Miniaturized High Density Solderless interconnect solutions (Interposers)

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Summary

In order to ensure easy and reliable interconnection between active components (LGA, FPGA, CSP, MCM…) and PCB's, Hypertac has developed with the major player of space industry a range of interposers (miniaturized high density solderless connectors). Those solutions fulfill the most common requirements for space applications: harsh environment (vibrations, climatic sequences…), low contact resistance, miniaturization (low profile connectors), high density of contacts, easy assembly process, multi-purpose applications, RoHs compliance. Hypertac interposers are supporting Space Industry with the aim of providing solutions "smaller-faster-lighter-cheaper".

Keywords:
Hypertac Interposer, miniaturized solderless connectors, high density solderless connectors, harsh environment, low contact resistance.

Introduction

General trends to increase the complexity of PCB (Printed Circuit Boards), modules and electronic systems ask for an appropriate evolution of stacking connectors for board to board and MCM (Multi-Chip Modules). Among those connectors, the solderless ones, who give facilities for mounting and dismounting, have the additional advantage of satisfying the RoHS requirements. For these reasons, Hypertac that was the leader of the European Eureka "PIDEA Hymstac" project has developed a 3D solderless stacking low profile (less than 3 mm thick) connector for Z-axis interconnections of 1 mm pitch [1-2]. The need for long term reliability, low impedance, and compliance to planarity defects of the surfaces to connect have led to a solution with miniature copper alloy compression springs enclosed in an insulating package.
The paper is divided in 2 main parts. In the first one, we introduce electrical and mechanical characterizations on the contact alone. Then, we show an assembly designed to connect a 625 LGA ceramic hermetic package and the first evaluation results performed (environmental and dynamic). Standard optical inspection, gross leak and fine leak were used to assess the reliability of LGA packages. Following these tests, improvements in term of weight based on design and choice of material is done.

1- Study of contacts

“PIDEA Hymstac” solution is based on miniature springs that work on the elastic field. To characterize these contacts, an experimental bench was developed in the LGEP laboratory. Electrical and mechanical properties as well as dynamic evaluation like fretting corrosion were investigated. Forces were measured with a precision better than 0.01 N, displacements of a few micrometers and impedance of a few micro ohms.
The device under test (DUT) is a 2 mm thick insulating parallelepiped, with 30 individual spring contacts (Fig. 1). These copper alloy springs are plated with nickel-gold to have a good contact resistance [3-7].

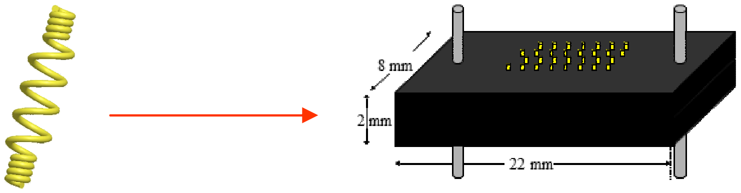

Fig. 1. The device to test (on the right side) with a non-representative shape of the spring (on the left).

a- The experimental test bench

The experimental test bench is presented on fig. 2. It is able to connect individual contact without touching theirs neighbors. Forces by using constraint gauges, displacement with capacitive sensors and impedance with 4 point technic are measured. Hereafter, the fig. 3 shows the whole mechanical assembly that looks like a 30 cm wide cubic box.

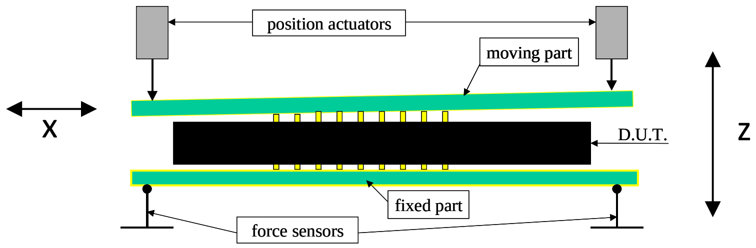

Fig. 2. Principle of the experimental bench.

