NEGESAR
NEw GEneration Satellite Architecture

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Abstract. Reduce to the minimum any analog-based system on board the next generation satellites and replace them with the more performing and reliable digital platforms shall be the challenge for all the Space Business World in the next decade. The micro-size NEGESAT Company (2 experienced Space Engineers) has launched, since early 99, the project called NEGESAR (NEw GEneration Satellite ARchitecture) aiming at this objective: to give the Space User a way to launch active and complex Electronic Equipment into space using commercial quality components, that is the same ones developed for the highest performance on Ground. The result is enclosed in 4 statements: drop of high vibrational loads, thermal efficiency improvement by permitting to use standard low heat conductive PC boards materials, raise of the shielding capability against electrons and protons fluence radiations of at least one order magnitude, multiplication of the global performance to cost ratio of a minimum factor of 3. NEGESAT has made a Joint Venture with the MEGSAT Company with the aim to space qualify the new Technology: SOFTEQ, the Flight Demonstrator will be launched on 25th August 2000.

Introduction

The NEGESAR Technology is born around the introduction of three basic principles never applied before in the World Space Industry. They are respectively:

- A revolutionary structure concept that allows to dramatically reduce the design load factors.
- A simple but efficient heat exchange concept capable of greatly improve the thermal dissipation of thermal active equipment.
- A life for the Electronic components into a 1 bar environment very similar to the one on Earth.

The design is aimed basically to the new generation Telecommunication Spacecraft market, but this new kind of architecture can also be applied to other types of S/C missions.

By means of these three new principles NEGESAR-based satellites shall be able to strongly raise the Performance to Cost ratio, for a generic Telecom Satellite by reducing at maximum mass, development time and components costs.

The effectiveness of this Technology is going to be verified by a Test Program based on two Ground Demonstrators, the SMALL DEMONSTRATOR and the ADVANCED DEMONSTRATOR, while a Flight Demonstrator, SOFTEQ, has been prepared and mounted on board the MEGSAT1 microsatellite belonging to the MEGSAT Company, with the aim to space qualify the new Technology

The NEGESAR concept

The NEGESAR technology takes its origin from the following simple consideration: the usage of ground standard components and the assembly methods normally employed in ground applications are not allowed in current S/C due to the severe mechanical, thermal and radiation environment typical of space missions. The satellites developed making use of the NEGESAR technology shall allow the integration of high performance last generation digital Electronic assy normally employed in ground based applications, thanks to reduced mission load factors, improved thermal exchange and adequate protection and redundancy against radiation.

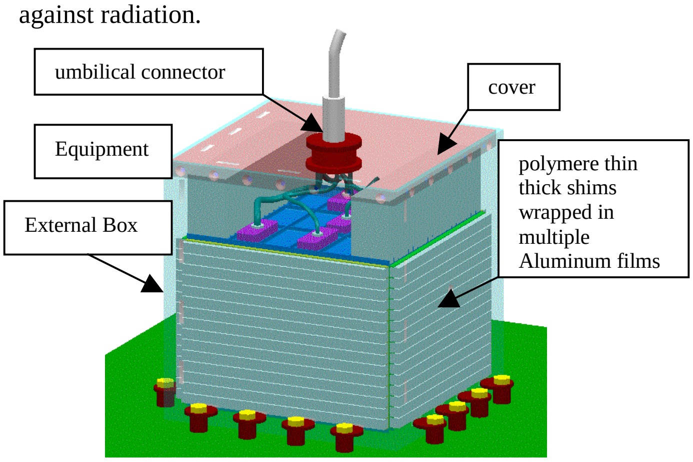

Fig.1 – Single Equipment configuration

The traditional concept of Equipment or boxes screw-fixed in a pre-calculated position is abandoned and replaced by a configuration in which such Equipment Boxes are compressed into an External Box by means a ‘Filler’ having elastic plus shock absorption properties.
In this way, what is mounted on the S/C structure, is not the Equipment itself but a structural Box (External Box) within which one or more Electronic Equipment are assembled and protected against all the S/C vibrations. The filler is normally made up of polypropylene or polyethylene thin thick parallelepiped-like shims enveloped in multiple Aluminium films. The wrapped shims assure, on one side, all the mechanical properties typical of a shock-absorber configuration with full dynamic de-coupling with the sustaining structure and, on the other, dissipate the thermal heat power of the Electronic components located inside the Equipment casing.


Fig.2- the NEGESAR filler

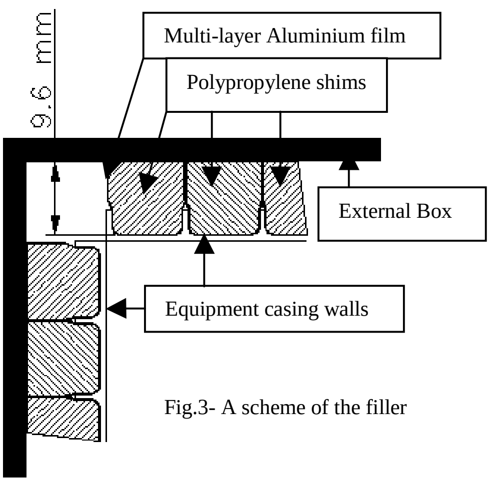

Fig.3- A scheme of the filler

This means that the Electronic Box casing (Equipment) has thinner machined walls, the design of which is the same for a wide range of Equipment size.
An immediate advantage to have Equipment not fixed by screws on a sustaining structure but uniformly surrounded by a soft Filler is that all punctual forces on it are get rid of forever. This not negligible matter has a strong impact on the design of the Equipment casing that never will be influenced by whatever Mechanical ICD anymore, independently from the S/C mission. Because the stress path on the Equipment casing is far less complex than in current S/C assembly, Electronic Equipment Furnishers have not to perform any stress or couple load analysis on it, transforming it in a mere recurrent cost. Less loads on the PC boards means also less worries on the Electronic Furnishers side that are not asked to solve complicated mechanical specifications.
Giving to the Electronic Furnishers only Electronic work means, furthermore, to raise the number of potential procurement Furnishers and cutting down costs.
The logic of the NEGESAR Technology is then to shift to the System level all the Mechanical and Thermal Design specifications, with a Product Tree splitted in two parallel branches : that of the Equipment, simplified by relaxed design requirements, and that of the External Box and the Filler, completely dissociated by whatever is Electronics and fragile, and treated as two mere structural items.
Someone could claim that, anyway, also the External Box has to be fixed to a sustaining structure with concentrated forces in corrispondence of the screws, but a thing is to design a casing with Electronics inside, other is to design a container working only at flexure stress around a soft Filler: the punctual forces at screw level are neglible.
Because it is well known that polymeric materials are also good thermal insulators, our effort has been to transform these poor thermal characteristics into good ones: Fig.2 and Fig.3 show how we have solved the matter.
Multiple Aluminium films 0.015 mm thick are wrapped around the parallelepiped-like polymeric shims giving a global thickness of around 0.1 mm of Aluminium. These shims are then integrated inside the consecutive 0.8 mm ribs of the Equipment casing walls. This configuration has been thermally tested in vacuum chamber giving Thermal Conductance from 4 to 15 W/K depending on the number of layers, values that can fully satisfy the worst Equipment thermal dissipation requirements.
This Thermal solution do not carry, anyway, any improvements on the design of the Equipment as far as the Thermal dissipation from the components to the Equipment walls is concerned. If we want, in fact, to use standard commercial PC boards in place of the costly space qualified ones we must not forget of their poor thermal conductivity that in vacuum conditions would give too high temperatures at component level.
Equipment costs will dramatically drop only if we maintain the same design solutions offered by Industry for the Ground applications.
The NEGESAR Technology claims that thanks to its revolutionary Mechanical system, with a Filler surrounding the Equipment, it is possible to build at low technological costs a full tight External Box in such a way that Equipment components work at 1 bar atmosphere like on Earth. What is claimed is also that the result of such a solution takes to have a global mass that is lower than the one normally obtained with a standard Technology, despite pressurisation.
The air inside the Equipment casing is a strategic mean to multiply the thermal paths between the Electronic

components and the Equipment.

