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STRUCTURAL MODELS AND MECHANICAL TESTS IN THE DEVELOPMENT OF A COMMUNICATIONS SPACECRAFT

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ABSTRACT

The objective of this paper is to discuss the computational structural models that were developed to check the strength and orbital alignment of the communications spacecraft ARSAT-1, designed and built by INVAP S.E. at Bariloche, Argentina.

The results of the computational models were used, by the satellite developers, to check the structural integrity of the spacecraft structure and its ability to withstand the in-orbit thermal cycles without losing the communication devices pointing. In more details, it can be assessed that the output of the computational models was used by the spacecraft developers for:

- verifying, at the structural design stage, that the structure had the required strength and stiffness and that its dynamic behavior was compatible with the dynamic environment of the launching vehicle and no undesirable resonances were to be encountered;
- planning the physical tests and establishing their limits in order to protect the integrity of the spacecraft, of its instrumentation and of the testing machines;

After the execution of the physical tests the simulation results and experimental determinations were confronted to validate the computational – experimental spacecraft qualification process.

Two consecutive physical models are normally used in the qualification of a spacecraft [1] [2]:

- first the structural test model (STM): it is a full size model in which all the structural components are assembled but the actual spacecraft equipment is replaced by syntonized dummies. The wiring and insulation blankets are not installed on this model;
- finally the protoflight test model (PFM): it is basically the actual spacecraft in its launching configuration. Due to the presence of the wiring and insulation blankets this physical model presents

[1] The work presented in this paper was developed while at SIM&TEC S.A.

more damping under dynamic excitations than the structural one.

In this paper some of the tests and numerical models used to qualify the STM are discussed.

The physical tests are:

- dynamic tests: sinusoidal frequency dependent excitations (sine sweep test and acoustic excitations). These tests simulate the mechanical excitations of the spacecraft inside the launcher;
- vacuum thermal loading test (TVAC): used to simulate the thermal cycles that undergoes the spacecraft in orbit.

While the objective of the dynamic tests is to check the structural integrity of the spacecraft when inside the launching vehicle, the objective of the thermal test is to check the structural integrity and alignment preservation of the spacecraft in orbit under thermal cycles.

The spacecraft structure is assembled using threaded connections; hence, bolted joints are very important structural components; therefore, special attention was given to the simulation of their behavior: an ad hoc elastic-plastic model was used to incorporate into the model the possibility of the frictional joints slipping and the effect, on the communication devices pointing, of the slipping hysteresis that may be accumulated during the planned length of the spacecraft mission.

The effect of the shocks induced by the pyrotechnic devices used for the separation of the spacecraft from the launch vehicle and for the deployment of the solar panels and antennas were experimentally investigated using the STM and the PFM.

All the possible failure modes that can be encountered during the testing, launching and orbiting were investigated with the developed computational models and mechanical tests.

The finite element analyses were conducted using the commercial code FEMAP with NX Nastran.

The finite element model is depicted in Figure 1 and the number of elements used in the model is shown in Table 1

