# DEMISABLE JOINT

## CLEAN SPACE INDUSTRIAL DAYS 2021



**Date :** 17/09/2021
**Ref :** non referenziato
**Rif. Modulo :** 83230347-DOC-TAS-IT-010

# TEAM

**Lilith Grassi** - Study manager

**Simone Bianchi**– Senior system engineer

**Thorn Schleutker** - DLR study manager

**Ali Gülhan** - Support and coordination to plasma wind tunnel tests


**Date :** 17/09/2021
**Ref :** non referenziato
**Rif. Modulo :** 83230347-DOC-TAS-IT-010

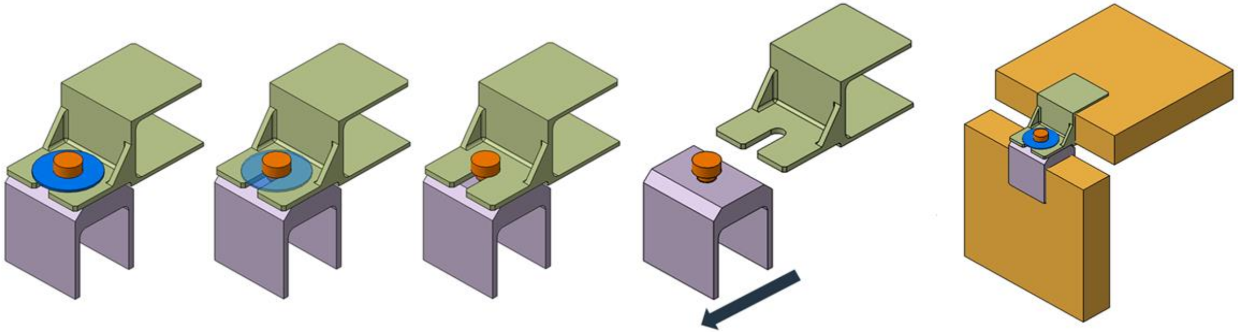
# STUDY CONTENTS & GOALS

/// The proposed Demisable Joint solution is a special joint design composed of an innovative washer made of easily-demisable material (i.e. having proper thermal properties, such as low melting point, low heat capacity, etc.). This demisable washer must be able to accomplish its structural and functional role during the S/C operative life.

/// The materials selected are the zinc-based alloy EZACTM and tin-based BABBIT grade 3.

/// The goal is to apply the demisable connection to at least the key satellite structural joints, inducing the detachment of the satellite external structures with a consequent earlier exposure of massive internal equipment, enhancing the disintegration of all satellite parts.

/// This jointing concept has been patented (Pub. n. EP3227184 – pub date 11.10.2017) by TAS-I as *Passive Device Designed to Facilitate Demise of a Space System During Re-entry into the Earth's Atmosphere*





**Date :** 17/09/2021
**Ref :** non referenziato
**Rif. Modulo :** 83230347-DOC-TAS-IT-010

# STUDY CONTENTS & GOALS

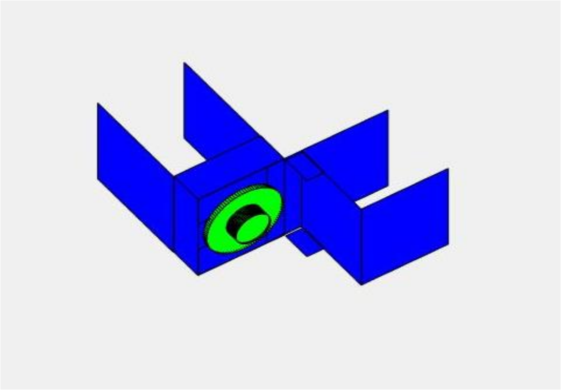
/// The detailed contents of this activities are:

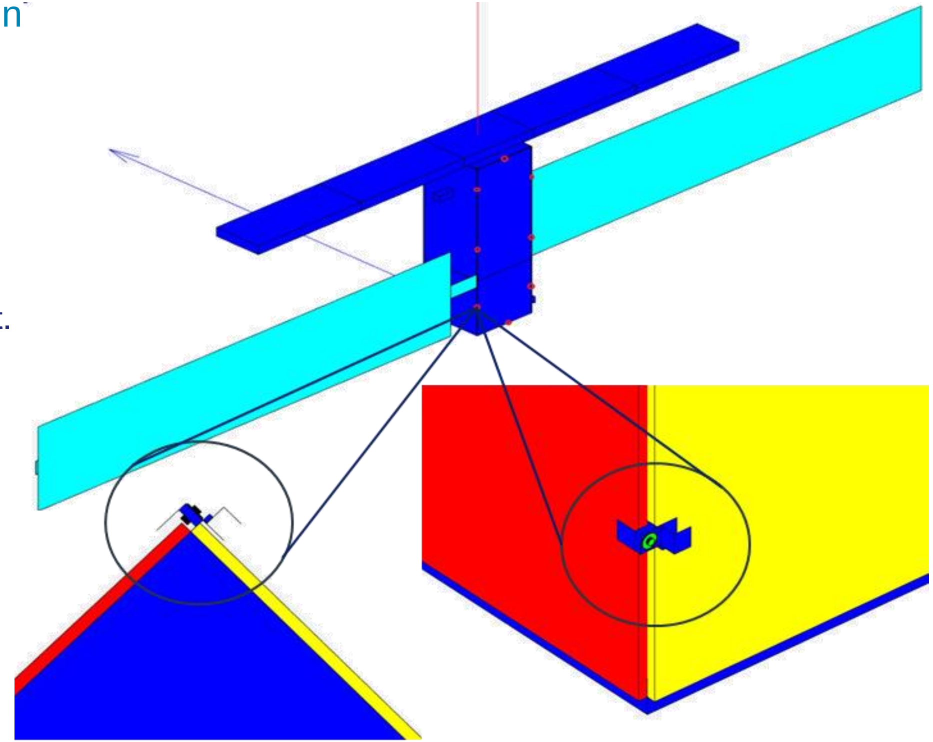
- Identification of the environmental conditions, reviewing past re-entry simulations and carrying out specific ones to identify the DJ behaviour.
- Breadboard the design of the Demisable Joint, detailing the geometrical and functional characteristics in view of the manufacturing phase.
- Test definition: the representative re-entry and test conditions, approach/plans for testing of the demisability of Demisable Joint Breadboard, sample characteristics, measurement techniques, post-test analysis methods.

/// Based on these assessments, two different test campaigns have been carried out on the Demisable Joint, to check the feasibility of the joint separation in the relevant environment (PWT test campaign) and to verify the possibility to ensure early joint separation due to the mechanical loads acting on the joint (static test campaign).

# IDENTIFICATION OF THE ENVIRONMENTAL CONDITIONS

- Identification of environmental loads / conditions (aerothermodynamic and structural) occurring on both existing and future S/C joints, through:
  - Review of available data and simulations (see inputs),
  - Perform dedicated low-fidelity re-entry analysis with internal TAS-I tool TADAP and
  - Identify the proper test conditions for the breadboard testing of TAS-I's "Demisable Joint" design and concept.






Date : 17/09/2021
Ref : non referenziato
Rif. Modulo : 83230347-DOC-TAS-IT-010

# IDENTIFICATION OF THE ENVIRONMENTAL CONDITIONS

| Time | Altitude | Temperature | Centrifugal Force | Local Forced Convective Heat Flux | Local conductive heat flux |
|---|---|---|---|---|---|
| [s] | [km] | [K] | [N] | [kW/m2] | [kW/m2] |
| 0 | 120 | 300 | 0 | 0 | 2 |
| 100 | 120.5 | 315 | 0 | 0 | 2 |
| 200 | 121 | 325 | 0 | 0 | 2 |
| 300 | 122 | 345 | 0 | 0 | 2 |
| 400 | 123 | 350 | 0 | 0 | 2 |
| 500 | 124 | 355 | 0 | 0 | 2 |
| 600 | 125 | 360 | 0 | 0 | 2 |
| 700 | 125.5 | 365 | 0 | 0 | 2 |
| 800 | 126 | 370 | 0 | 0 | 2 |
| 900 | 125.5 | 375 | 0 | 0 | 2 |
| 1000 | 125 | 380 | 0 | 0 | 2 |
| 1100 | 124 | 385 | 0 | 0 | 2 |
| 1200 | 121.5 | 390 | 0 | 0.5 | 2 |
| 1300 | 118 | 395 | 0 | 0.7 | 3.5 |
| 1400 | 114 | 405 | 0 | 1 | 4.5 |
| 1500 | 107 | 430 | 0 | 2 | 6.5 |
| 1600 | 102 | 485 | 0 | 3 | 11.5 |
| 1700 | 95 | 590 | 0.5 | 10 | 26 |
| 1770 | 91 | 670 | 1.5 | 13 | 37 |

