Space Flight Materials in the Jovian Environment

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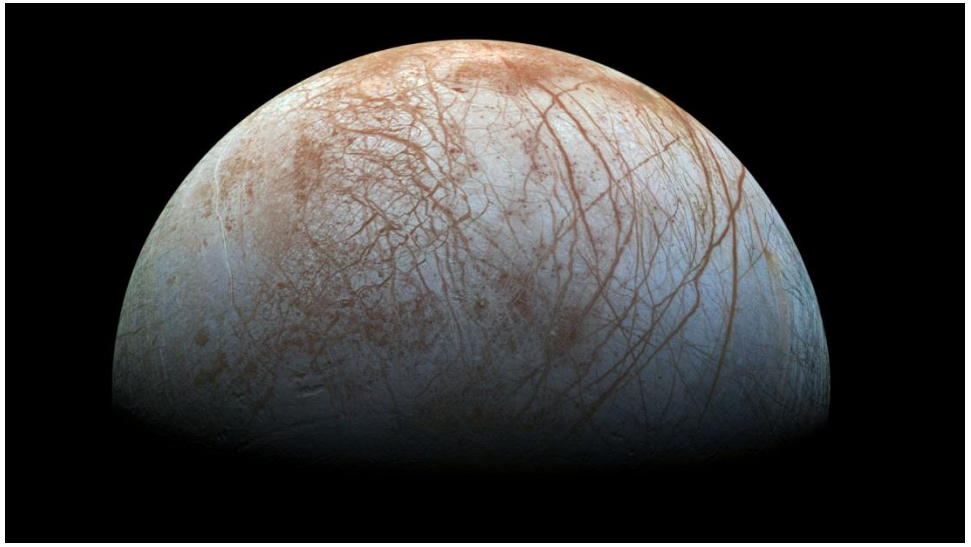
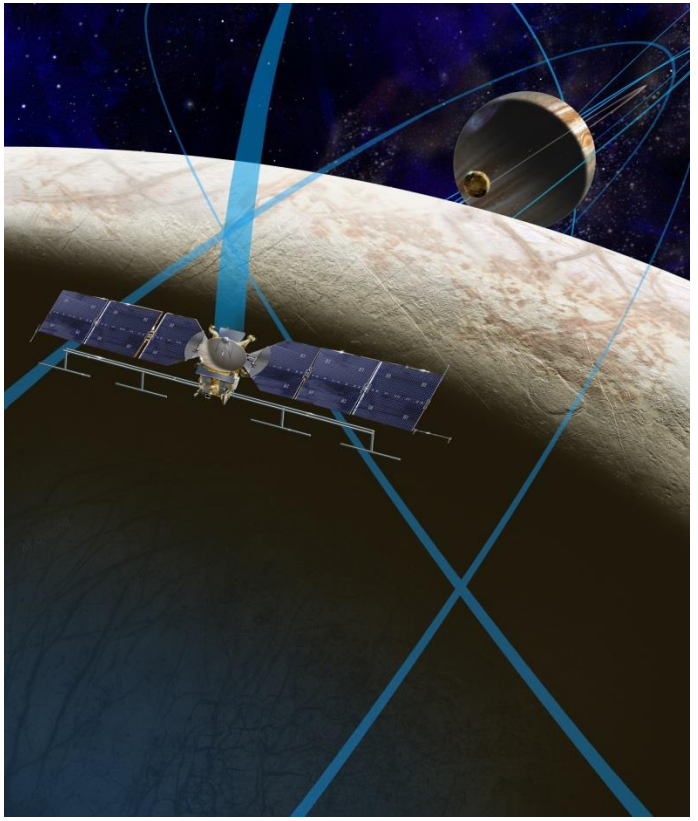
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Europa Clipper Project

- **NASA planned mission to Jupiter's moon Europa will perform scientific investigation to understand Europa's potential to harbor life**
- **Mission duration**
  - **45 flybys around Europa**
- **Jovian environment**
  - **High radiation levels on the order of GigaRads**