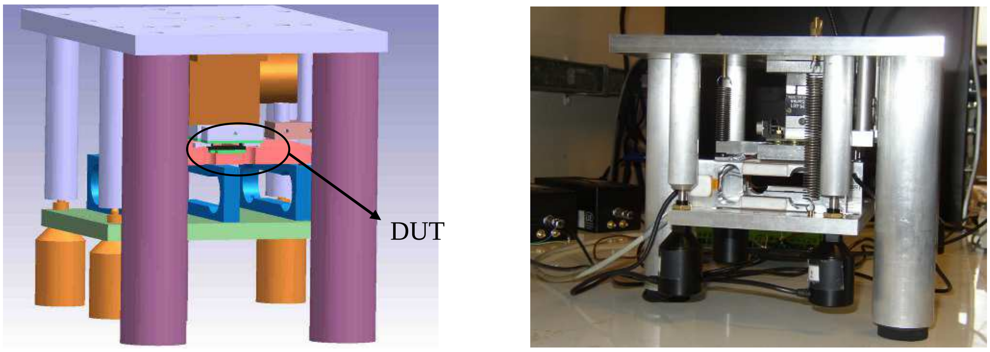

Fig. 3. Drawing (left) and photo (right) of the whole experimental setup.

To drive this experimental bench, we used LabView instrumentation software. So, we have tested each individual contact point, ie force along the Z axis and contact resistance, as functions of the displacement and in second time, contact resistance vs. number of cycles (X axis)for the fretting corrosion (Fig. 2).

b- Measurements

The measurements have given that compression force is 0.5 N and the contact resistance is less than 30 mΩ when the contact spring is totally compressed. Fretting test was performed on compressed spring with a frequency of 10 Hz and amplitude of +/- 40 µm. No fretting corrosion phenomena appears after 10 000 cycles because the contact resistance doesn't degrade as shown on the next graph (Fig. 4). This is linked to the design of the contact, more exactly if we look at the interface between the spring and the host pad of the PCB, we can see that the shape of the contacting wire on the PCB surface is a lateral part of the end of the coil (see the end of the spring, Fig. 1).

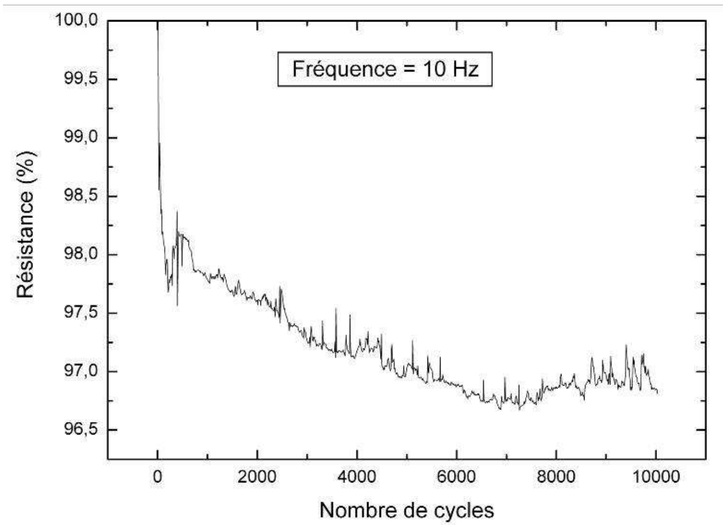

Fig. 4. Fretting corrosion behavior of a contact

c- Summary of results

Others evaluations were performed as thermal shocks, random vibration and insertion/return losses (S21/S11).
To conclude on the contact, we summarize in the following matrix (Table 1) the performances as height, pitch, deflection, contact resistance, maximum current… and the benefits given to customers.

Table 1. List of the different tests done on the contact.

	Performances	**Benefits customer**
Height, pitch	2.15 mm, 1 mm	Packaging, high density, weight saving
Deflection	0.3 mm	Reliable connection, compatible PCB, MCM, QFN…
Total contact resistance	30 mΩ	Reliable resistance
Insulating resistance	> 5.10^3 MΩ	No failure due to low insulation
Maximum current	1 A	Good current capability
Maximum force per contact	0.5 N	Low and stable force
Thermal shocks	-55°C/+125 °C/ x250 cycles	Adapted to harsh environments
Random vibration	48 g RMS 10-3000 Hz /30 min without opening circuit (>1 ns)	Reliable connection, adapted to harsh environments
Insertion losses	1 dB @ 3 GHz	Adapted to medium frequency
Mechanical cycling	20 000 without change	Reliable connection

2- Interconnection of a ceramic 625 LGA device

First study

The frame of this work is the issue of connecting active component like land grid array (LGA) 625 points to print circuit board (PCB). A well know possibility is to use column ceramic grid array (CCGA) interconnect solution. But CCGA may provide breakings in solder joints at board side mainly due to coefficient of thermal expansion (CTE) mismatches between the board material and column, column and ceramic substrate [8-9]. It causes shear displacement at each solder joint interconnect. A huge benefit is that our solution is solderless one, so our system is not concerned by this important issue.