# SAMPLES MANUFACTORING

/// Two different typologies of breadboard are manufactured because of the different features of the two test facilities:

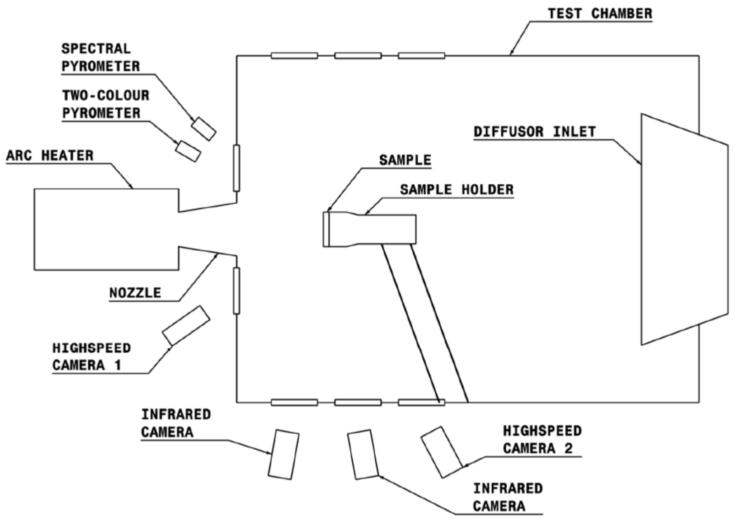
- For the PWT tests, the H/C panel section are needed in order to properly simulate the heat flux distribution and the heat exchange between the cleat and the H/C panels. The heat conducted from the panel to the cleat is a significant contributor to the heat received by the cleat. Sample given in the figure below, right.
- For the static testing , the HC panels are not needed both because the washer is directly heated by the coil of the induction system and also because the tests will be guided by the temperature of the washer (given in the figure below, left).

**Demisable joint only (DJ) (left); Cleats of the Demisable Joint attached to two sections of satellites H/C external panels (DJ+HC) (right)**


