 2 deg/s around the roll axis and lower than 2,5 deg/s around the pitch axis. These values are necessary to have photos of good quality but also to be able to communicate with the ground station.

![Figure 6. Nominal Operations of Microsatellite PALAMEDE](image-url)
The image acquisition system, the communication system and the GPS system can be turned on independently because they are connected and controlled by the relay board. The number of transition on-off has been demonstrated [6] being fully compliant with the expected Palamede lifetime of one year.

6. CONCLUSIONS

The PALAMEDE design is now going to be completed, with more and more activities on the testing and manufacturing of the flight hardware. Almost 75% of the on board electronic components are now available at Politecnico di Milano, ready for the integration. About 80% in mass of the total satellite hardware will be ready by fall 2001. The launch is foreseen by the end of 2003.

7. BIBLIOGRAPHY