In this study, we have employed (LGA) 625 daisy chained electronic packages in this preliminary reliability study. The physical dimensions are 29 mm x 29 mm with a 25 x 25 array of land and a 1 mm pitch (Fig. 5). The lands have a diameter of 0.68 mm and are plated with nickel-gold. This LGA was used because constrains were the most important in term of number of points and pitch among others LGA proposed by the CNES (349 or 472 points with a pitch of 1.27 mm).

The print circuit board (PCB) is in polyimide laminate that can withstand temperature as high as 200°C. The host pads have got a diameter of 0.85 mm and are plated with nickel/gold. This circuit is complementary to the daisy chain of the LGA so that all contacts are tested in series.

The first step of this study is to assemble the parts (PCB, interposer, LGA…) and to measure the impedance of the whole system. Then, the assembly was subjected to temperature thermal atmospheric cycling to assess the reliability. The impedance of daisy-chained interconnect was monitored continuously during thermal cycling.

Applicable documents

The technical solution has been developed considering the compliance with the following documents:

- The materials used must satisfy specification ECSS-Q-ST-Q70-02,
- The developed connector must answer the requirements of the specification ESCC 3401.
- Test plan is established according to the document ECSS-Q-ST-70-38, ESCC basic specification n°2263400, 2269000.
- The design and the materials of the PCB are chosen according to the document ECSS-Q-ST-70-11.

a- 625 contacts interconnection

Hereafter, we show the solderless interconnection Hymstac solution that has 625 points of contact (Fig. 5). The material of the insulator is a polyamide-imide compliant with space requirements (outgassing) and with a coefficient of thermal expansion (CTE) 16 ppm/°C to offer the best compromise because of CTE matching: ie PCB with 16-18 ppm/°C and LGA with 6.8 ppm/°C. We will see in the following lines how it's integrated in the assembly and how to mount/dismount it.

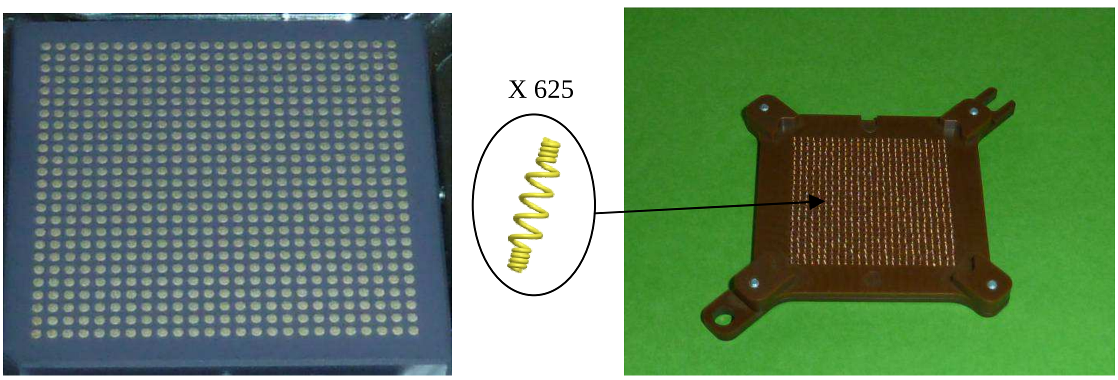

Fig. 5. Photo of LGA 625 points daisy chain from Atmel (left) and the 625 contacts HYMSTAC interposer (right)

b- Principle of interconnection

First of all, the concept of the assembly is presented on the following drawing with an exploded view (Fig. 6): PCB, interposer and the LGA with the parts that realize the compression. The connection between the LGA device and the PCB is achieved by an interposer within a clamping system.