**Date :** 17/09/2021
**Ref :** non referenziato
**Rif. Modulo :** 83230347-DOC-TAS-IT-010

# PLASMA WIND TUNNEL TESTS

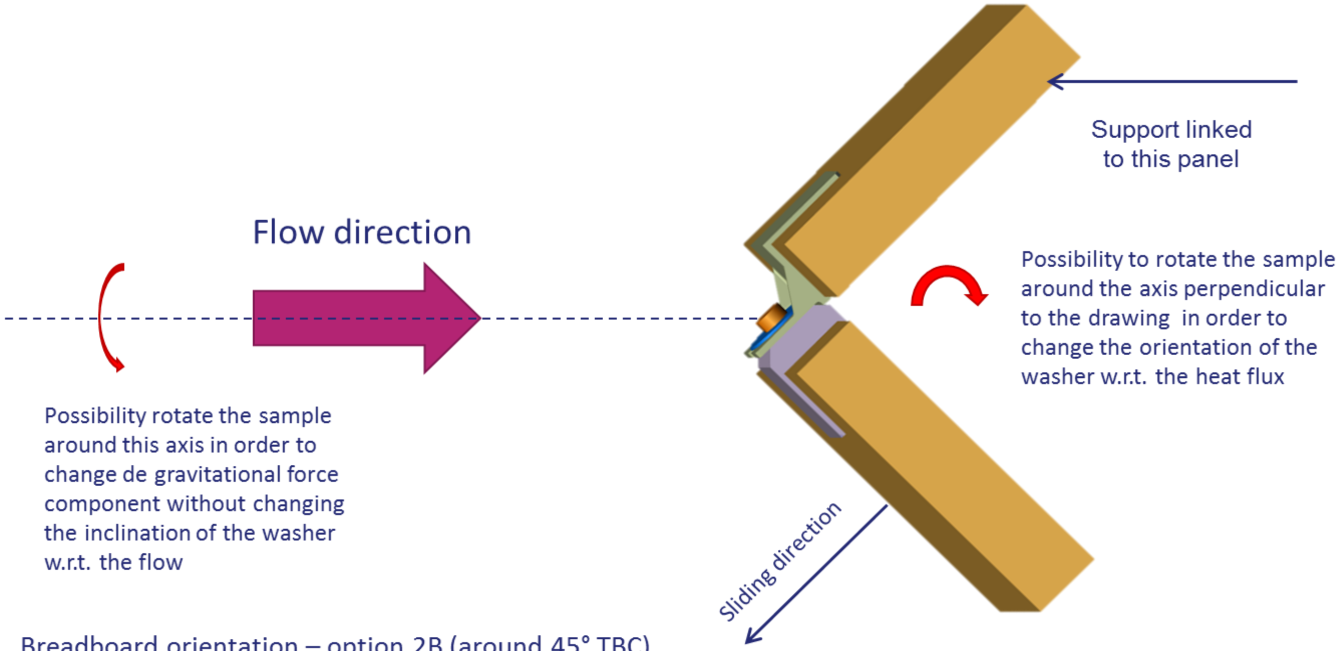
- The wind tunnel tests of the campaign were performed in the L2K wind tunnel, which is one of the two test legs of DLR's arc heated facilities LBK.
- The heat flux and surface pressure seen by the sample can be modified by variation of the air mass flow rate, the electrical current of the arc heater and the position of the model behind the exit of the conical supersonic nozzle. The angle of attack of the model is an additional variation parameter to match the required surface pressure and heat flux rate combination of the flight.
- As the tests primarily focus on revealing the demise processes and phenomenology, the most important optical instruments are the UHD cameras, which provides a high quality video footage of the test. This footage is used for investigating the macroscopic behavior in the time scale of the complete test. The camera is installed behind the window closest to the nozzle to allow a semi-frontal view onto the sample. This ensures that the behavior of the front facesheet can be investigated.




Instrumentation set-up in L2K


**Date :** 17/09/2021
**Ref :** non referenziato
**Rif. Modulo :** 83230347-DOC-TAS-IT-010

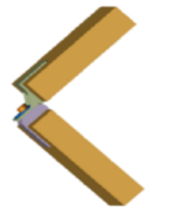
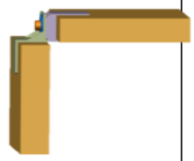
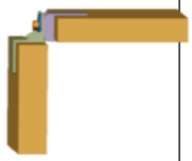
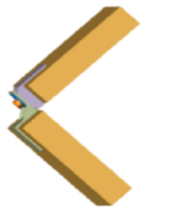
# PLASMA WIND TUNNEL TESTS




Breadboard orientation – option 2B (around 45° TBC)
exposing the samples to the flow at an angle of attack of about 45°

# PLASMA WIND TUNNEL TESTS

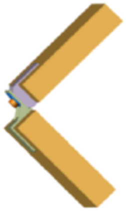
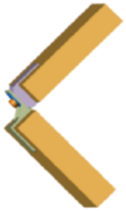
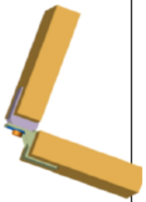
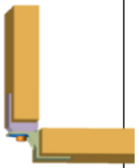
/// The plasma wind tunnel campaign consisted of 10 different tests divided into 2 sub-campaigns of 5 tests each. The test objects were Demisable Joints with both EZAC and BABBIT washers of various thicknesses and diameters. The test matrix of the PWT tests is reported hereinafter:

