Data exchange between SINDA/FLUINT and MAYA/TMG for a payload thermal control design: NINA and MITA

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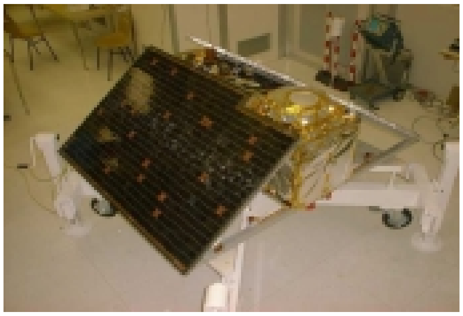
MITA minisatellite - an overview

- MITA is an Italian Space Agency (ASI) project for the development of a standard satellite platform, supported by Carlo Gavazzi Space as the Prime Contractor. The aim of the project is to develop a low cost, **modular** and **flexible** platform, 200 [kg] class, to support several kind of small missions: scientific, technological, Earth observation, communication.



FEATURES

Low recurring costs (5 MEU* * 1999 economic conditions)

Bus modularity

Fast implementation of the mission (typical C/D phase duration: 18 months)

Compatibility with different payloads (several A-phase successfully performed)

Compatibility with different launchers (Cosmos, Start, Pegasus, Vega, Delta)

NINA Payload

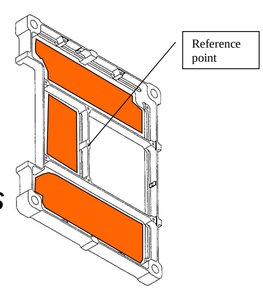
- In this mission MITA will carry the **NINA** payload, a silicon particle detector provided by INFN (Italian Institute of Nuclear Physics). The detectors are stacked to build up the tower.
  - NINA is able to detect charged particles in the 12-100 MeV range.

NINA tower (without vessel)

NINA (with vessel)

NINA payload thermal requirements

- *The silicon detector, installed on an aluminium frame (see figure) cannot be outside the range 0°C ÷ +25°C*
- *A thermal control of the whole tower (made of stacked frames) by means of heaters / thermostats was designed in an iterative way*



MITA and NINA modelling standard

- MITA SATELLITE: *MAYA TMG*
- PAYLOAD: *SINDA/FLUINT*
  - *A direct include of the NINA model in TMG was accomplished by means of a reduced model, lumping the thermal characteristics of NINA in a few nodes that were included in the large satellite model.*
  - *The NINA thermal control sizing was done on the NINA detailed model*

DATA EXCHANGE

TMG	SINDA/FLUINT
• Model size: >1000 nodes	• Thermostats set point in the detailed model
• Average power budget for the heaters	• Time dependent heater power in the detailed model

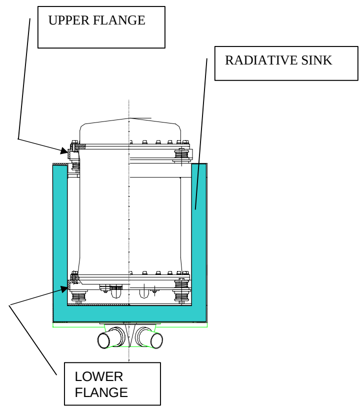
Similar temperatures!!

ENERGY CONSERVATION

- The average heater power put on NINA tower model has to be taken into account in the general satellite model
- The detailed model is used to locate precisely the thermostats and to calculate the average power dissipated by the heaters: a transient analysis is performed letting heaters switching on and off
- The reduced model provides the information how the heat power is distributed to the satellite structure by radiation /conduction
- A final check is done comparing the solutions obtained running the NINA complete model alone and the MITA satellite complete model

Payload thermal control design:
NINA and MITA
CARLO GAVAZZI SPACE SPA

NINA reduced thermal model (1)



The NINA thermal control is based on radiation heat rejection on the satellite bus lateral/rear walls.

