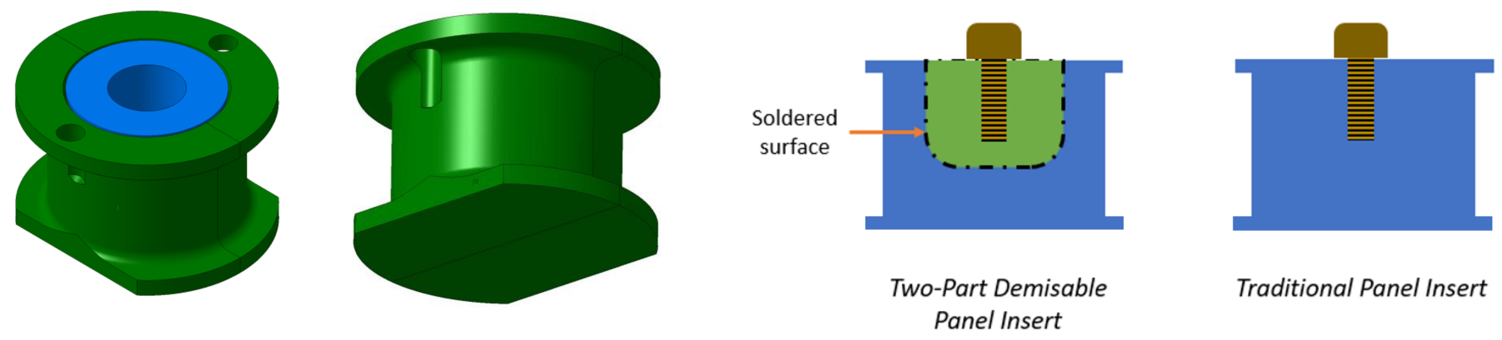
DEVELOPMENT AND VERIFICATION OF DEMISABLE INSERTS FOR JOINING OF SATELLITE PANELS AND EQUIPMENT



Motivation and Objectives

As the space industry continues to expand, the challenge of responsible satellite disposal becomes increasingly pressing. One critical aspect of satellite disposal involves ensuring complete demise during re-entry into Earth's atmosphere. However, uncontrolled re-entry scenarios often result in certain parts of the satellite shielding others from the intense heat flux, diminishing their demisability and increasing the risk of debris reaching the ground. This poses a significant hazard to terrestrial populations, as individuals may be at risk of being struck by falling debris. Therefore, an urgent need emerged for mechanisms that will allow early separation of the satellite equipment.

This thesis focused on optimizing the design of demisable inserts for manufacturing, establishing a soldering method for a new design and developing a test campaign aimed at establishing and validating the proof of concept to reach Technology Readiness Level (TRL) 3.

Methodology

The design of the D4D inserts aimed for a near 1:1 replacement of traditional panel inserts with a demisable version, minimizing system impact and simplifying satellite integration. The final shape was chosen through a trade-off, considering mechanical performance, manufacturability, solderability, and separation performance.

Insert sizing was finalized using previously validated mathematical model based on data from previous demisable joint tests, with the joint's ultimate strength calculated using the following formula:

$$F = \tau_b \eta_s \eta_d A$$

Where η_s is the rate of functional soldered area, η_d is the loading angle coefficient, τ_b the shear strength of the solder, and A is a total soldered area.

Figure 1

The soldering methodology was developed through soldering trials, where various soldering parameters, like soldering duration and vacuum were studied, with subsequent X-ray evaluations of solder void content, with analysed sections shown and described in **Fig. 2**.

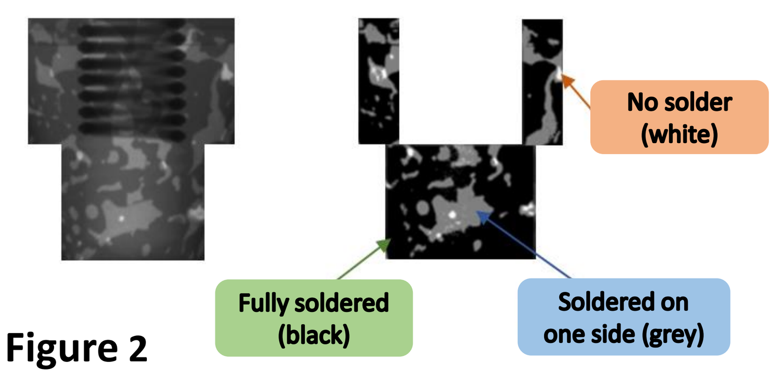


Figure 2

The permissible tension loads for a single insert were calculated with an internal tool following the *'ECSS-E-HB-32-22A' insert design handbook.* Allowables for selected cases listed in **Table 1** were used to establish three test load levels (L). $L1 = 1.5 \cdot Psst_{1-2}$, $L2 = 1.5 \cdot Psst_{3-2}$, $L3 = 2 \cdot Psst_{3-2}$, $L4 = \text{until rupture}$.