The Thermal tests performed by the SMALL DEMONSTRATOR in vacuum chamber have demonstrated that for low power levels typical of digital based Equipment, it is possible to use standard PC boards mounting assemblies thanks to air circulation inside the External Box. Even if the External Box is a closed system where air convection is poor and, on orbit even poorer than on Ground because of the lack of gravity, it has been noticed that air helps to have smoother thermal gradients between components and drops in great part the components high temperatures.

For specific high power components, low power consumption air fans, like the ones mounted on top of PC microprocessors, have been used in Ground tests with the result of drastically lowering high temperatures and averaging them.

The penalty to build a sealed box is anyway far compensated from the fact there will not be whatever out-gassing constraints for the components and materials used internally. This not negligible advantage means, in fact, that Equipment assembly operations do not require 100.000 class clean room for Integration. This fact further enlarge the number of potential Furnishers for procurement Items.

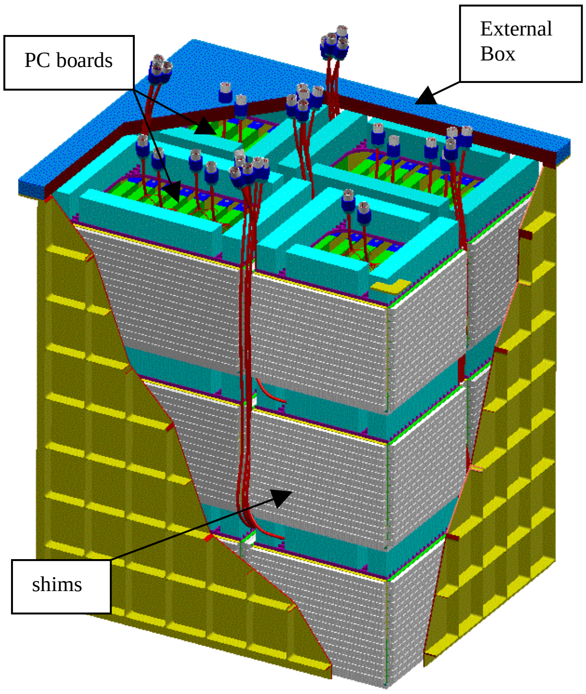

Fig.4- Typical layout of a microsatellite based on the NEGESAR Tecyhnology

Looking at the layout for a typical NEGESAR-based microsatellite we can immediately appreciate the advantage offered by the filler as far as the part list number is concerned: there are no attachments, brackets, beams typical of current designs but only six machined or honeycomb panels. To have full air-tight properties the panels are first impregnated with metachrylic resin, then chemically nickelized. The panels are then bonded one another with Araldite resin around the internal Equipment assembly by means of special GSE. The cover is then sealed after the functional checks by using not out-gassing sealing paste like RTV566.

The NEGESAR philosophy is oriented to privileging the last step of the overall development chain of a typical space product, the testing phase, leaving much less time schedule to analytically based work in favour of a more pragmatic plan centred on functional, mechanical and thermal tests. This logic, that is believed very cost saving, is justified by the design characteristics of a NEGESAR-based system in which lower load factors, efficient thermal dissipation let to overcome the Qualification phase without need of prediction analysis.

Last but not least is the capability, offered by the strategic NEGESAR feature of having an air-tight External Box, in storing gases like CO_2, liquids such as H_2O and outgassing materials such as polyethilene that are able to contribute in a level never attainaed before at the S/C shielding against radiation. Fig. 5 shows the recent conclusion of the study made on a generic NEGESAR –based satellite, in which, thanks to the thickness of the Filler sorrounding the Electronic components it is possible to drastically cut down the total dose of Protons and Electrons on both GEO and LEO orbits.

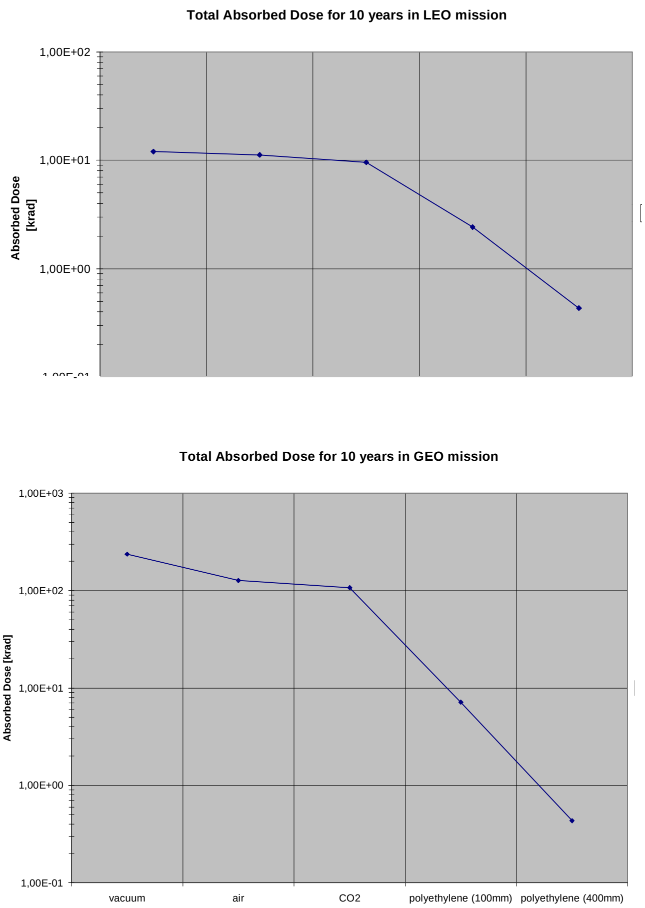

Fig.5- Electrons and Protons absorbed total dose in function of different shielding materials

Background

Shock-absorber systems have over the time successfully been employed in several technological fields including space. However they are generally based on elastomers or other kind of shock-absorber material screw-fixed to a sustaining structure: it is demonstrated, in the case of Space applications, that these systems are heavier and thermally less performing than normal fixation systems.