The NINA vessel is fixed to the satellite structure by means of dampers, with a low thermal conductivity (0.1 W/K each).
•4 dampers are located on the upper NINA flange
•4 dampers are located on the lower NINA flange

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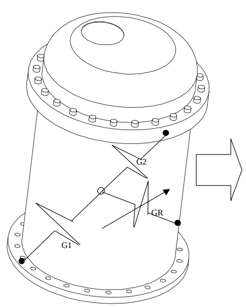
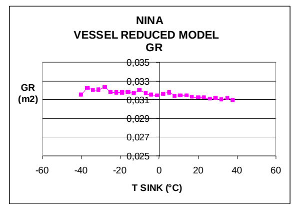
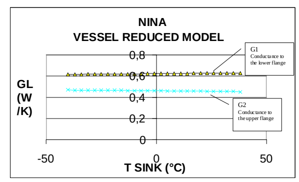
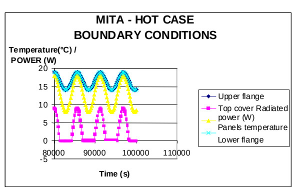
NINA reduced thermal model (2)



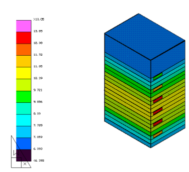
The NINA thermal model has been reduced to a simple network with 2 GL and 1 GR, temperature dependent.
The sink temperatures have been used as free parameters for calculating the reduced model conductances.

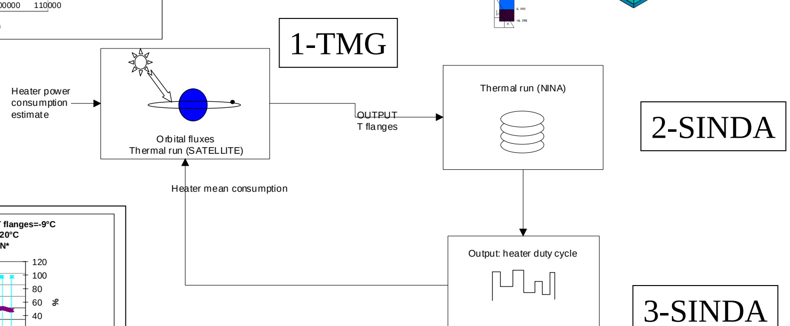


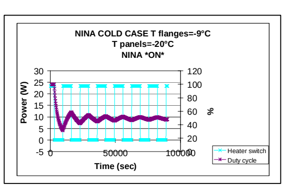




Iteration steps







Iterations description

1) Orbital loads are calculated and MITA model is run (TMG)
   TMG gives TRANSIENT sink temperatures (radiative and conductive) for NINA;

2) The detailed NINA thermal model is run (SINDA) using the actual sink, time varying - Thermostats are sized and

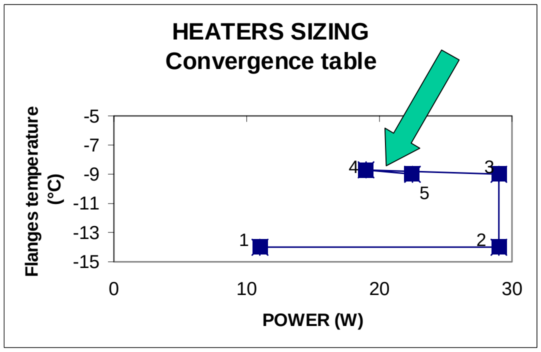
3) The average power dissipation (duty cycle) is calculated and given back to the general MITA thermal model

**) If temperatures obtained at point 1) are within 1°C the one obtained at point 2), the iteration is stopped

HEATERS SIZING

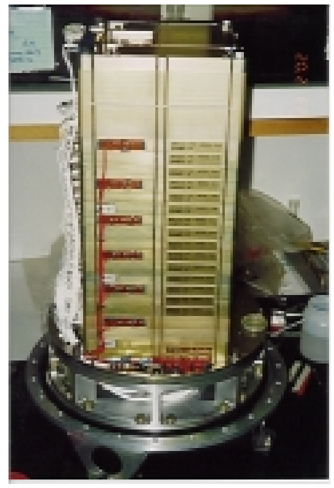
DESIGN POINT:

- Flanges temperature = -9°C
- Heaters power = 20 W



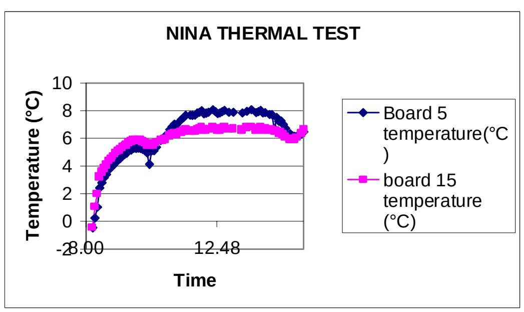
Heaters and thermostats installation

- Hardware implementation:
  - HEATERS: 6 x 3.8 W= 23 W
  - THERMOSTATS: NORMALLY OPEN,
    CLOSES @ 3 °C ±2.2 °C



NINA thermal tests

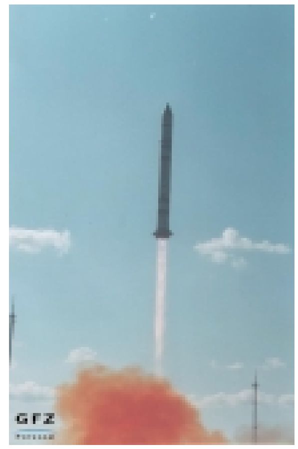
- NINA thermal tests in air allowed to validate the NINA modelling: the outer temperature was at –9°C: the boards remained over 6°C.



- The thermostats are located on the tower coldest point.

MITA launch

- 15/7/00
- 12.00 GMT
- Plesetsk Kosmodrom
- Temperature at launch 25°C
- ORBIT: i= 87°, h=450 Km



MITA THERMAL MODEL

- *In the commissioning phase a MITA thermal model was built in SINDA, confirming that the above mentioned approach was providing a correct description of the payload-to-satellite heat exchange mechanisms (with less than 1°C between the complete and the reduced model), but showing moreover that the lumped parameter approach allows a better tuning of the model, when experimental data are available.*

MITA MISSION PHASES

- *LAUNCH - DEPLOYMENT*
- *After deployment:*
  - *SAFE MODE (SUN POINTING)*
  - *NOMINAL MODE (NADIR POINTING)*
    - *Thermally affected by Beta angle changing from 0° to 90° due to orbit precession.*

In all the following graphs are plotted
•the NINA vessel temperature
•the radiator temperature (sampled in two points).

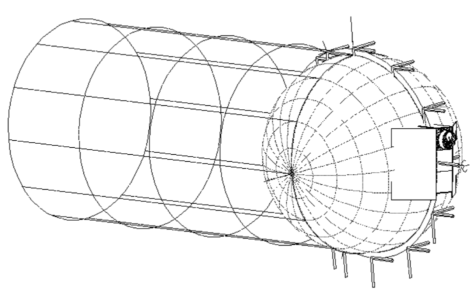
Payload thermal control design:
NINA and MITA
CARLO GAVAZZI SPACE SPA

SAFE MODE

(SUN POINTING inertial attitude, β=20°)

•In the sun pointing attitude the radiator always faces the deep space.

•For this reason, even if this attitude was combined with a hot beta angle, the NINA temperatures were at their lower limit.



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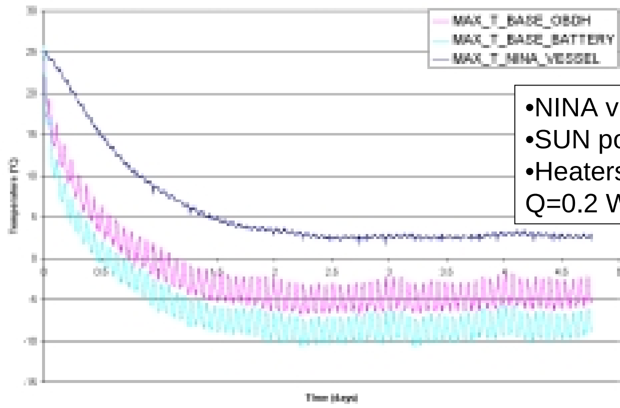
NINA thermal behaviour on orbit (1)