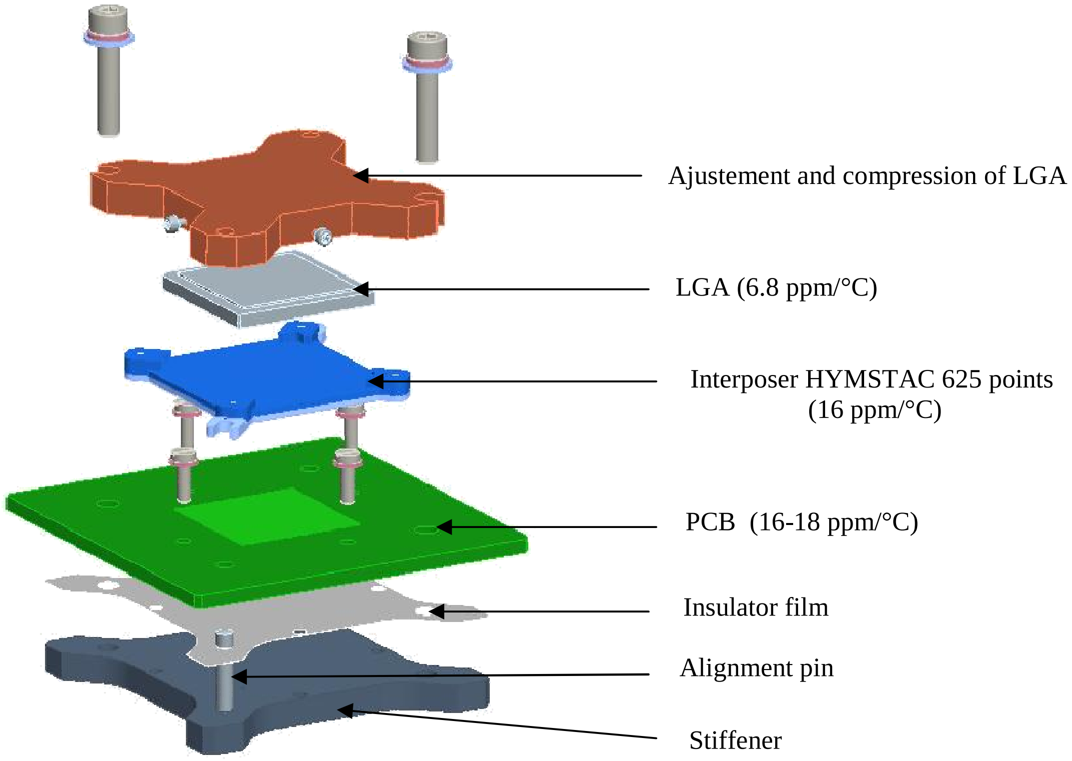

Fig. 6. Exploded view of the interconnection including LGA, Hymstac and PCB.

c- Mounting procedure

To facilitate the mounting of the PCB, we use a part (Fig. 7) that adjusts precisely the host pads with the alignment pin. It's used because of the tolerances of manufacturing PCB are too large for a good alignment of the pieces.
So after mounting the PCB on the stiffener (Fig. 8), we locate this part that has two visual references: as shown on the photo, we make the alignment of two pads that are diagonally opposed. Thus, we are sure that the pads are localized relative to the alignment pins.

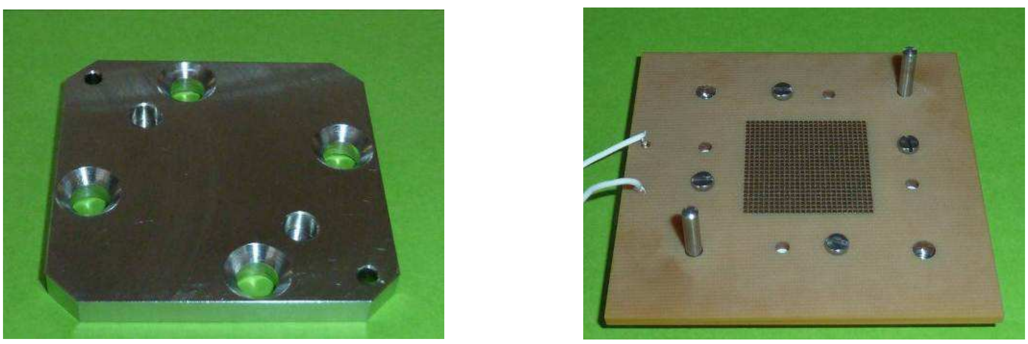

Fig. 7. Additional part used for the adjustment of the PCB (left) and the PCB daisy chain (right)