Analyzed case	Face Sheet thickness [mm]	Honeycomb Core type	Permissible Tension Load (Psst) [N]
1-2	0.5	3/16-5056-0.01	3362
3-2	0.5	1/8-5056-0.002	5971

Table 1

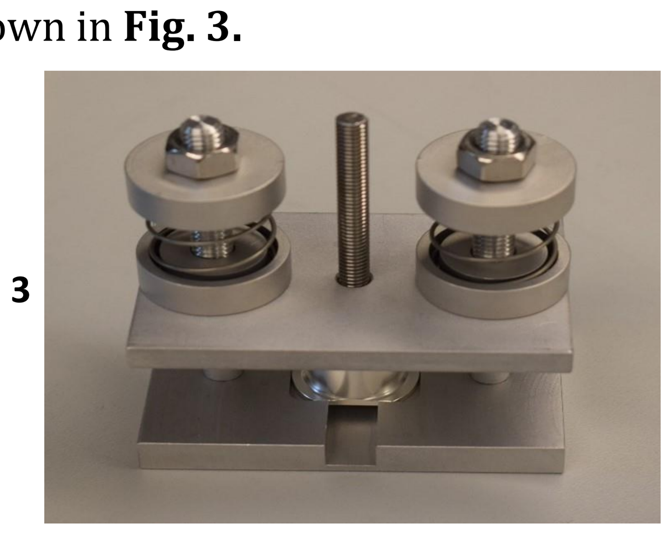
The functional test was conducted with the insert placed at three different angles: 0°, 45° and 60°. To simulate a minimal force exerted on the insert (here defined as 5N) a weight was attached to it.

Results

Initial trials resulted in selection of baseline design as an optimal configuration of cone and spool, providing better results than configurations with modified (shorter) cone and a spool with additional venting holes, while being less complex for manufacturing.

The soldering process for the demisable inserts built on the techniques developed for the Sentinel-1 two-part separation bracket is using an adapted vapour phase soldering process. This process involves placing the parts and their assembly jig in a chamber filled with an inert medium with a boiling point above the soldering temperature. The assembly jig secures the parts during soldering and applies a consistent pressure between the solder surfaces through a spring mechanism, as shown in **Fig. 3.**

Figure 3



The solder quality was found to have a strong positive corelation with increasing soldering time, as shown in **Fig. 4**. The plotted results in **Fig. 5** indicate that the effect eventually reaches a plateau. A tradeoff needs to be performed between the additional functional area and a longer manufacturing time.