The NEGESAR technology, that has been developed with the aim to improve the Mechanical and Thermal properties of a Space System, lets also to obtain a strong mass reduction despite the pressurisation of the main containment box. This mass saving in the overall S/C mass budget can be really significant if the plurality of single sized equipment normally mounted on a huge surface of the S/C platform can be drastically reduced or just eliminated. By adopting the NEGESAR approach more functions and systems can be concentrated into a far smaller number of containment boxes that we can call Electronic Pressurised Box (EPB). In fact, not only the mass saved for a single Equipment is important, but also the mass saved at S/C level. The usage of small sized miniaturised components, thin thick plate Equipment casing and shortened harness routing lines allows to decrease the overall Equipment mounting surface, thus saving mass at system level. The increase of mass due to the need of more redundant functions to account for lower commercial components reliability and/or shielding plates to protect critical components is in this way largely compensated for.

What is surprising looking to the NEGESAR potential performances is the capability to obtain a design less heavier than an even performing one developed traditionally despite the pressurisation of the External Box. Pressurisation of Electronic assy's was in the past attempted by ex Soviet Union Companies by welding the external structure, but the results were not certainly in favour to reduce the mass.

An attentive reader could affirm that a mass reduction is not, anyway, the main concern of current Space Business Companies, but rather, the means to protect Electronics against radiation exposure, that, if found, would permit to use ground graded Electronics. The Consortium NEGESAT/MEGSAT believes possible to arrive to radiation shielding means to be able to guarantee the success of a typical S/C mission by increasing the shielding capabilities without using heavy materials. Heavy usage of commercial-based Electronics shall be accepted only if full redundancy is applied to the S/C main systems. It has been calculated, for traditionally developed S/C, that the need to inboard more Equipment than necessary with a thicker casing, would take to add more mass and complexity (active heat transfer means), at a point that the increase of costs would hardly compensate the acceptance of a risk to inboard a cheaper and more powerful technology.

Only applying a new technology, in which both the mass and complexity are deeply optimised, it shall be possible to use powerful but cheap ground-graded Electronics.

The Ground Demonstrators

Two Demonstrators have been developed to verify from a Mechanical and Thermal point of view the properties of the new Technology. The first one, the SMALL DEMONSTRATOR has just ultimated the Mechanical and Thermal Test Program with results that demonstrate the validity of the previous statements.

The SMALL DEMONSTRATOR

This demonstrator consists of one dummy Equipment of about 150*200*200 mm size enclosed into an external container where only the equipment structure is really

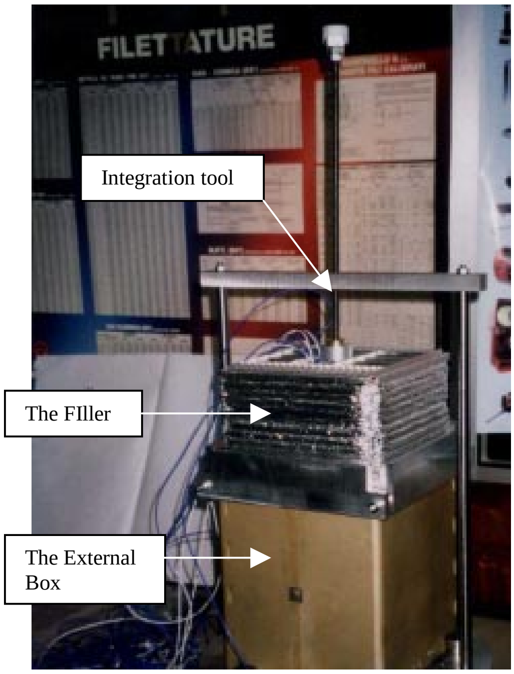

Fig.6- The SMALL DEMONSTRATOR in the integration phase

representative of the future Flight Model and everything else is dummy at low procurement costs.

The External Box has been rough dimensioned and is not representative of a flight design. This because the aim was to test the Mechanical and Thermal properties of the internal Equipment and not the containment box from which no surprise was expected.

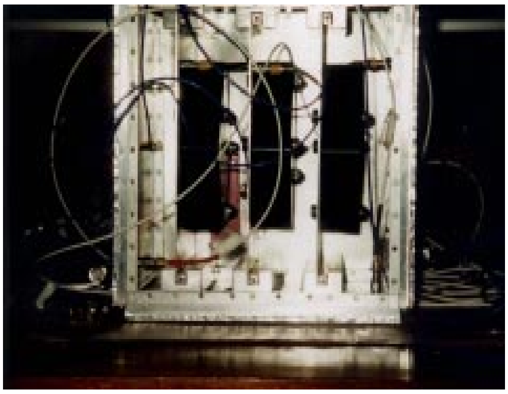

Fig.7- The dummy mass and instrumentation inside the internal Equipment

For the characteristics of the SMALL DEMONSTRATOR, the selected Mechanical Tests are typical of that performed on an Equipment assy : low and high level sine test on the 3 axis. Random test have also been performed as acceptance test valid for P/L's mounted on COSMOS Launcher. A total of 9 tests have been performed:

- 3 Sine tests at 1g between 5 Hz and 2000 Hz, 1 Oct/min (Z axis, Y axis, X axis).
- 3 Sine tests at 5g between 13 Hz and 2000 Hz, 1 Oct/min (Z axis, Y axis, X axis).
- 3 Random tests as per figure below (Z axis, Y axis, X axis).

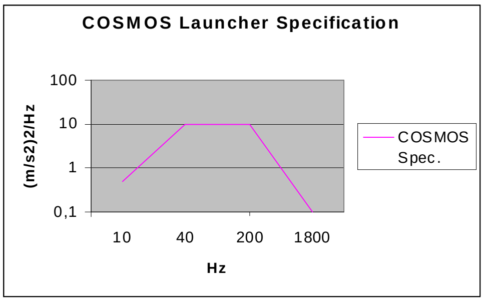

Fig.8- COSMOS Launcher Specification

The main objectives were related to :

1. Verify the amount of amplification factors between the External Box and the Equipment. The limit of maximum acceptable amplification is set to 10 along the overall frequency range.
2. Demonstrate the high stiffness of the Equipment casing, despite its low mass.
3. Determine the amplification between the Equipment casing and the dummy cards.
4. Determine the extension in frequency of the dumping zones and, per complementarity, the amplificated fields.
5. Verify the stability of the output accelerations when undergoing the Test Article for a cumulative time of 2 hours of high level sine and random test .

Mechanical Test Results

Note:

FRF 2/1 is related to the acc. mounted on the analogic card in the same direction of the shaker axis.

FRF 3/1 is related to the acc. mounted on a rigid part of the Equipment casing in the same direction of the shaker axis.

FRF 4/1 is related to the acc. mounted on the analogic card in the direction normal to the shaker axis.

FRF 5/1 is related to the acc. mounted on the barren digital card in the direction normal to the shaker axis.