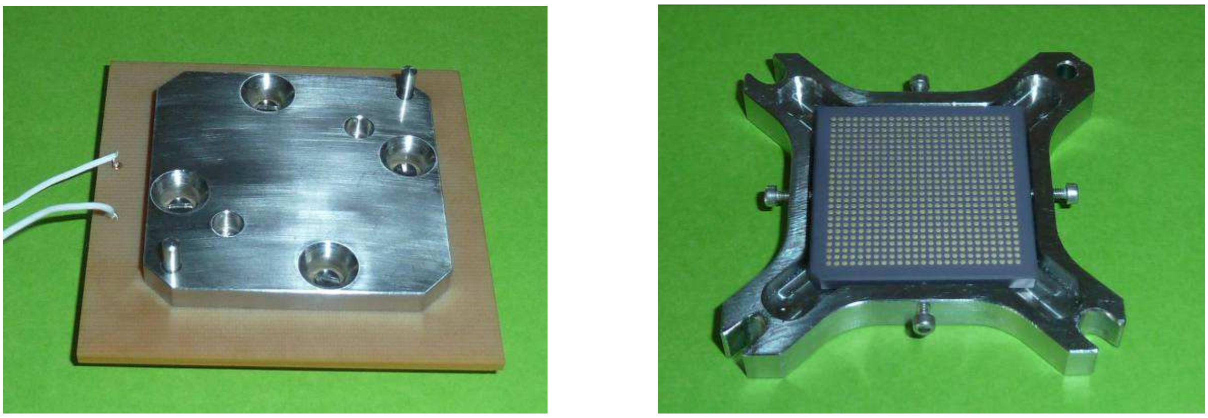

Fig. 8. Example of assembly for the adjustment of the PCB (left) and LGA inside the compression part (right)

The same protocol is used for the alignment of LGA relative to the alignment pins. As we can see on the photo (Fig. 8) the adjustment is realized with four screws. Then, we just have to place the Hymstac interposer on the PCB as shown on the photo (Fig. 9)

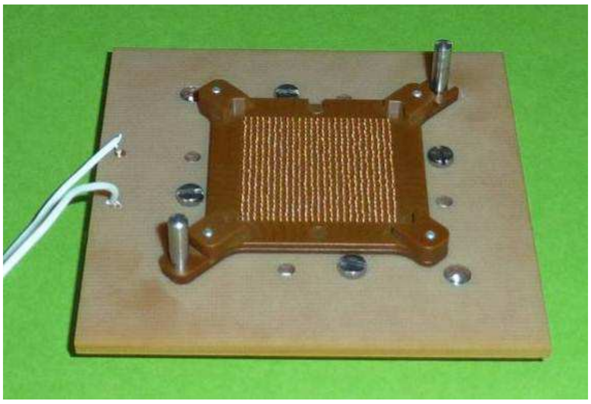

Fig. 9. Assembly of the Hymstac interposer on the PCB

Finally, we can put the LGA on the top. And to finish, the compression of the parts is ensure with 2 screws (Fig. 10). The alignment is ensured with the 2 alignment pins as seen on the photos.

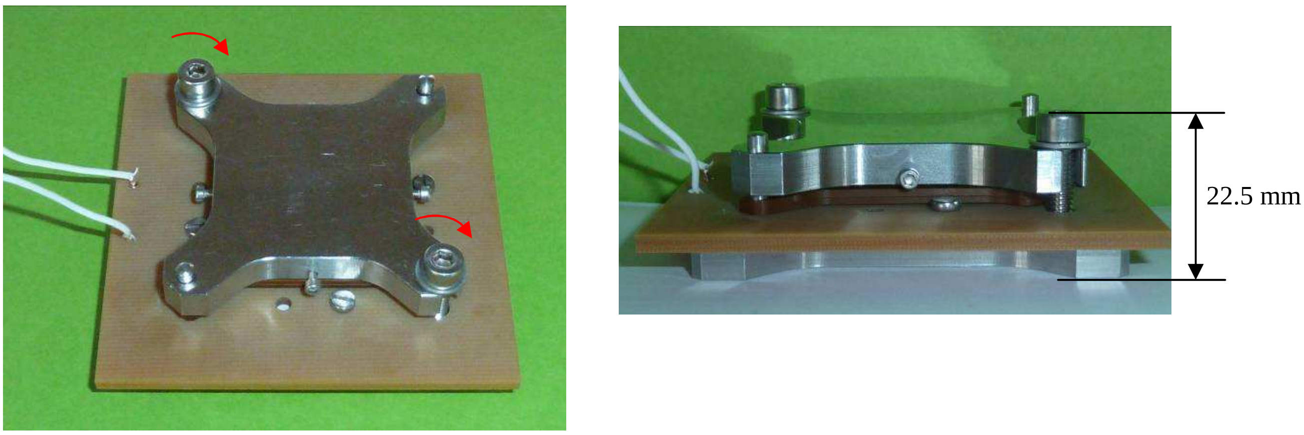

Fig. 10. Screwing of the LGA part that apply the pressure on the Hymstac (left) and final height of the assembly (right)

