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SOLAR ARRAYS FOR "VICTOR" MICRO SATELLITE

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Summary. *Microsatellite general requirements imply that some subsystems or parts should be obtained in the market and must be specially adapted or developed.*
The design and development of the μ sat panels is presented in this paper.
Preliminary power consumption calculations were performed in order to have a power requirement. Thermal control calculation provides information about service temperature of solar cells. Environmental requirements were compatibilized after an extensive study of available standards and related microsatellites literature.
Solar cells were obtained in the market and an intensive test program was performed to simulate thermal , fatige, and degradation . U.V. irradiation damage was also tested.
Optical properties were determined in order to increase confidence in theoretical calculations.
Peel test of cells bonded to aluminium plates with silicone rubber were used to define surface finishing and bond layer thickness.
Anothe prototype panel was built and tested under noise , vibration and shock enviroment.
Finally two flight panels werw built and tested for the μ-SAT Victor Satellite and continue working succesfully since its launching in August 1996.-
These activities provide μsat technical staff a good knowledge in solar panels technology, and the confidence that these parts will work properly in space conditions
Key words: *Microsatellite, Solar Panels, Solar Cells.*

1. FOREWORD

When μ-SAT Argentine Satellite was defined, (fig 1) the decision of the in-house development of its solar panels, was made. The main reason of this decision, was that solar panels technology was considered very important and valuable for future developments.
The main topics of this development are presented in this paper.

2. MICRO-SAT SOLAR PANELS GENERAL REQUIREMENTS

Taking into account preliminary studies and related literature, a set of requirements was defined "Mission Requirtements Documents Revision 01", 1995).

2.1- Power requirements

Not less than 16.5 V and 8 W with 0° incidence and 30 °C. Minimum degradation after one year in orbit must be assured.

2.2- Thermal and mechanical requirements

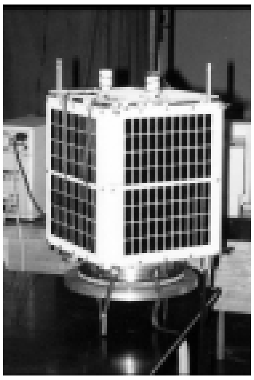

Fig.1 : µ-Sat Satellite

Solar panels thermal control must assure service temperatures between +45°C and -20 °C. Resonance frequency must be above 50 Hz, and amplification factor less than 5, in the first resonance frequency response.

2.3- Technological requirements

a) Solar cell space quality with cover glass.
b) Solar cells bonded to structure with silicone rubber space quality material.
c) Tin soldering for cells interconnection.
d) Monocoke aluminium structure lightened by chemical milling (R.Garay, E.Galian, 1997).
e) Thermal sensors positioned on each face in order to measure service temperatures.
f) Repair of damaged cells during handling, transport and/or assembly.
g) Low absortivity / high emisivity surface finish for thermal control on areas of the structure non covered by cells.
h) Easy assembly and unassembly of panels.

3. CONCEPT DEFINITION

Based on the mentioned requirements, preliminary study calculations, and size restrictions (350x350x400 mm.) design were defined. In order to perform a description, we could make a division in the following items :

3.1 Solar cells array

Using a commercial space solar cell, its data sheet and in-house test results, an array that fullfils the electrical requiremenrts was designed (”Definición del Concepto”, 1994). It consists of two series-paralell circuits with a total of 88 cells on each face.
The interface between cells and series connectors must be perfomed with thin soldering and high quality copper strips. (fig.2).

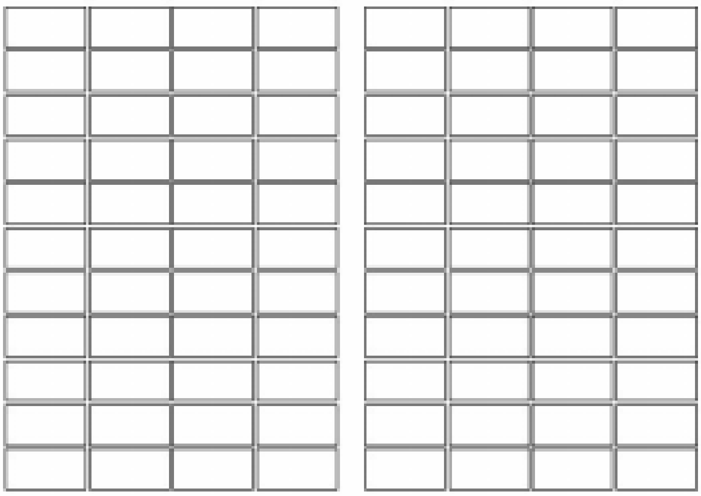

Fig.2 Solar Cell Array

3.2 Structure

Monocoke type aluminium plate welded and chemical milled. Holes, windows and thread were projected for easy interfacing and assembling. Appropriate surface finishing must be assured for proper bonding.