Here are reported the main average results:

- Casing wall natural frequency: 400 Hz
- Analogic card natural frequency: 175 Hz
- Digital card natural frequency: 200 Hz
- Casing max. amplification: 3.7 at 410 Hz
- Analogic card max. amplification: 7 at 175 Hz
- Digital card max. amplification: below 0.4

*Module FRF is the ratio between the Output acceleration and the Input acceleration independently from the kind of test (sine or random)***)**

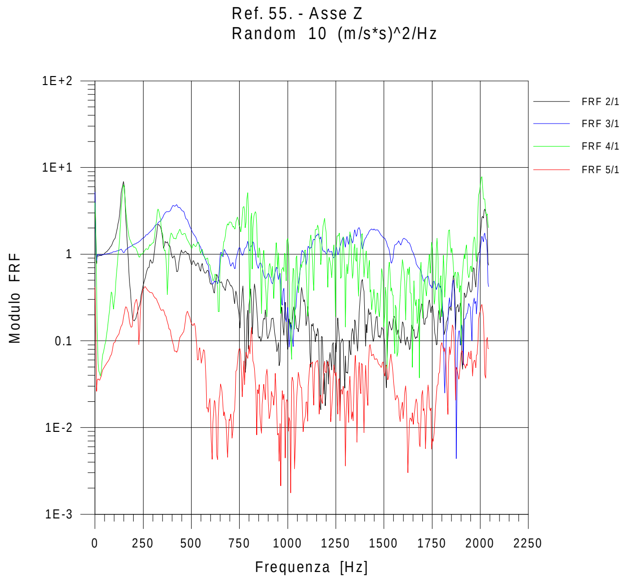

Fig.9- Random Test on the Z axis.

The first impression as far as the dynamic behaviour of the Equipment casing is concerned is that it does not exist a global natural frequency of the casing, but the first frequency is the one of its sub-elements like the walls. Previous structural analysis on the casing walls have in fact sorted out the same values of frequencies.

This claim, if confirmed by the following Test Program on the ADVANCED DEMONSTRATOR, would mean that the filler, by surrounding homogeneously the Equipment casing without restraining it in fix points like with current Equipment fixed technology, does not determine a global natural frequency. This fact reinforces further the claim that a filler like that of the NEGESAR Technology is essential not to amplify the Equipment casing.

Thermal Test Results

Two different Campaigns have been performed to verify the Thermal characteristics of the Filler.

A first one, in which the main objective was to perform Thermal Balance Tests in Vacuum chamber of a portion of filler (polypropylene shims 30 Kg/m3) wrapped with a different number of Aluminium layers.

A second one, performed after the Mechanical Test Campaign without dismounting the internal Equipment, in which after the instrumentation refurbishment of the dummy PC boards with a set of heaters, the Test Article was seal closed and put in a temperature controlled Vacuum Chamber for a new set of Thermal Balance Tests.

These two Test Campaigns have very well permitted to understand the difference in performance of the Filler for different assembly methods, and to point out the parameters that mostly influence its properties.

The objectives linked to the first Test Campaign were to determine conductance factor of the following configurations:

1. Shims with 2 layers of Aluminium 0.015 mm thick (total 0.030 mm), assembled for the first time.
2. Shims with 7 layers of Aluminium 0.015 mm thick (total 0.105 mm), assembled for the first time.
3. Split shims with 5 layers of Aluminium 0.015 mm thick (total 0.075 mm), assembled for the first time.
4. Shims with 2 layers of Aluminium 0.015 mm thick (total 0.030 mm), assembled for the second time.
5. Shims with 7 layers of Aluminium 0.015 mm thick (total 0.105 mm), assembled for the second time.

The Tests have been performed in a thermo-vacuum chamber where we had the opportunity to control the environmental temperature, but the control system acted so that the temperature fluctuated round five degrees up and down. For this reason we decided not to use this device, just because in this way the chamber temperature could only slowly rise; in order to check the path of this value we put a thermocouple on the shroud of the chamber itself.

As far as the pressure is concerned, we had the possibility to use two pumps:

a) mechanical, which could lower pressure down to 10^{-3} tor;
b) diffusion , which could lower pressure down to $3*10^{-6}$ tor.

The heat source was a couple of power resistors located on the cover , which could dissipate up to 25 W each, but actually they were controlled in order to dissipate only

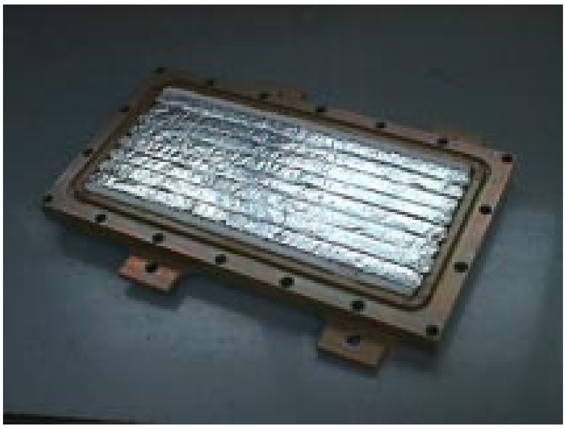

Fig.10- The Test Article used to test a portion of Filler

20 W each. The sink was the basement of the chamber; it was fixed with 4 screws to the wall of the chamber and there was a heat sink compound to make a better link between the two objects.

The other sink was the shroud of the chamber: there was a radiative dissipation from the top of the box and from the heaters to the shroud itself.

2-D Thermal Test Results

To take into account the boundary conditions given by the assembly of the cover screw fixed with insulated screws compressing an O-Ring between the cover and the basement a tests has been performed without Filler in the shallow box. The obtained ΔT has permitted to obtain the conductance of whatever but the Filler

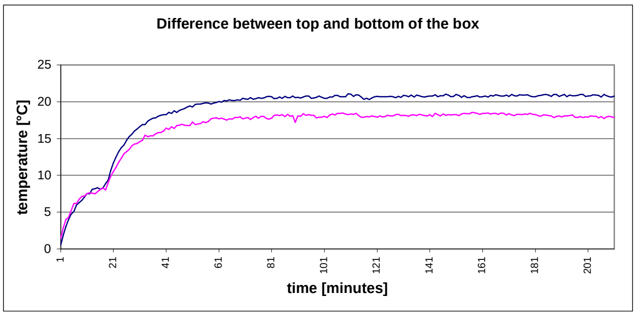

Fig.11- ΔT in the case of empty box.

Having a **ΔT= 19°C** , we can determine the thermal conductance of whatever is not Filler (the walls), which is:

$$K_{wall} = \frac{Q_{cond}}{\Delta T} = \textbf{2.1 W/K}$$

Afterwards many tests have been performed with the Filler and different number of Aluminium layers.

Fig.12 shows the results obtained with the 2 Al. layers and 7 Al. layers configurations.