An appropriate tightening torque is applied according to the number of contact points, and in our case a torque of 11 N.cm is adequate. We measure that height of the assembly between the bottom of the stiffener and the top of the compression screws is less than 22.5 mm (Fig. 10).

c- First tests

This assembly has been pre-evaluated and the target was to quickly identify if our assembly was on a good path for development or not. The tests included as a priority:
- Electrical continuity measurements to ensure our assembly is working properly.
- Tests of rapid change of temperature on a range [-55 ° C ; +100 ° C], which have shown no electrical continuity cut for 5 cycles.
- Sinusoidal vibration which has allowed us to highlight the absence of micro-electrical cut according to ESCC 3401 (Fig. 11).
- Gross leak and fine leak tests on LGA packages were successfully passed after these evaluations. It ensures that our system of clamping doesn't degrade the LGA.

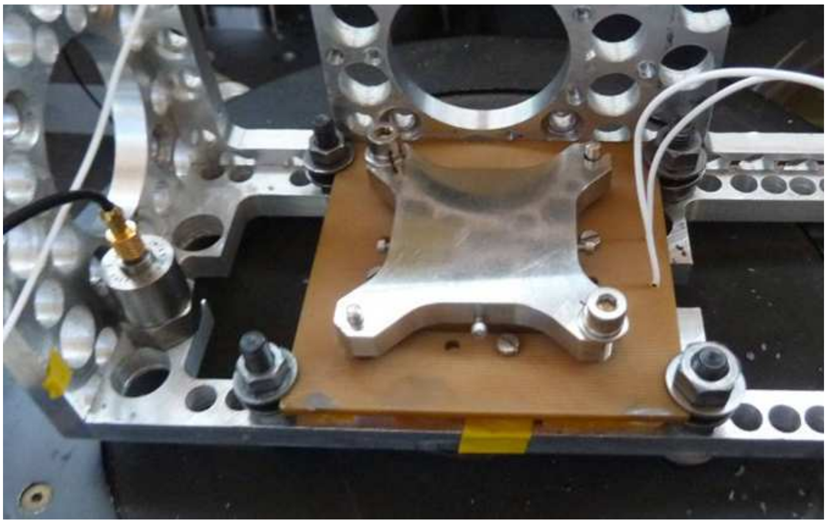

Fig. 11. Sinusoidal vibration test: frequency from 10 to 2000 Hz with acceleration of 20g for 30 minutes per axis

This assembly has shown encouraging results for further evaluation. But to be a part integrated on embedded system, the weight of the system has to be drastically reduced

3-Improvement of the assembly

To fulfill the requirement mentioned above, several axes of improvement in the system are proposed. The proposed modifications mainly concern the design and the material of the clamping system.

a- Choice of material

An important element that we must take into account in the design of our assembly is the choice of material for the mechanical assembly. Indeed, several features must be considered, notably the mechanical strength, thermal conductivity and coefficient of thermal expansion (CTE) and density. We need to find a compromise which will integrate these parameters.
From a mechanical point of view, the deformation of the clamping system has to be as low as possible when applying the load, in our case 30 kg, due to the force of contact. Young's modulus of materiel must to be high.

From a thermal point of view, the expansion of the parts to each other is also an important parameter that we have to integrate in our design process. This expansion is tested during rapid change of temperature tests (RCT). The thermal expansion coefficients must be as close as possible so that the contacts (springs) do not come out of the host pads of the PCB and/or LGA device under the effect of temperature. In addition, thermal conductivity should not be too low to ensure good thermal pumping.
Finally, a possibility to reduce the weight and have a substantial gain is the use of a material with lower density.

In the table 2 are listed the density, coefficient of thermal expansion (CTE), the Young's modulus and thermal conductivity for the stainless steel, titanium and aluminum.

Table 2. Summary of some parameters used for the material choice of the tool assembly.

	Stainless steel	Titanium	Aluminum
Density	8	4.5	2.7
TCE (ppm /°C)	16-17	8.6	23.1
Young Modulus (GPa)	193	116	74
Thermal Conductivity ($W^{-1} m^{-1} K^{-1}$)	26	6.7	237

The trade of analysis between mechanical and thermal parameters, machinability capability, had shown that aluminum is the best material for the camping system.

b- Improvement of the design

Proposition of concept

Remember that the stiffener presses at the PCB for rigidity and ensure proper plating on the interposer. However, we can imagine that the decoupling capacitors for example, could be reported under the PCB. Consideration should be given a release material at the PCB pads.
Five proposals of stiffener profiles were made as shown below. We can group them into three categories (Fig. 12):

- Without reinforcement, with only the adjustment holes LGA (a),
- A single reinforce bar or a diagonal reinforce cross including the adjustment holes (b),
- A solid plate ensuring high stiffness of the system (c).