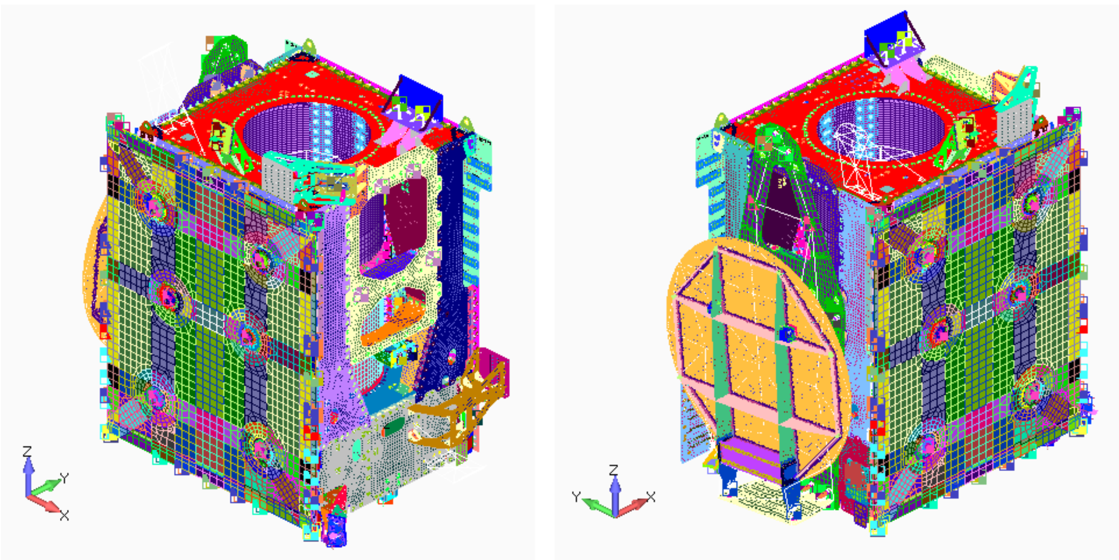


Figure 1. ARSAT-1 STM Finite Element model

Table 1. Elements used in the developed models

	ARSAT-1 STM	8 F-L SHA+SL	16 F-L SHA+SL	8 F-L SHA+HE	16 F-L SHA+HE
Element Type	**# Elements**	**# Elements**	**# Elements**	**# Elements**	**# Elements**
Bar	1,243	1,243	1,243	1,243	1,243
Beam	1,146	1,146	1,146	1,146	1,146
CBUSH	3,284	3,540	3,612	3,540	3,612
DOF spring	4,911	4,911	4,911	4,911	4,911
Plate	138,218	265,334	265,334	385,167	385,167
Laminate	276,682	276,682	276,682	276,682	276,682
Solid	0	206,488	206,488	206,488	206,488
Mass	355	371	387	371	387
Rigid	9,778	11,326	11,374	11,395	11,443
TOTAL	**435,617**	**771,041**	**771,177**	**890,943**	**891,079**

The function of the spacecraft handling adapter (SHA) is to fix the spacecraft to the shaker test table. The configuration of de shaker adapter is the same for Slip Table (SL) (X and Y horizontal directions) and Head Expander (HE) (Z vertical direction).

In Figure 2 to Figure 4 the first calculated natural modes are shown.