STABILIZATION AFTER LAUNCH



•NINA vessel 3 °C
•SUN pointing attitude
•Heaters duty cycle 1%
Q=0.2 W

Payload thermal control design:
NINA and MITA
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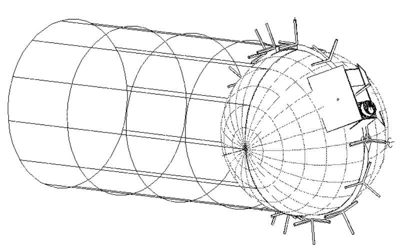
NOMINAL MODE (1)

(Nadir pointing attitude, β=0°)

- ACTUAL HOTTEST CASE
- Beta=0° (10th August 2000)

HOT DIMENSIONING CASE Beta=0°



NINA temperature between 10°C and 15°C
Heaters OFF

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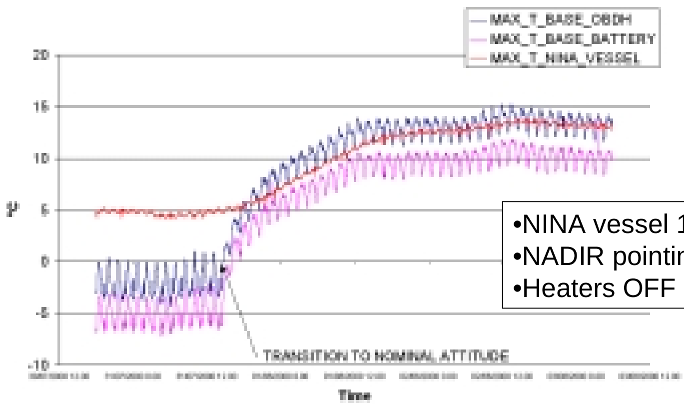
NINA thermal behaviour on orbit (2)

TRANSITION SUN POINTING NOMINAL

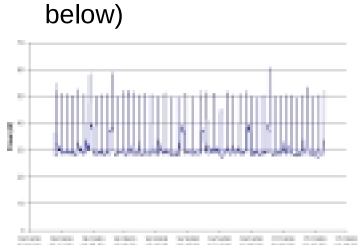


•NINA vessel 13 °C
•NADIR pointing attitude
•Heaters OFF

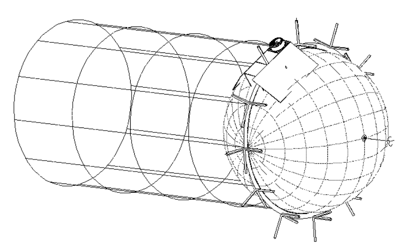
NOMINAL MODE (2)

(Nadir pointing attitude β~90°)

- ACTUAL COLDEST CASE: Beta=82°
(20th October 2000)
In this case the heaters are switching on and off (see below)

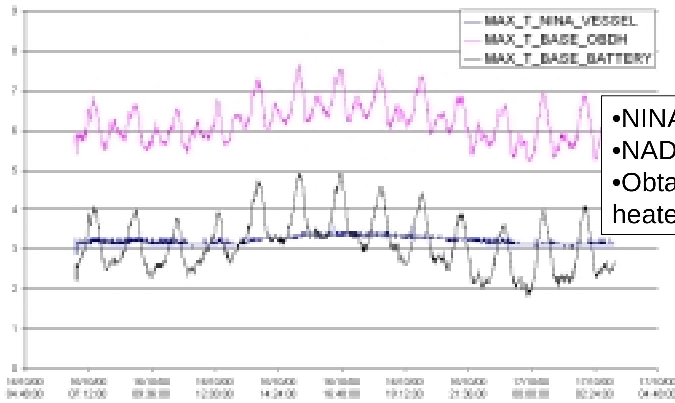


COLD DIMENSIONING CASE
Beta=90°



NINA thermal behaviour on orbit (3)

COLDEST ORBIT - NADIR POINTING



- •NINA vessel 3 °C
- •NADIR pointing attitude
- •Obtained by means of heater power (4W)

NINA thermostats operations

- Heaters switch on (at β~90°)
- Average heater power = 4 W (due to flanges temperatures hotter than predicted (1°C instead of -9°C)
- NINA temperature is kept at= 3°C by heaters

CONCLUSIONS

- The data exchange between SINDA and TMG models is possible making accurate reduced models;
- The model can be run using transient interface data;
- The thermal control is providing excellent performance, confirming models predictions.