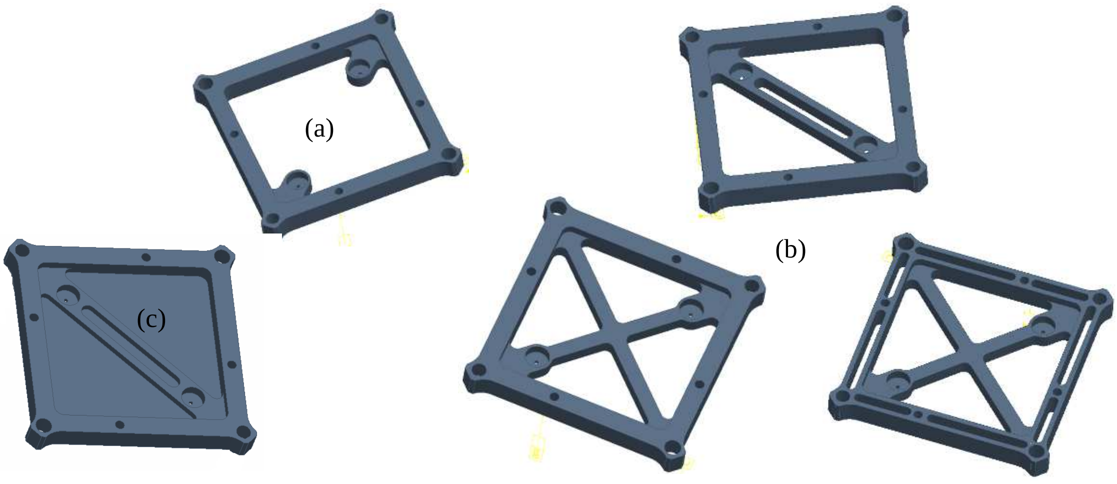

Fig. 12. 3D model of the five concepts proposed to decrease the weight of the stiffener

Anyway all these proposals bring us to reduce the weight of the device in a more or less significant way.

Finite Element Analysis simulation

However, to determine the best compromise in terms of deformation / mass of the part, we used a software based on finite element (Autodesk simulink), which allowed us to perform simulations we show an example below (Fig. 13). We have shown that the best trade of between low deformation and low weight is obtained with the stiffener design presented below.

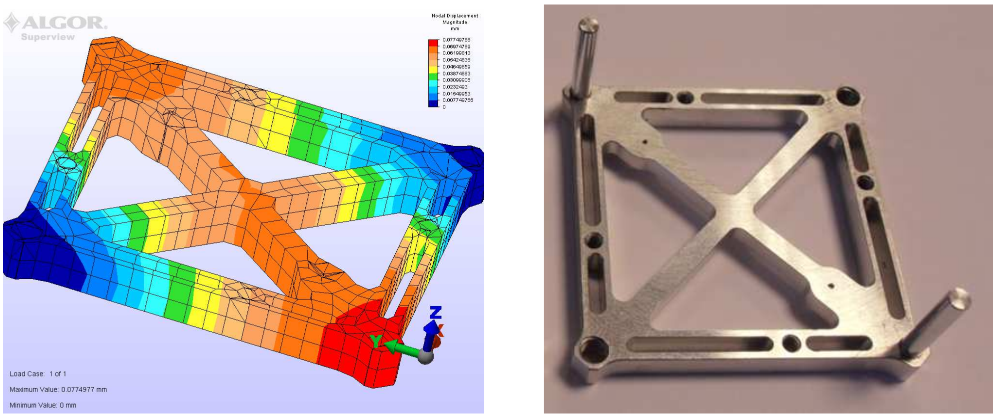

Fig. 13. Finite element simulation of the stiffener (left) and an example manufactured with the pin of alignment.

The same method was used to develop the upper part that adjust and compress the LGA on the interposer. This optimization has allowed an opening at the upper portion of the LGA to press on the periphery of it. This pressure is now applied via a heat seal as seen on the next picture (Fig. 14).