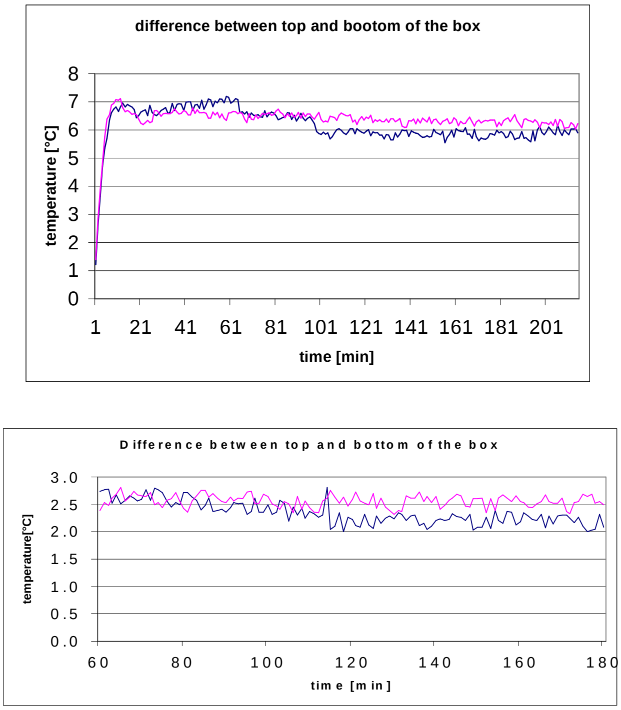

Fig.12- ΔT with Filler wrapped in 2 (0.03 mm) and 7 (0.105 mm) Aluminium layers

With 2 Al layers results a steady state difference of around **6 °C**, that means $K_{tot} = \frac{Q_{cond}}{\Delta T} = \textbf{6.6 W/K}$

In this case the wall of the Box and the Filler are in parallel, thus the global conductance is the sum of conductance:

$$K_{tot} = K_{wall} + K_{filler}$$

Which implies that the conductance of the Filler is

$$K_{tot} - K_{wall} = K_{filler} = \textbf{4.5 W/K}$$

For 7 layers the values are:

$$K_{tot} = \frac{Q_{cond}}{\Delta T} = \textbf{17.9 W/K}$$

$$K_{filler} = \textbf{15.8 W/K}$$

It' s interesting to notice that increasing the thickness (or the number) of the aluminium layers of a factor **3,5**, the conductance increases of a factor **3,5.** This result should make us understand that the driving matter is the number of layers.

The Campaign has then been carried on by performing a batch of other tests in which the Filler has been removed from the Equipment wall and replaced several times. In that case the Tests performed with the same configurations have given results lowered of a factor of about **3**.

This behaviour can be explained by the permanent deformation accused by the Filler shims once introduced into the Equipment ribs, deformation that when it happens the first time guarantees an ideal contact between the layer surfaces with 0.1 + 0.1 = 0.2 mm of Aluminium total thickness over the distance of 4 mm that gives a theoretical conductance of:

200 W/mK * .0002* 190*8/ 4 = **15.2 W/K**

A value very close to the measured **15.8 W/K** (190 mm is the length of the Filler shims and 8 is the number)

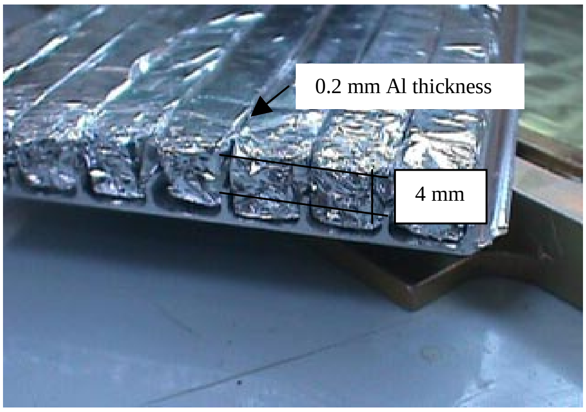

Fig.13- Contact conditions of the Filler

In the exploitation of these results it seems then possible to reach unexpected conductance values and to be able to sustain high thermal power Equipment by acting on both the number of Aluminium layers and the mating conditions of the shims themselves and these ones with the Equipment ribs.

The second Campaign on the whole SMALL DEMONSTRATOR has been carried out with a configuration very close to a Ground Electronic Architecture in which the thermal conductance between the components and the casing through the Epoxy resin PC boards is very poor. For this purpose some dummy components (heaters) have been mounted on these boards and switched on, while a certain number of thermal resistors have recorded, in different points of the Test Article, the temperatures for 3 basic configurations:

1. Vacuum inside the External Box
2. Forced air inside the External Box by using some fans mounted on the PC boards.
3. Stagnant air inside the External Box.

Working on 10 W total power and by evacuating radiative heat only towards the proxy shroud walls set to 0°C, the balance temperatures in the 3 cases has been:

1. 80°C
2. 40°C
3. 60°C

These results have been obtained by applying the worst thermal conductive conditions on the thermal resistence made up by the PC boards + boards supports.

Forced air (convection) is then able to drop to half the temperature measured in vacuum conditions, while natural convection lowers it of one fourth.

Even if these data have to be further investigated and other tests have to be carried out to arrive to a complete definition of the technological potential applications, the Auhors believe possible, by using last low cost SDM PC board generation and miniaturised low power components, the qualification of the all digitalised systems and the most part of analogic Equipment by considering as design rule a complete passive thermal control system and so without need of air fans.

Other thermal means have been thought interesting always for the purpose of raising the thermal paths between components and casing. One of these consists of applying a filler also in the Equipment internal volume, in the vacancies between the components and the Equipment walls. The filler is normally made up of small pellets of polypropylene, polyethilene or other polymeric material wrapped in Aluminium film like for the filler between the Equipment walls and the External Box. This method has been considered thermally equivalent to the case of convective air through air fans.

In this case the PC boards have to be electrically insulated from the conductive filler. The solution of that can be found by applying a small film of a potting made of silicon liquid paste mixed to Aluminium dioxide powder that guarantees the thermal conductivity without compromising the electrical insulation.

The Advanced Demonstrator

Also this demonstrator shall be developed under an ESA contract won by the NEGESAT Company. The layout of the ADVANCED DEMONSTRATOR shall be the one shown in Fig. 6, that is a typical Electronic

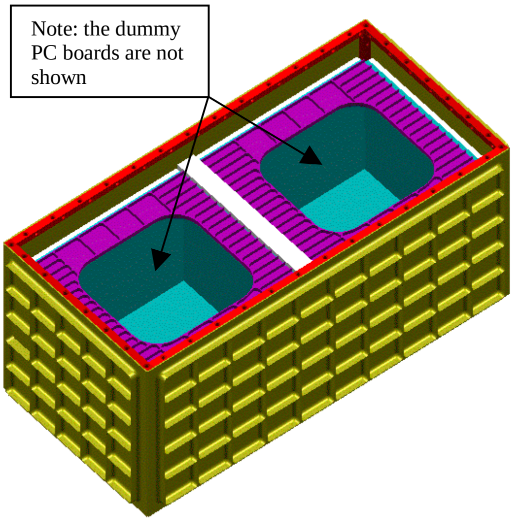

Fig.14- The ADVANCED DEMONSTRATOR

Pressurised Box (EPB) of about 460 x 230 x 220 mm size.
The objective of this demonstrator is to validate the results obtained with the SMALL DEMONSTRATOR for a more complex configuration with 2 Equipment pieces (for simplicity the Equipment size will be the same), carrying each a different mass of P/L (dummy cards) with the aim to simulate 2 different Electronic Boxes and Procurement Items.
Another difference from the previous demonstrator will be that, in this case, also the External Box shall be designed to Flight Specification, that is at best designed to withstand pressure loads, to have a full tightness capability with an umbilical bulkhead and to stay into a targeting mass, while the Equipment structure will be the same as developed for the SMALL DEMONSTRATOR.
The Test Plan Specification is still based on Mechanical (low and high level sine sweep), and Thermal Test (Thermal Balance in vacuum chamber), in which the dummy cards are to be equipped with accelerometers, strain gauge, heaters and thermocouples following the type of test to be performed.
But other tests shall be performed to validate the technological manufacture and assembly methods that are included in the performance of a NEGESAR-based product. These test include a Leakage and Proof Test (these test were not performed during the SMALL DEM. Phase because the External Box was not representative of a Flight structure), and a Mass Property.