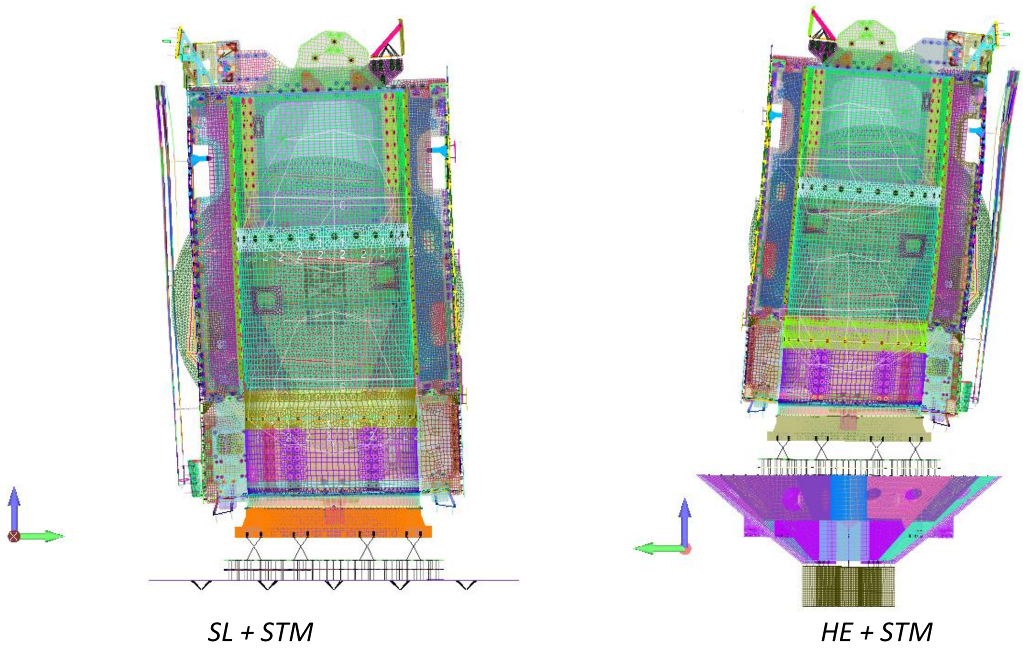
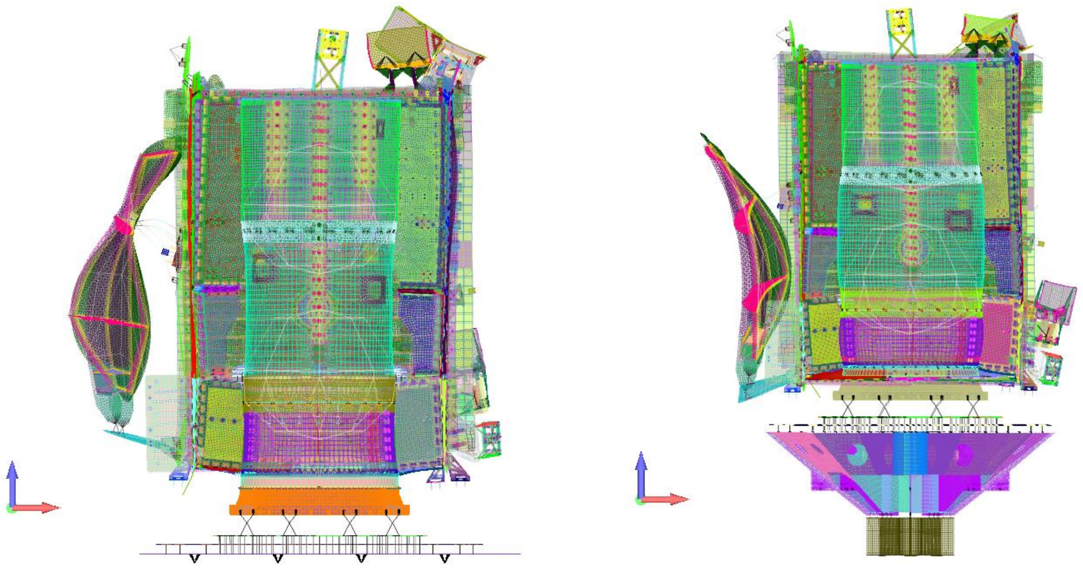
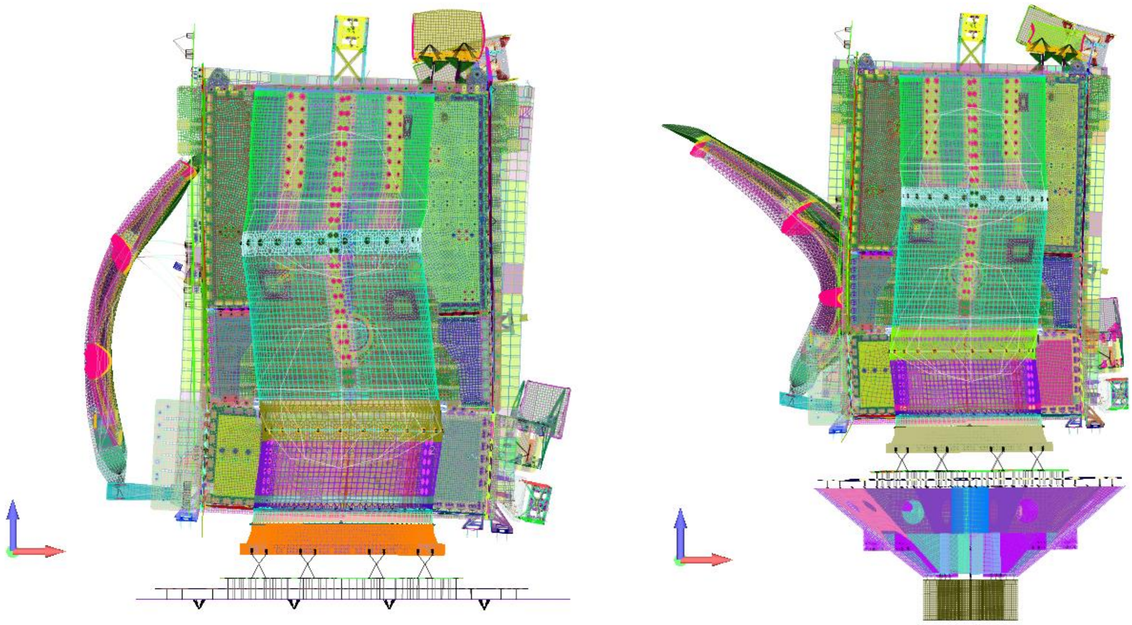


Figure 2. First flexural mode in Y-direction (8 force-links)



SL + STM *HE + STM*

Figure 3. First axial mode (8 force-links)



SL + STM *HE + STM*

Figure 4. Second flexural mode in X-direction, counter-phase tanks (8 force links)

In Figure 5 and Figure 6 the results of sine sweep test using different number of force-links between the spacecraft and the shaker are shown.