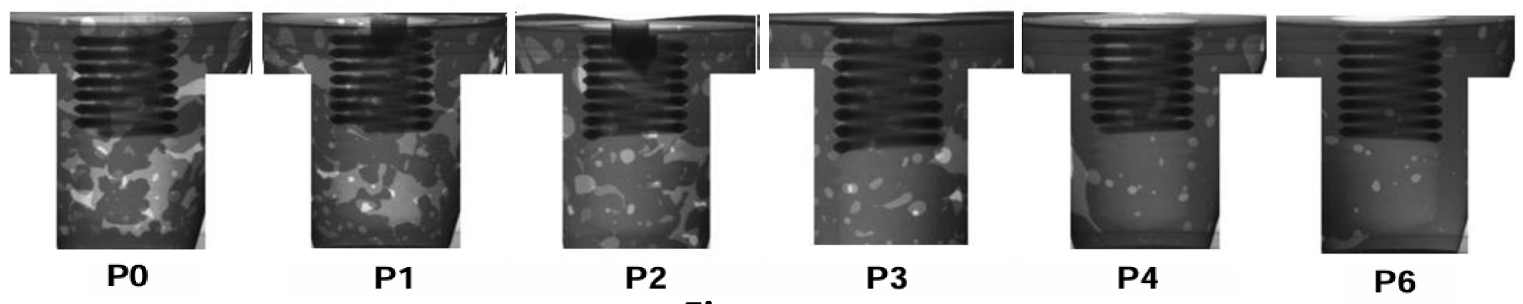


Figure 4

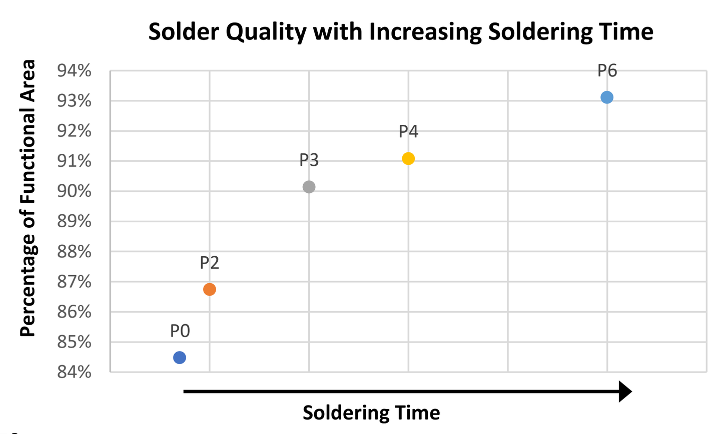


Figure 5

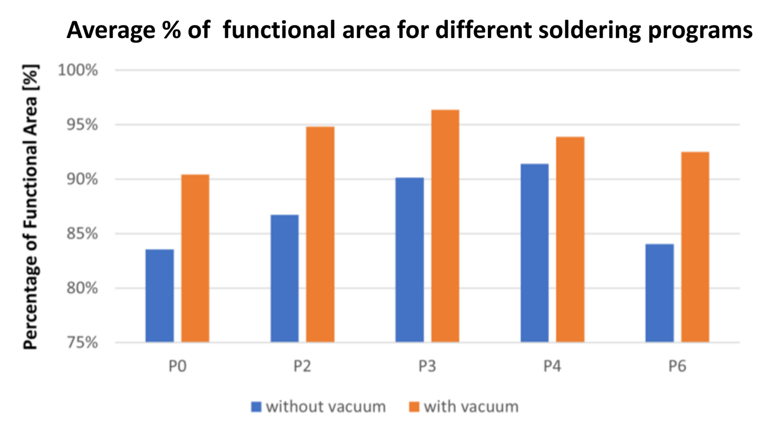


Figure 7

Although the ratio of functional area in the final trials from **Fig. 4** were satisfactory, an attempt was made to mitigate the homogenous voids that were present in most of the joints. Since the voids were proved to be present due to an entrapped solder flux agent, an additional stage was introduced, where the solder still in the liquidus state is placed under vacuum.

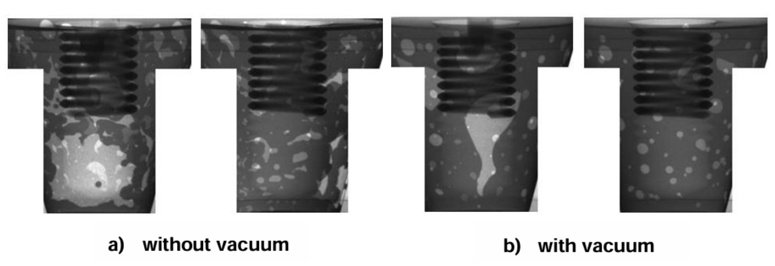


Figure 6

Analysis of the data from **Fig. 7** revealed that introduction of the vacuum stage provide ratio of functional area increase ranging from 6% to 9%.

Optimal parameters obtained from the trials included a P4 program with an additional vacuum stage.

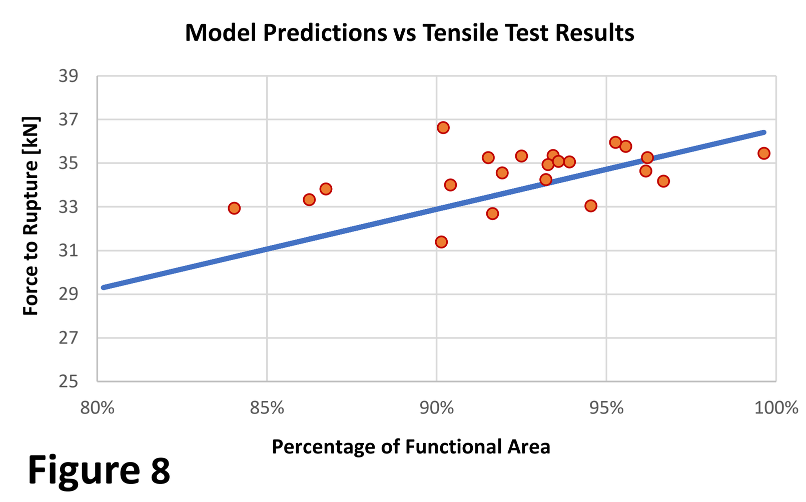


Figure 8

Inserts manufactured with both optimal and non-optimal parameters were tested and they all passed the test showing an ultimate strength significantly greater than the allowables.

Insert No.	Angle [°]	Release	Time of Release*
0924_01	45	yes	< 5 min
0924_09	0	yes	< 5 min
0924_25	60	yes	< 5 min
0924_29	45	yes	< 5 min
0924_30	0	yes	< 5 min
0924_33	60	yes	< 5 min

Table 2

Successful release was seen at all tested angles demonstrating the release functionality of the design.

Future Work

- Perform additional soldering trials with the jig manufactured to high precision and small tolerances.
- Refine void content analysis tool and method.
- Conduct additional testing across different load cases, including shear & fatigue
- Develop another insert version for machined panels
- Perform testing on samples after environmental treatment (thermal cycling/ vacuum treatment, corrosion test)
- Perform panel pull-out testing

Conclusions

The load capacity estimation model was validated, with results showing less than 5% deviation from test data, proving its effectiveness for use in preliminary sizing of D4D inserts.

The obtained optimal soldering parameters have proven to result in <20% solder void content, which is an ECSS requirement for soldered joints.

Influence of several parameters was tested and both increased soldering time and additional vacuum stage proved to have strong positive impact on the solder quality.

Testing of inserts with optimal parameters showed failure loads between 33 kN and 36 kN. With a theoretical permissible tensile load of 6 kN, a safety factor between 5 and 6 is expected, demonstrating robustness of the design.

The functional test demonstrated that the release occurred at all of the three tested angles within 5 minutes after reaching the solder liquidus temperature range of 135°C to 145°C.

Connect

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