The Flight Demonstrator: SOFTEQ

It is a backup transmitter mounted onboard the MEGSAT1 microsatellite. Many news are well visible looking at Fig.15: the Equipment walls are full separated from the External Box that is mounted on the satellite sustaining structure; the Filler between the External Box and the Equipment is 7mm depth and compressed in such a way to compensate the deformations due to the pressurisation (delta pressure of 1 bar, on orbit); the PC boards are also sustained by polymeric guides because the thermal exchange through the epoxy card is anyway poor; a film of H2O-absorber paper has been layed and sealed on each Equipment internal wall. Some heaters have been added on the PC boards as well as a RISK microprocessor.

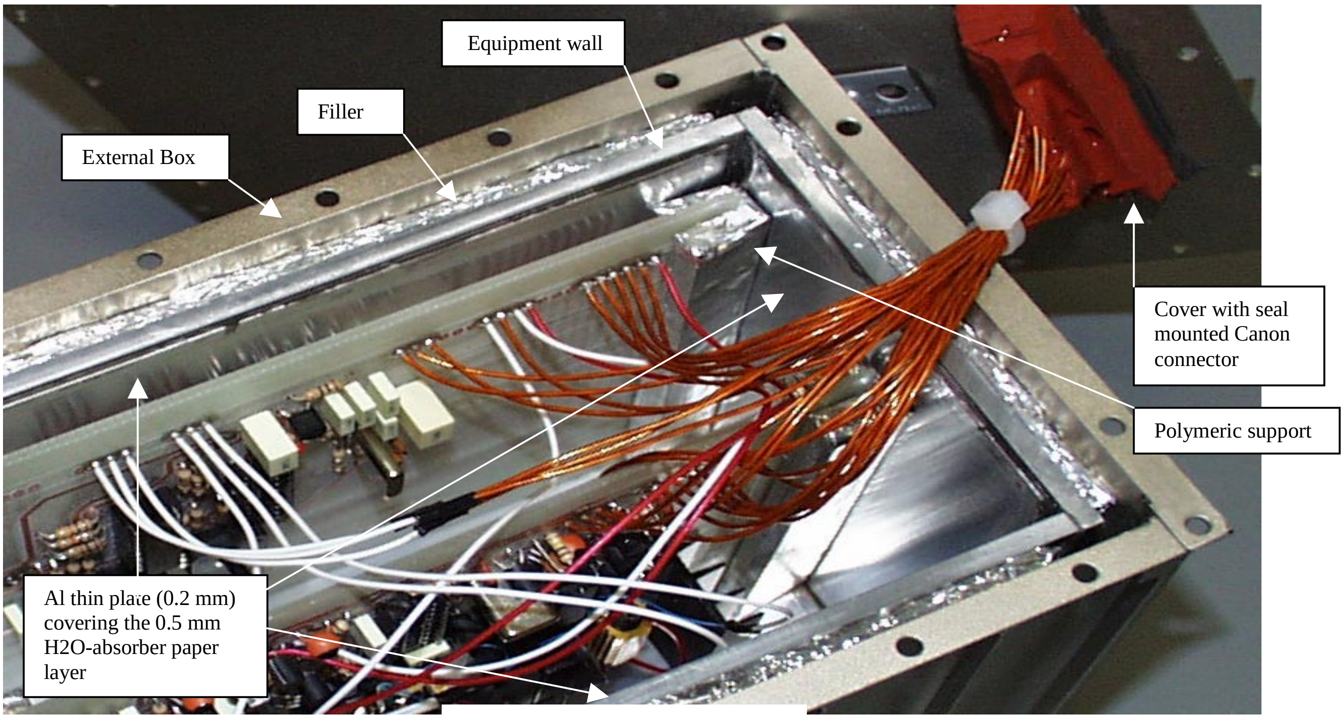

Fig.15- SOFTEQ (SOFT EQuipment)

The MEGSAT Ground Segment will be used to control, monitor and download the data transmitted by the P/L and by the MEGSAT1 backup transmitter.
Some Tests will be performed by regulating the heaters power so as to look at the temperatures distribution related to the different S/C attitude and position.
Looking at Fig.15 the general architecture typical of the NEGESAR Technology can be appreciated. The 200*150*120 mm External Box is made up of two parts: the basement and the cover. The basement is made up of five 1 mm ribbed machined panels bonded one another with Araldite Epoxy resin.

Each wall, before assembly, received a methacrylic impregnation to increase air tightness properties with successive outgassing protection by adding a chemical layer of nickel.
At less than 4 mm distance in each internal direction the Equipment is located and surrounded by the compressed Filler.
A study has then been performed as far as the possibilities, offered by the NEGESAR feature to have an air-tight container, to optimise the shielding properties is concerned. Taking the geometrical data from SOFTEQ we have:

Al [mm]	H2Oliq [mm]	polypropylene [mm]	CO_2 [mm]	polyethylene+Al [mm]	
1.1 + 0.9 + 0.2	0,5	7	50	50	
density					
Al	H2Oliq	air	CO_2	polyethylene+Al	polypropylene
2,7	1	1,19E-03	1,81E-03	0,053	0,03

Table 1 - Electrons Energy Drop after crossing the several materials layers

Eincident [MeV]	Al (1.1mm)	polypropylene (7mm)	Al (0.9mm)	H_2Ol (0.5mm)	Al (0.2mm)	polyethylene (50mm)	CO_2 (50mm)
1,3	0,858	0,817	0,439	0,33	0,227	-	0,205
2	1,55	1,51	1,15	1,05	0,97	4,31E-01	0,955
3	2,53	2,49	2,12	2,03	1,95	1,44E+00	1,93
4	3,52	3,48	3,09	2,99	2,91	2,40E+00	2,89
5	4,5	4,46	4,06	3,96	3,87	3,35E+00	3,85

Table 2 - Equivalent Al thickness for the same Electrons Energy Drop

Eincident [MeV]	Al (1.1mm)	polypropylene (7mm)	Al (0.9mm)	H_2Ol (0.5mm)	Al (0.2mm)	polyethylene (50mm)	CO_2 (50mm)
1,3	1,1	1,2	2,1	2,34	2,54	3,85	2,58
2	1,1	1,21	2,11	2,35	2,55	3,85	2,59
3	1,1	1,21	2,11	2,32	2,51	3,77	2,56
4	1,1	1,19	2,09	2,32	2,51	3,72	2,56
5	1,1	1,19	2,09	2,31	2,52	3,71	2,56

Table 3 - Protons Energy Drop after crossing the several materials layers

Eincident [MeV]	Al (1.1mm)	polypropylene (7mm)	Al (0.9mm)	H_2Ol (0.5mm)	Al (0.2mm)	polyethylene (50mm)	CO_2 (50mm)
25	19,6	19	13,3	11,4	9,71	-	9,33
40	36,4	36	32,8	31,9	31,5	26	31,4
60	57,4	57,2	55,1	54,5	54	50,6	53,9
80	78	77,8	76,1	75,7	75,3	72,7	75,2
100	98,3	98,1	96,7	96,3	96	93,9	95,9

Table 4 - Equivalent Al thickness for the same Protons Energy Drop

Eincident [MeV]	Al (1.1mm)	polypropylene (7mm)	Al (0.9mm)	H_2Ol (0.5mm)	Al (0.2mm)	polyethylene (50mm)	CO_2 (50mm)
25	1,1	1,21	2,12	2,36	2,56	3,89	2,6
40	1,1	1,23	2,13	2,39	2,5	3,89	2,53
60	1,1	1,21	2,11	2,35	2,55	3,91	2,6
80	1,1	1,19	2,1	2,32	2,54	3,88	2,59
100	1,1	1,23	2,13	2,38	2,58	3,9	2,64

The following radiation fluxes have been considered:

1. Radiation belt (electrons and protons) particles from the AE-8 [1] e AP-8 [2] Programs.
2. Solar Flux protons from the JPL-1991 [3] model.