| ID | 01 | 02 | 03 | 04 | 05 |
|---|---|---|---|---|---|
| Washer | EZAC 20/1 | EZAC 20/1 | Babbit 20/2 | Babbit 20/1 | Babbit 20/2 |
| Orien-tation | ±45°, baseline | 0/-90°, panels switched | 0/-90°, panels switched | ±45°, panels switched | ±45°, panels switched |
| |  |  |  |  |  |
| Weight Addition | No | 150g | 150g | 100g | 150g |
| Result | No detach-ment | No detach-ment | No detach-ment | No detach-ment | Successful! |



Date : 17/09/2021
Ref : non referenziato
Rif. Modulo : 83230347-DOC-TAS-IT-010

# PLASMA WIND TUNNEL TESTS

| ID | 06 | 07 | 08 | 09 | 10 | 11 |
|---|---|---|---|---|---|---|
| Washer | EZAC 20/1 | Babbit 10/2 | EZAC 10/1 | EZAC 20/2 | EZAC 20/2 | Babbit 10/2 |
| Orien-tation | ±45°, baseline | ±45°, panels switched | ±45°, panels switched | ±45°, panels switched | +70/-20°, panels switched | +90/0°, panels switched |
| |  |  |  |  |  |  |
| Weight Addition | 150g | 150g | 150g | 150g | 150g | 100g close to bracket |
| Result | No detach-ment | Successful! | No detach-ment | No detach-ment | Successful! | Successful! |

/// The melting of the washer did not in all cases result in a separation of the joint itself during the test. The aerodynamic forces where able to maintain the panels of the breadboard in position in these cases.

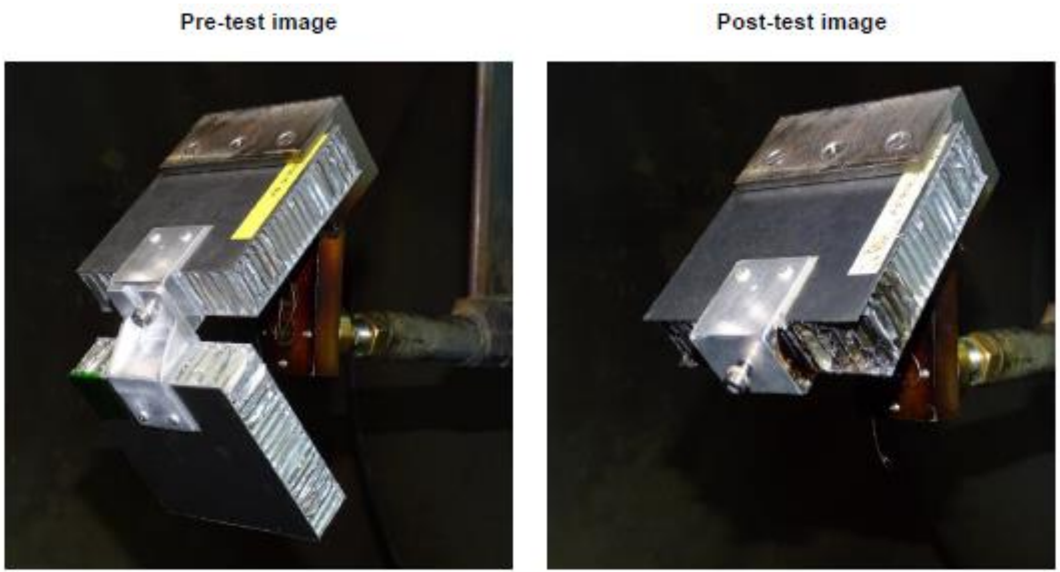
/// Despite these issues, the separation of the joint was achieved in 4 cases during the test running. In other 4 additional cases, separation occurred just after the shut down of the flow, once the pressure that was keeping the panel in place stopped. These cases cannot be considered fully successful.

/// In other terms, during PWT test, the separation of the joint once the washer has demised, is not ensured and it depends on some parameters -sliding parameters- as:

- Gap characteristics,
- Molten washer viscosity,
- Weights (overall value and position),
- Aerodynamic forces.