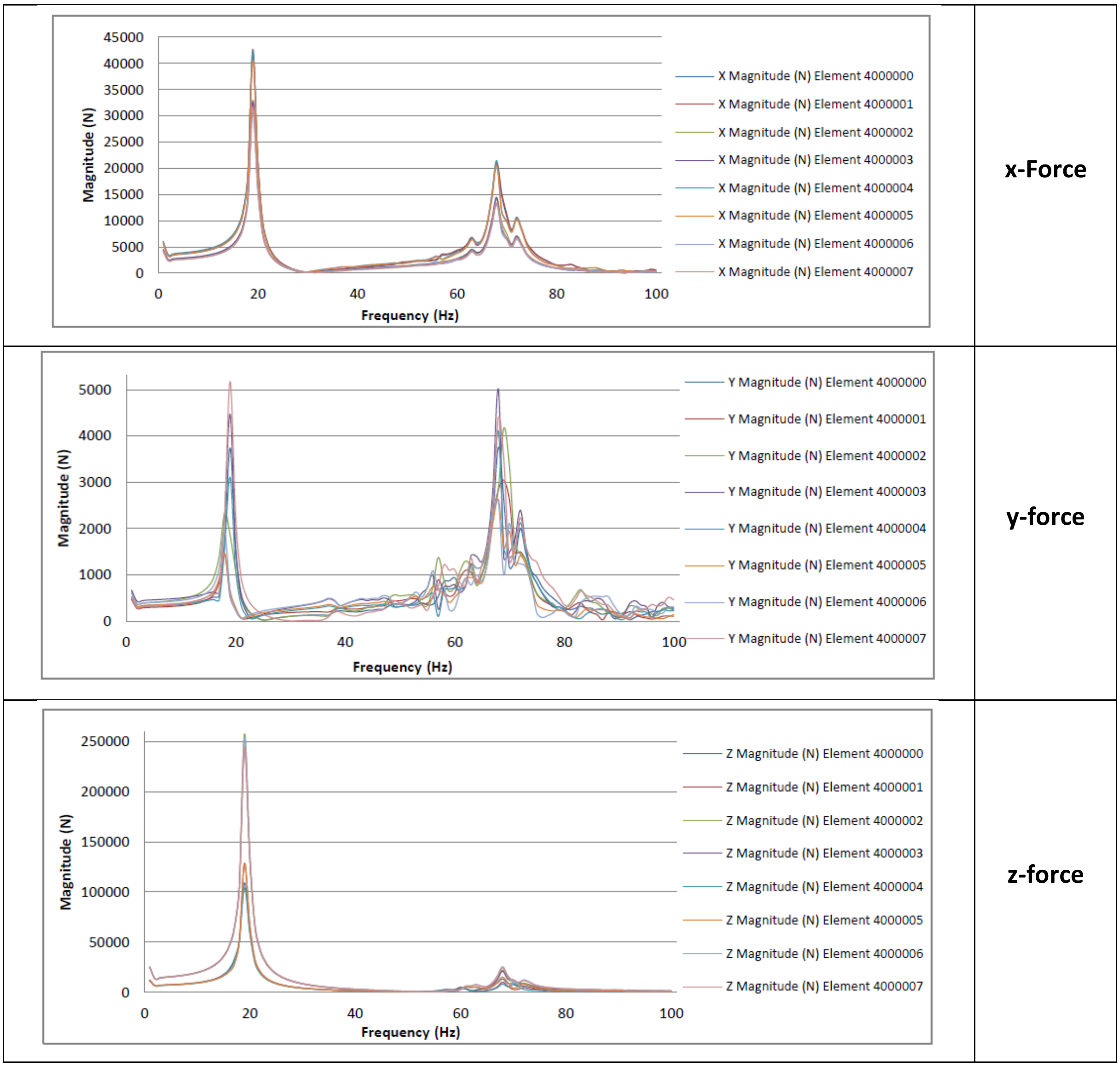


Figure 5. Forces in the 8 force-links arrangement for an excitation along the x-direction