Cosmic high power ions have not been considered because of low flux and hard shielding.
Also X rays born out from the screening/electrons interaction have not been considered because of lower magnitude.
The Equivalent Al layers have been taken from the ESA "ECSS Space Environment Standard" E-10-04 document [5].

What sorts out from these values is the strategic importance of having a Filler (also inside the Equipment) that, even if, on its own, gets to a lower physical shielding constant, the high thickness offered by the architectural arrangement of the components inside the SOFTEQ volume lets further improve the global shielding properties than if there were vacuum in place as happens in current space applications.
This Filler thickness is, furthermore, not compensated from an equivalent mass increase because of the very low specific weight of the Filler.

With the objective to calculate the absorbed dose for a typical Equipment built with the NEGESAR Technology for a 10 years LEO mission we have linearly extended to 10 years the values obtained at 7 years with 90% confidence. The physical constants, that is, the range of the ions for the used materials, have been calculated from the ESTAR and PSTAR [4] Programs. All the values are referred exactly to the materials used except for the Polyethylene. This one, in fact, is wrapped with Aluminium film. For the calculation, then, we have used the values relative to the Polyethylene for the protons and a mixture Polyethylene/Aluminium (99% and 1% respectively) for the electrons. The material density has then been rectified by taking into account the presence of 10% of air.
The results are shown below:

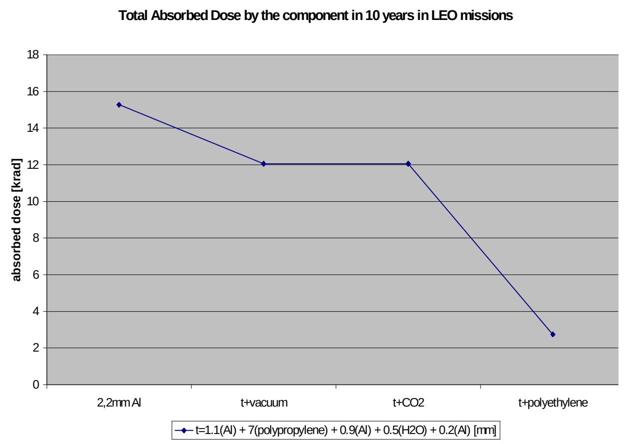

Fig.16- Total Absorbed Dose for a NEGESAR-based Equipment in LEO missions

It can be seen that the Absorbed Dose drops from about 15 to 2.7 Krad if we apply a full NEGESAR-based architecture where 15 Krad is the value obtained for a generic Equipment built with the same Aluminium thickness (2.2 mm).
The contribution of the Filler (outside and inside the internal Equipment) is still more evident in the case of a GEO mission (Fig.17). In that case, in fact, for the presence of high level Electronic fluence with respect

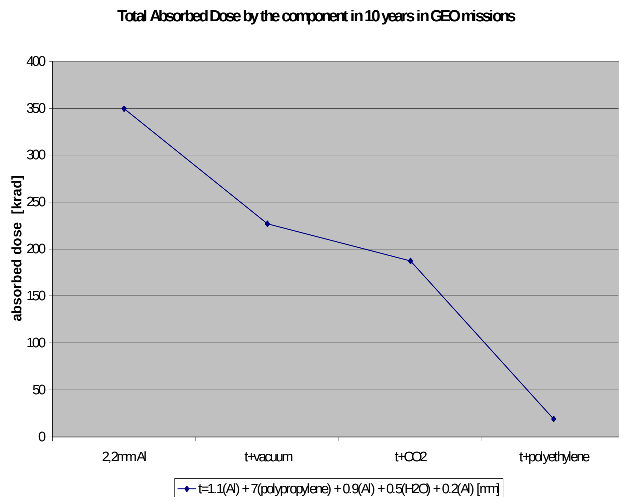

Fig.17- Total Absorbed Dose for a NEGESAR-based Equipment in GEO missions

to LEO orbits, the Absorbed Dose drops from 225 to 19 Krad that is more than one order magnitude.

These results, that seem very encouraging, have to be investigated in all details. The fact to have a Filler also inside the Equipment in the vacancies left by the PC boards, means, for the fact that the pellets are wrapped in multiple Al film, that the boards have to be electrically but not thermally insulated from the Filler. This constraint implies that both the components and boards have to be potted with a film (0.2-0.5 mm) made up, for example, of a slurry of Al dioxide powder mixed with some silicon paste.
The Al dioxide is in fact a not electrically but a thermally conductive material, that, even if with not high conductive performances, for very thin layers of potting, permits to have a good heat transfer to the Filler.
In the case of SOFTEQ we did not apply this technique for lack of time, and the shielding means are based on a 0.5mm H_2O layer, air and 2.2 mm Aluminium shell.

MEGSAT1 microsatellite

MEGSAT 1, second flight unit in the satellite program of MegSat S.p.A., will be launched on 25th August 2000 aboard a Russian Dnepr vector from the site of Baikonur, Kazakhstan.
MEGSAT 1 has a 55-Kg mass and the shape of a parallelepipedon of 405x435x650mm. It will operate at 650 Km of altitude along an orbit with a 65 degree inclination. It is expected to have a four-year operational life.
MEGSAT satellites perform data retrieval for environmental monitoring as well as for commercial survey.
MEGSAT 1, apart SOFTEQ, will also host on board an experiment, developed by the CARSO lab in Trieste (Center for Advanced Research in Space Optics), concerning the monitoring and mapping of the Aurora UV emission and its correlation to solar activity in oxygen lines. A contemporary experiment will test the UV emission in the night sky. The experiments consist of a couple of small telescopes named “Alba” (Dawn) and “Notte” (Night), both oriented towards the nadir in order to measure aurora and night sky brightness in different light bands (colours). Alba is optimised for the green emissions of aurora borealis and australis, while Notte measures the UV emission in the night sky. The study on the night sky is also connected to a very important scientific experiment to come: EUSO (Extreme Universe Space Observatory), which will analyse extreme energy cosmic rays (EECR) by their interaction with the Earth atmosphere.
MEGSAT 1 activity will allow MegSat system a better global spreading, more power and optimised performances.
Up to schedule, a new MEGSAT satellite, with a total mass between 30Kg and 80Kg, will be launched every year and will be able to carry the payload to perform the commercial mission, together with some scientific and space qualification experiments with a mass between 5Kg and 40Kg. Experiments can be different as far as (mini-satellite) at a lower cost thanks to high performing

subject and complexity, their software can be modified from the ground. Data can be collected and sent to the Ground to be analysed and checked. Solutions and volumes allowed by MEGSAT microsatellites can suit technical and logistic requirements of a number of experiments and speed up the access to space at reduced costs.