Date : 17/09/2021
Ref : non referenziato
Rif. Modulo : 83230347-DOC-TAS-IT-010

# PLASMA WIND TUNNEL TESTS




PWT Test 07

- It is worth mentioning, that the washer always demised before a relevant damage of both the cleats and the panels was seen, especially in the case of BABBIT washers (see figure below on the right).
- Furthermore, EZAC appears to have criticalities concerning outgassing, which are likely to prohibit its application. In light of this relevant consideration and the results of the test campaigns, BABBIT appears to be the reference choice for the future development phases of DJ.

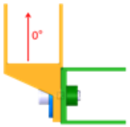
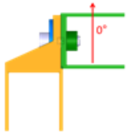
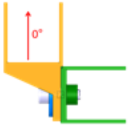
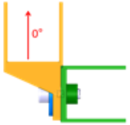

Date : 17/09/2021
Ref : non referenziato
Rif. Modulo : 83230347-DOC-TAS-IT-010

# STATIC TESTS

- The scope of the static tests (performed at the premises of EXOVA srl – Crema - Italy) is to verify the influence of the limited mechanical loads acting on the joint during the early phase of re-entry, to eventually assess if the separation of the joint could occur before the washer reaches its melting point.

- The test results are summarized in the following test matrix, which reports each test in detail. The outcome of the test can be assigned via simple coloured labels (rightmost column):
  - Red label: the test was executed correctly, but no improvement on joint separation was provided by the added weights
  - Green label: the test was executed correctly, improvement on joint separation was provided by the added weights
  - Blue label: the execution of the test had problems or the results are not reputed coherent.

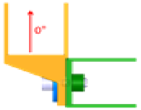
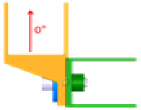
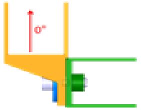
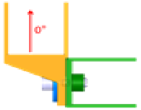
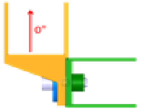
# STATIC TESTS

| Test ID | Test Sample ID | Test Sample Type | Temperature Profile | Force Profile | Cleat Connected to the holder | Test Result / Comments | Test Mark Rationale | Test Mark |
|---|---|---|---|---|---|---|---|---|
| #1 | 18 | Babbit, 20, 1 | baseline | baseline |   green cleat (cleat with insert) | Only a small part of the washer melted. The traction system didn't work due to friction | This test did not allow to assess the influence of weight on joint separation | |
| #2 | 18 | Babbit, 20, 1 | baseline | baseline |   yellow (cleat with opening) | Only a small part of the washer melted. The traction system didn't work due to friction | This test did not allow to assess the influence of weight on joint separation | |
| #3 | 19 | Babbit, 20, 2 | baseline | Simple weight of 150 g |   green cleat (cleat with insert) | Due the difficulty in the execution of the tractioning via tractioning machine, 150 g weights were added to the sides of the green cleat.<br>The cleats separeted at abuout 280 °C, when the washer was totally melted. | No influence of weight detected | |
| #4 | 23 | Babbit, 10, 2 | baseline | Simple weight of 150 g |   yellow (cleat with opening) | The TC has been welded to the washer thickness. 150 g- weights were added.<br>The cleats separeted at about 231 °C washer temperature | The cleats separeted at about 231 °C, it assumed the the washer was in viscous state, even if still not melted, but before its nominal melting point of ca 250-260 °C | |