Plate thickness was defined after thermal control, and mechanical calculations.(L.Emmer, 1994) (fig. 3).

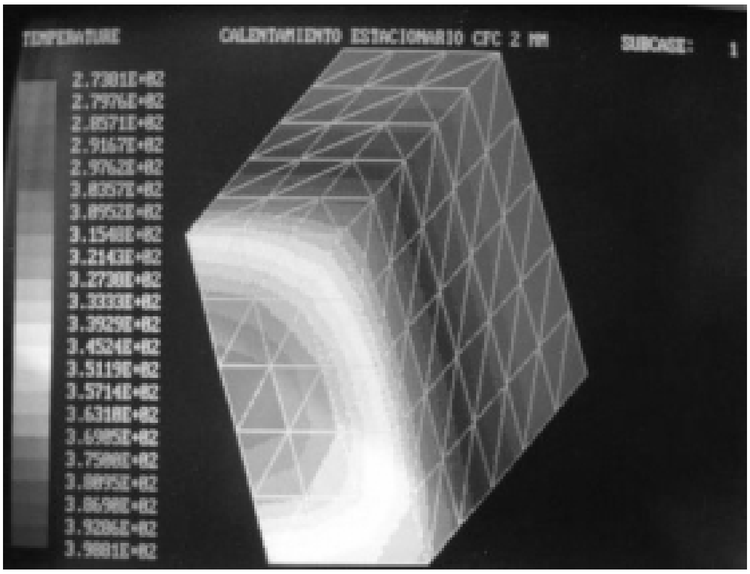

Fig.3 Thermal Analysis

3.3 Electric interfaces

A commecial connector miniature type 9 pines and electric wires according NASA D-8008, were selected.

3.4 Temperature sensor

A commercial YSI- 44005 thermistor was selected and placed in the center of the each face.

3.5 Rubber layer

A silicon rubber layer was placed on the structure surface according to an in-house developed procedure.

4. Materials and processes development

In order to produce a ditailed design and define associated material and process (M&P), a test plan was carried out:

Test specimens according to the following list werw built and evaluated.

a- M & P set up tests.

b- Environmental test (vacuum, thermal cycling and radiation)

c- Mechanical properties evaluation test.

d-Comparative tests betwen candidate materials.

e- Degradated test specimens behaviour in space environment.

The most remarkable test performed on specimens was a thermal cycling combined with UV radiation test, to evaluate survivaland degradation of an experimental panel.It consisted in a 11x2 cells array alectrically connected and bonded to an aluminium plate.

After 1200 cycles between +80 °C, and - 45 °C, and U.V radiation equivalent to nine times sun U.V radiation, no damage was detected . This specimen is shown in figure 4.

5. DETAILED DESIGN

When enough confidence in commercial parts and M.& P. was assured, a detailed design was performed. It consists in:

a- Design of the electrical array.
b- Geometrical design (drawings)
c- M & P and QA documentation.

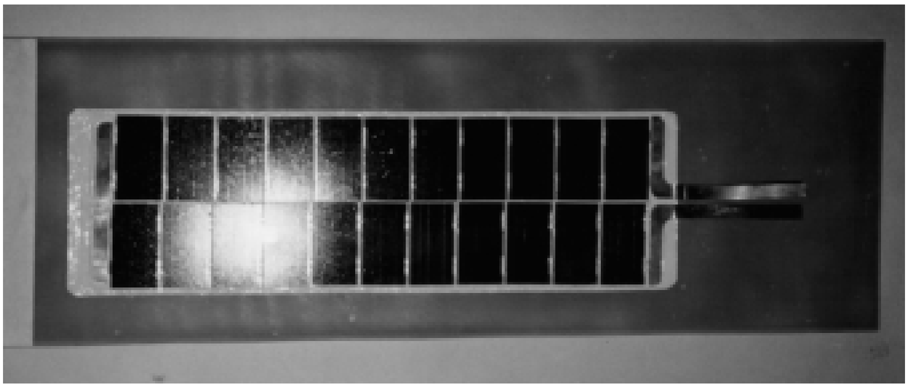

FIG.4 : EXPERIMENTAL PANEL

7. MANUFACTURING

Next step consisted in manucfaturing of a prototype, which was used as:

a- Technology test bench.
b-Design and M & P qualification.