It is just in the effort to drastically save costs (that for a privately owned Company is a not negligible matter) by maintaining and, possibly, increasing the reliability of the current space systems that a Joint Venture has been made with the NEGESAT Company owner of the European and US patented NEGESAR Technology.

The common objective to build a whole micro-satellite capable to work as well as only a larger size S/C can do digital components taken from the common Ground Application Market and a new satellite Architecture able to cut in a great part the Development costs, is believed possible.

This politics is straight in line with the European Foundation for SPACE in which MegSat is member and promoter . It is a scientific and cultural institution established in order to educate youth to human achievements in the outer space and to technologies used in the space field. SPACE aims at informing people about international space activities and supports extreme research concerning science and technology. SPACE also aims at taking space technology applications into everyday life.

The NEGESAR-based micosatellite

The main objective is to qualify the technology for a full scale microsatellite having a TBD Telecommunication mission.

The design basic rules are grounded in the following points :

1. Because of the size between 0.25 $m^3 \div 0.8$ m^3, the most suitable structural baseline is based on an External Box made of Al honeycomb panels with 2 x 0.3 mm thick Al skins and total thickness ranging from 20 to 30 mm.
2. Mandatory concentrated fixation points for antennas, solar panels and adaptor shall be made only in the outside part and exclusively by using inserts The Equipment design is taken from the already developed SOFTEQ design.
3. A Filler within the Equipment shall also be used in the sense to optimise the shielding properties of the whole S/C.

The last point expectations are enclosed in the following Tables and the diagrams in Figure 5:

Al [mm]	**H2Oliq [mm]**	**polypropylene [mm]**	**CO_2 [mm]**	**polyethylene+Al [mm]**
0.6 + 1	2	400	400	100 / 400
		density		
Al	**H2Oliq**	**air**	**CO_2**	**polyethylene+Al**
2,7	1	1,19E-03	1,81E-03	0,053

Tabella 5 - Electrons Energy Drop after crossing the several materials layers

Eincident [MeV]	Al (0.6mm)	H_2Ol (2mm)	Al (1mm)	aria (400mm)	CO_2 (400mm)	polyethylene (100mm)	polyethylene (400mm)
1,3	1,06	0,683	0,23	0,097	-	-	-
2	1,76	1,39	0,987	0,906	0,864	-	-
3	2,75	2,38	1,97	1,89	1,84	9,29E-01	-
4	3,74	3,36	2,93	2,85	2,8	1,86E+00	-
5	4,73	4,34	3,9	3,81	3,76	2,80E+00	-

Tabella 6 - Equivalent Al thickness for the same Electrons Energy Drop

Eincident [MeV]	Al (0.6mm)	H_2Ol (2mm)	Al (1mm)	aria (400mm)	CO_2 (400mm)	polyethylene (100mm)	polyethylene (400mm)
1,3	0,6	1,53	2,53	2,73	2,82	5,04	11,44
2	0,6	1,51	2,51	2,71	2,82	5,04	11,44
3	0,6	1,47	2,47	2,66	2,78	5,04	11,44
4	0,6	1,47	2,47	2,66	2,78	5,03	11,44
5	0,6	1,46	2,46	2,65	2,77	5	11,44

Tabella 7 - Protons Energy Drop after crossing the several materials layers

Eincident [MeV]	Al (0.6mm)	H_2Ol (2mm)	Al (1mm)	aria (400mm)	CO_2 (400mm)	polyethylene (100mm)	polyethylene (400mm)
25	22,1	16,9	9,57	7,36	5,94	-	-
40	38,1	35	31,4	30,7	30,3	19,2	-
60	28,6	56,4	54,1	53,6	53,3	47,1	16,6
80	78,9	77,1	75,2	74,8	74,6	70	51,9
100	99,1	97,6	96	95,7	95,5	91,7	77,7

Tabella 8 - Equivalent Al thickness for the same Protons Energy Drop

Eincident [MeV]	Al (0.6mm)	H_2Ol (2mm)	Al (1mm)	aria (400mm)	CO_2 (400mm)	polyethylene (100mm)	polyethylene (400mm)
25	0,6	1,58	2,58	2,79	2,9	5,3	13,45
40	0,6	1,54	2,54	2,72	2,83	5,3	13,45
60	0,6	1,55	2,55	2,71	2,83	5,23	13,45
80	0,6	1,56	2,56	2,8	2,9	5,26	13,37
100	0,6	1,55	2,55	2,77	2,9	5,25	13,32

4. The Filler between the External Box and the TBD number of Equipment is the same as the developed one.
5. Air tightness shall be obtained by panels impregnation and nickelisation, araldite bonding of structural joints, not-outgassing high molecolar silicon paste of the romovable panel (cover), sealing of standard electrical connectors.
6. All the umbilicals shall use connectors at the I/F with the External Box.
7. Usage of Pentium microprocessor technolgy for the onboard computers and, in general, high performing digital and miniaturised components.

The importance to have a Filler also within the Equipment stays, then, in the sense that, for a traditional S/C Architecture, it is possible to reach the same values of shielding capability only by adopting 11mm and 13mm Aluminium plates for LEO and GEO missions respectively, that is quite impracticable.

We have, anyway, to admit that is not gold whatever shining: in high frequency (GHz) subsystem Equipment it shall not be possible to use an Al compounded Filler because of a strong dielectric alteration. The constraint consists of maintaining the Filler at a certain distance from the sensible components with cages made of good dielectric material.

It is just in treating some difficulties like the above one that sorts out one of the main advantages of this technology: the flexibility.

Thanks to Equipment dynamically decoupled from the Space Vehicle, it is possible to tune up all the systems by applying more loops of Test and corrective actions without affecting the Mechanical behaviour of the system that does not require analytical predictions. This results in a Development phase far shortened compared to the case with fixed structures.

Conclusion

Many news are part of this Technology. Each of them, on their own, is not extraordinary but taken all together gives an extraordinary result.

This is in fact the peculiarity of NEGESAR: simple basic ideas linked one another all of them studied and thought to amplify the capability of producing a complex system in a time never attainable before.

The money invested, so far, in the developement of a Ground and a Flight Demonstrator, roughly 70.000 US dollars is the clear evidence of being able to pragmatically arrive to qualification results in a very short time at advantageous costs.

The Authors believe the risk to build a whole NEGESAR-based S/C acceptable for the high value of the ratio between the potential economical return (the Technology is patented) and the amount of money is needed to invest.

Besides, the analytical work performed on the shielding capabilty against radiation seems already extraordinary on its own: if the values are confirmed by successive studies, the interest to employ cheap but performing Electronic components will never be closer.

And all of this, thanks to the use of a Filler that can stay only in a air tight container, and that can be made tight only by getting rid of any high loaded fixation point, what it means to have a Filler…..This is NEGESAR.

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