Date : 17/09/2021
Ref : non referenziato
Rif. Modulo : 83230347-DOC-TAS-IT-010

# STATIC TESTS

| Test ID | Test Sample ID | Test Sample Type | Temperature Profile | Force Profile | Cleat Connected to the holder | Test Result / Comments | Test Mark Rationale | Test Mark |
|---|---|---|---|---|---|---|---|---|
| #5 | 13 | EZAC, 10, 2 | baseline | Simple weight of 150 g |   yellow (cleat with opening) | The TC has been welded to the washer thickness. 150 g- weights were added. The cleats separeted at about 396 °C washer temperature | The washer melted at 396 °C, at that moment the green cleat moved but the assembly remained stuck, the washer re-solidificated aroud the cleats and the screw, keeping united the assembly | |
| #6 | 17 | Babbit, 20, 1 | baseline | Simple weight of 150 g |   yellow (cleat with opening) | The cleats separeted at 241 °C | The cleats separeted before BABBIT melting point | |
| #7 | 6 | EZAC,20,1 | baseline | Simple weight of 150 g |   yellow (cleat with opening) | The cleats remained stucked. The washer melted but no separation occured | No joint separation | |
| #8 | 1 | EZAC,20,0.85 | baseline | Simple weight of 150 g |   yellow (cleat with opening) | The washer apparentevely melted at 280°C, the joint remained stuck. | Here there were problems with the temperature measure, since it's not possible EZAC melts at 280 °C | |
| #9 | 2 | EZAC,20,.85 | baseline | Simple weight of 300 g |   yellow (cleat with opening) | The washer apparentevely melted at 250°C, joint remained stuck. | Here there were problems with the temperature measure, since it's not possible EZAC melts at 250 °C | |


Date : 17/09/2021
Ref : non referenziato
Rif. Modulo : 83230347-DOC-TAS-IT-010

ThalesAlenia Space
a Thales / Leonardo company

# STATIC TESTS

/// In summary the following outcome were collected:

- The first campaign had: 5 blue-labelled test, and 2 positive test, and 3 negative.
- The second campaign had: 3 blue-labelled tests, and 3 positive tests, and 4 negative.

/// In the context of an overall summary of the static tests, the following points can be underlined:

- The simulation of the a profile of mechanical loads during the early phase of re-entry is not trivial due to the very small loads
- The adoption of simple weights is however acceptable since the weights used represented the load that could ca happen when the washer is near the melting point and therefore the joint separation more likely to happen
- Other inconvenient (blue-marked tests) are likely associated to the issue of measuring of the washer temperature: actually the placement and fixing of the thermocouple which measured the washer temperature was not easy and probably this resulted in not correct evaluations of the washer temperature.
- The induction system however worked well, e.g. in terms of following the baseline temperature profile and retro-action – as said, its correct functioning depends on a correct measure of washer temperature.
- 5 out 20 tests ended positively, while 8 ended negatively. The overall frame provided by this data is not clear due to the following factors:
  - Many different types of washers (dimensions, materials, etc.)
  - Different types of weights.
  - Uncertainties on the exact melting point / range of EZAC and especially BABBIT
- A positive behaviour seems especially associated to BABBIT washers which proved to have in general a clear melting, while EZAC had a viscous melting which could avoid an earlier separation. Still, the only 2 positive test in the first campaign (with lower weights) are both with BABBIT washer.
- Eventually, few tests were clearly positive showing the possibility of early the separation of the joint.

/// Some lesson-learnt / suggestions for future activities can be derived:

- For future test activities, reduce as much as possible, the typologies of washer to be tested
- Have preliminary check about the feasibility of test set-up (especially in case of actuators)
- Have a dedicated activity for ensure a correct measurement of the washer temperature

# CONCLUSIONS

- /// The PWT tests proved positive, showing that the joint separation is achievable once the washer reaches the melting range / point.
- /// The major concerns of this campaign were represented by the shifting, and the difficulty of simulating in the PWT the real environment condition (low heat flux) of the early phase of re-entry.
- /// The issue of shifting should be tackled in future phase of DJ development not only a single-joint level but at panel level (i.e. assessing the separation of more joints at the same time), the second aspects basically depends on the characteristics of the available facility.

- /// The static tests proved that an early separation of the joint caused by mechanical loads is possible and detected in some case. The campaign itself was quite jeopardised by the large number of different typologies of breadboard tested and by difficulties with the tests set-up.

- /// **In conclusion, both types of test ended with positive outcomes, suggesting improvements to the DJ design and especially showing no clear, general factors which can always avoid a correct functioning of Demisable Joint.**


Date : 17/09/2021
Ref : non referenziato
Rif. Modulo : 83230347-DOC-TAS-IT-010