To accomplish these activities it was necessary to:

a- Establish quality standards and procedures to evaluate parts and materials.
b- Design , build and a/or adapt Q.C devices.
c- Design, build or adapt jigs and tools for manufacturing.

All these activities are documented.

6.1 Prototype # 1

Fig.5 : Acoustic specimen.

Consisted in a support structure with two faces covered by solar cells. It was manufactured to evaluate response and damage resulting from acustic loads during launching (fig. 5).

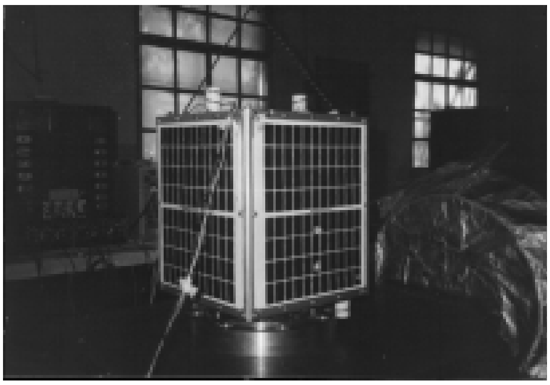

Fig.6 : Vibration Test.

6.2 Prototype # 2

Consisted in a support structure with two faces covered by solar cells. It was manufactured to evaluate in flight vibration and shoch response, and space environment behaviour (fig.6).

Fig.7 : Acoustic Test.

6.3 Flight solar panel

Finally after qualification of Prototype #2, two solar panels were built, inspected and flight qualified with vibration and electrical tests.

7. QUALIFICATION

To assure the proper in-service performance of the solar panels, a qualification plan was accomplished.

7.1 Vibration test

To confirm panels integrity under launching vibration and shock environment, a qualification test plan was designed. It consisted in :

- sinusoidal 3-axes sweep (1/2 octave/minute, 1 g) resonance test.
- Random vibration tests.
- Shock response tests.

Prototype #2 was used for this purpose (fig.6).

7.2 Acoustic tests

According to MIL-S-83576 and Lavochkin Institute recommendations, noise level in satellite placement could be very high. So, solar cells cover glass integrity must be tested.(fig.7).Accustic test was carry out using prototype #1 in a small reverberating chamber with loudspeakers and commercial amplifiers. Noise spectrum used for the test reached 140 db at 100 Hz.(ASAP User Manual DC/SC/324-90, 1993). Coverglasses breakage was optically inspected after the test, showing no damage.

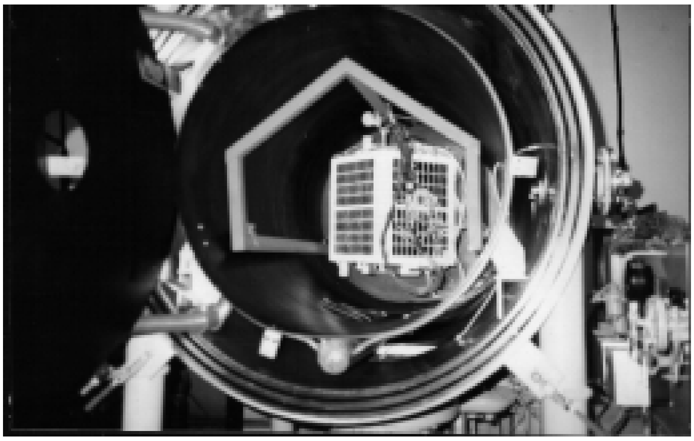

Fig.8 :Environmental Test.

7.3 Space environment test

Thermal behaviour of solar panels was evaluated during qualification test of µ-sat spacecraft.

A liquid nitrogen cooled, vacuum chamber was adapted. Thermal loads were reproduced with a xenon lamp solar simulator (R.Garay E.Galian, 1998) and a heater for earth infrared radiation simulation. The result showed that thermal control system of solar panels assured required in-service temperatures range (fig.8).

7.4 Electrical test

After acoustic and vibration tests an electrical evaluation of the panels was successfully carried out, showing no degradation in performance. A xenon lamp projector solar simulator was used for this purpose.