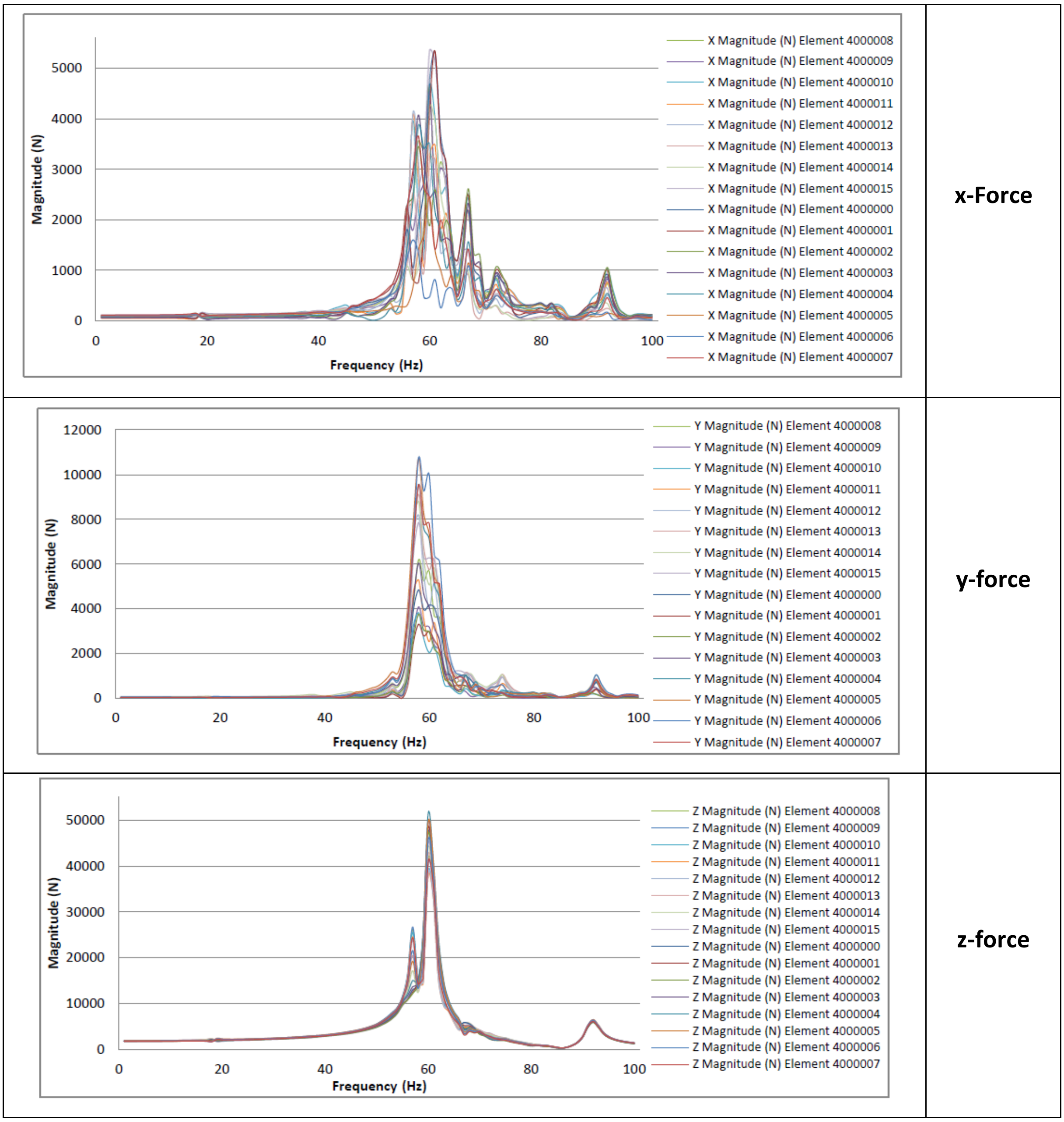


Figure 6. Forces in the 16 force-links arrangement for an excitation along the z-direction

The physical tests were developed at CEATSA (Bariloche, Argentina)

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