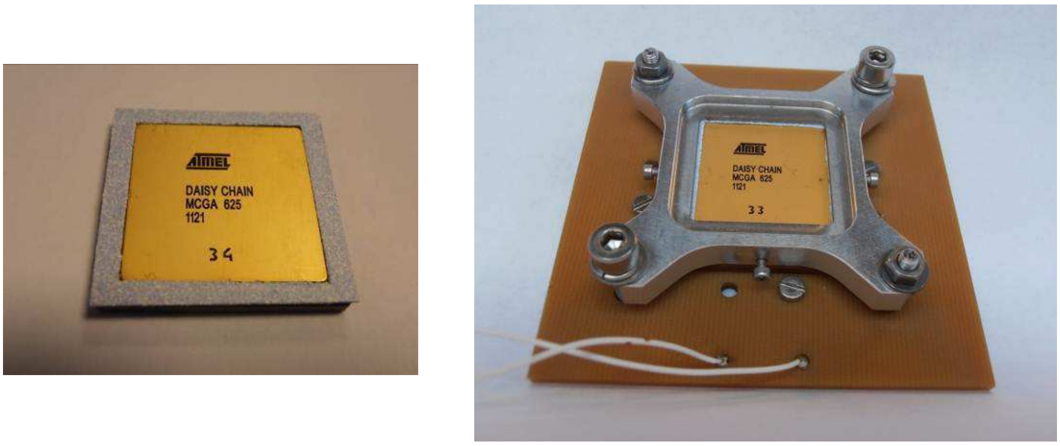

Fig. 14. Thermal seal mounted on the top of the LGA (left) and final assembly (right)

This improvement will allow:
- Installation of a heat extraction device LGA,
- The direct identification of the component installed.

In the end, the device is reduced from 137 g to less than 30 g (Fig. 15), which is 4 times less than the initial weight!

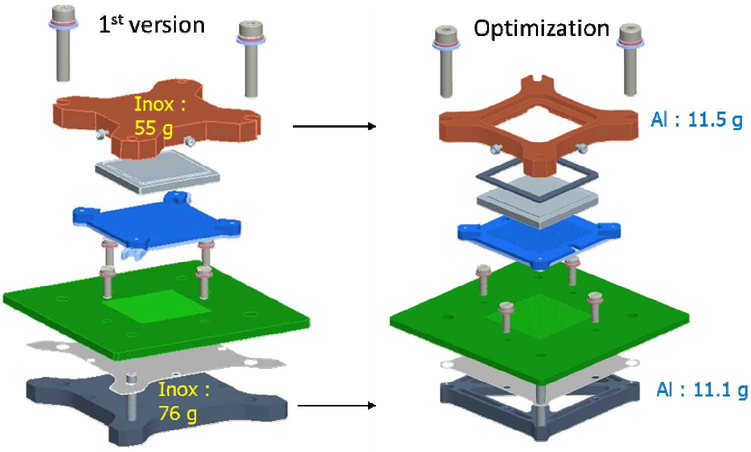

Fig. 15. Summary of the optimization of the assembly weight.

The new design of the clamping system has been validated by a continuity test and a rapid change of temperature.
In the second part of the project, it system will be deeply tested. The test plan is based on ESCC 3401 and ECSS-Q-ST-70-38C standard. The tests that we will be performed are:

- Harsh vibration 28 g RMS; 5 min per axe,
- Rapid change of temperature (RCT): 1500 cycles and electrical continuity,
- Storage test: 1000 h @ 125 °C according to ESCC 3401.
- Thermal behavior

These tests aim to evaluate our assembly in the most representative flight conditions environment by a prime satellite manufacturer.

Conclusion

To summarize, we have introduced the spring-contact used in our interposer. Some characterizations like static and dynamic evaluations were achieved with an experimental test bench developed especially for this purpose.
We have also presented on this paper a work on an assembly made with a Hymstac interposer 625 points and a compression tool. The principle of interconnection and a mounting procedure were shown. First tests were achieved on the assembly. To implant this system on flying equipment, an optimization of weight was proposed by using aluminum and by improving the design. Following this work on the weight, some tests were done and have given encouraging results to go further in the evaluation with a prime satellite manufacturer.
The result of this study is a system that has a weight light enough to be embedded. Thus Hypertac solution based on Hymstac spring could be an alternative of column ceramic grid array (CCGA) interconnect solution. In addition, this possibility avoids soldering process and associated soldering X-ray inspection.
To finish, the fact that it's a solderless connection offers the chance to mount / dismount it easily if something wrong with the LGA without stressing the card by a repairing process, for example a new passage in the oven to solder another LGA.

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