8. IN FLIGHT EXPERIENCE

Since launching date (august 29th 1996) careful monitoring of the panel performance has been carried out. More than 270 data set of power, tension and panel temperature were recorded and processed. Statistical calculations were adopted for data analysis assuming random attitude flight.

Two different analysis were performed:

a) Mean an standard deviation assuming gaussian-like distribution. Results are presented in Table I.

	Panel 1	**Panel 2**	**Panel 3**	**Panel 4**
Mean temperature	-0,53 °C	-0,38 °C	1,74 °C	1,60 °C
St.Deviation	8,48 °C	8,57 °C	10,46 °C	8,58 °C
Mean Voltage	16,825 V			
St.Deviation	1,619 V			
Mean Power	11,444 W			
St.Deviation	3,902 W			

Table I

b) Medians and quartile were calculated. Results are shown in "box and wiskers"diagram seen in fig. 9 and 10.

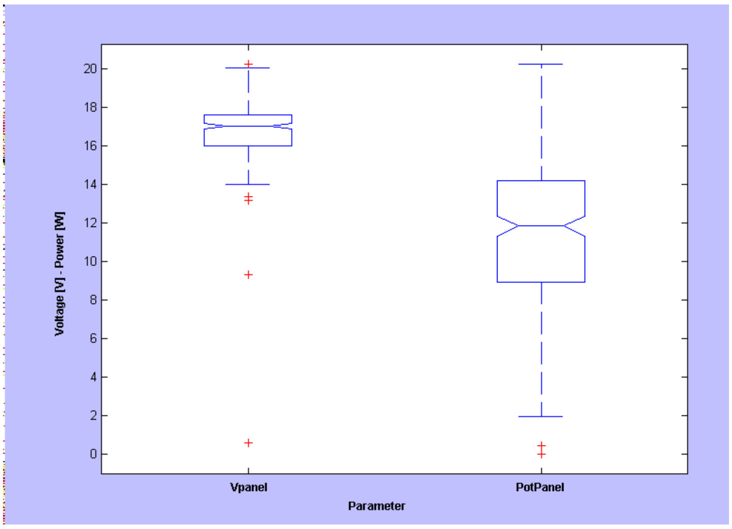

Fig.9: Medians and quartile V and W

c) Degradation evidence in panel performance could not be found in 2.5 years of monitoring. Time dependent results coming from statistical analysis of chronologically arranged data sets, show non-significant changes in mean and standard deviation values.

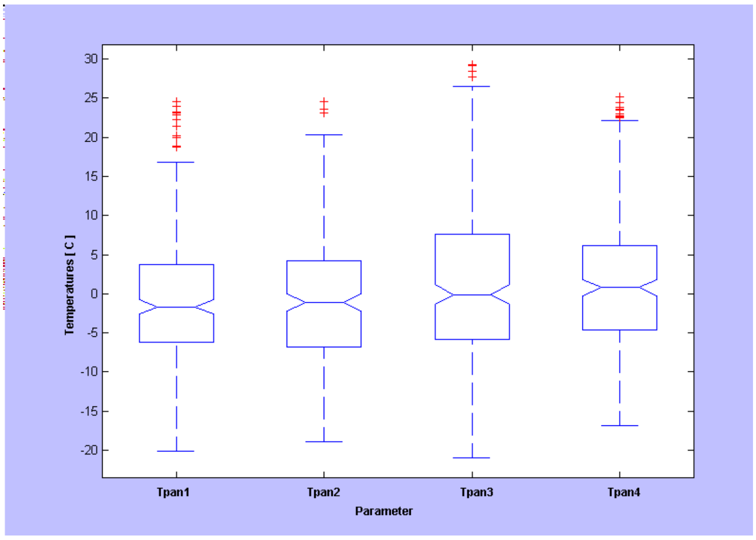

Fig 10: Medians and quartile temperatures.

9. CONCLUSIONS

Based on qualification tests, flight data analysis and satellite development program evaluation, some conclusions can be drawn:

- Design fullfils all requirement and related specifications.
- The know-how gained during development program assures a confidence in the quality and proper performance of the product.This know-how also allows the development of more complex and bigger solar panels in the future.
- The procedures developed assured repeatability and interchangeability.
- The procedure used for commercial parts qualification was in accordance with the desired quality level.
- In-flight experience demonstrates the reliability of the system and good behaviour of components in space environment.

  Cost of the micro satellite solar panel development program was affordable and compatible with the whole satellite budget.

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