Credits: NASA/JPL-Caltech/SETI Institute



Credits: NASA/JPL-Caltech

Intro/Objective

- **Europa Clipper Materials Radiation and Thermal Cycle Risk Reduction**
  - **JPL/APL collaboration, APL performed testing and analysis**
  - **Test candidate adhesive materials that will be potentially used on the Europa Clipper mission**
  - **Simulate Jovian radiation environment**
    - **Total Ionizing Dose (TID) with RDF=2**
    - **Thermal environment (cycling to min, max temps)**
  - **Focus on radiation survivability by testing mechanical properties**
  - **Selected common adhesives used in unshielded/external spacecraft applications**
  - **Sample groups of control, thermal cycling, radiation exposure, and TC+Radiation exposure**

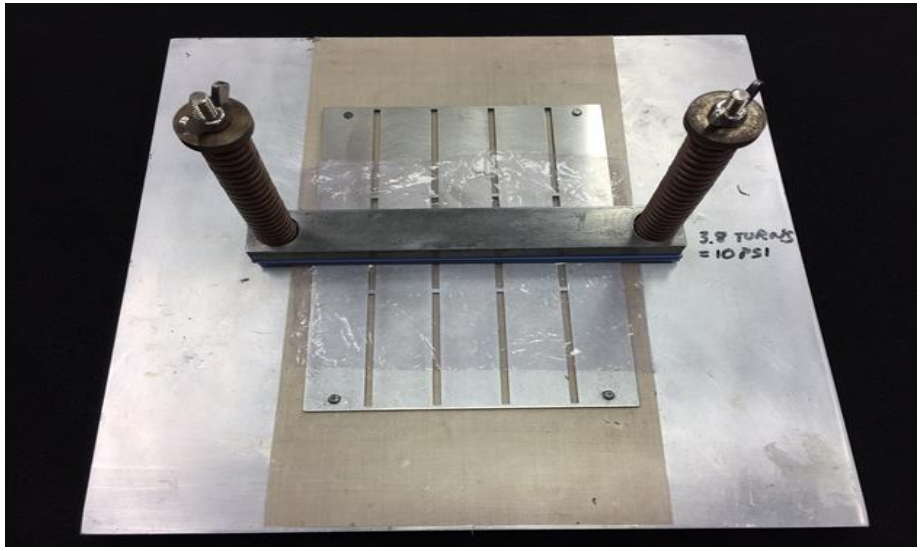
Sample Selection

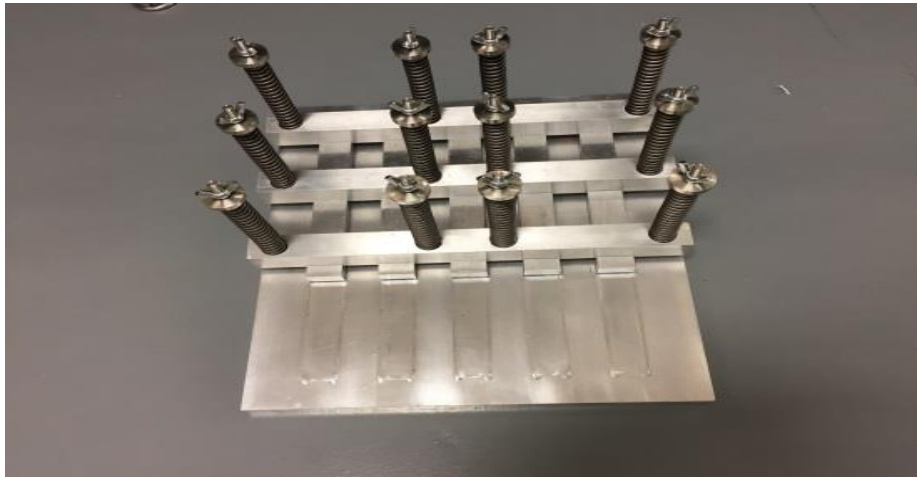
Adhesive	Vendor	Primer	Adhesive Type
966 Acrylic	3M	None	Acrylic
EA 9392	Henkel	BR-127	Epoxy
EA 9396	Henkel	BR-127	Epoxy
Stycast 2850FT /Cat 23LV*	Henkel	None	Epoxy
3140 RTV	Dow Corning	DC-1204	Silicone
566 RTV	Dow Corning	GE-SS-4155	Silicone
CV-2566	Nusil	SP-120	Silicone

Substrate	Material	Thickness
Rigid Metal	6061 Aluminum - Bare	62.5 mil
Flexible Polyimide	Kapton FPC- Etched*	5 mil

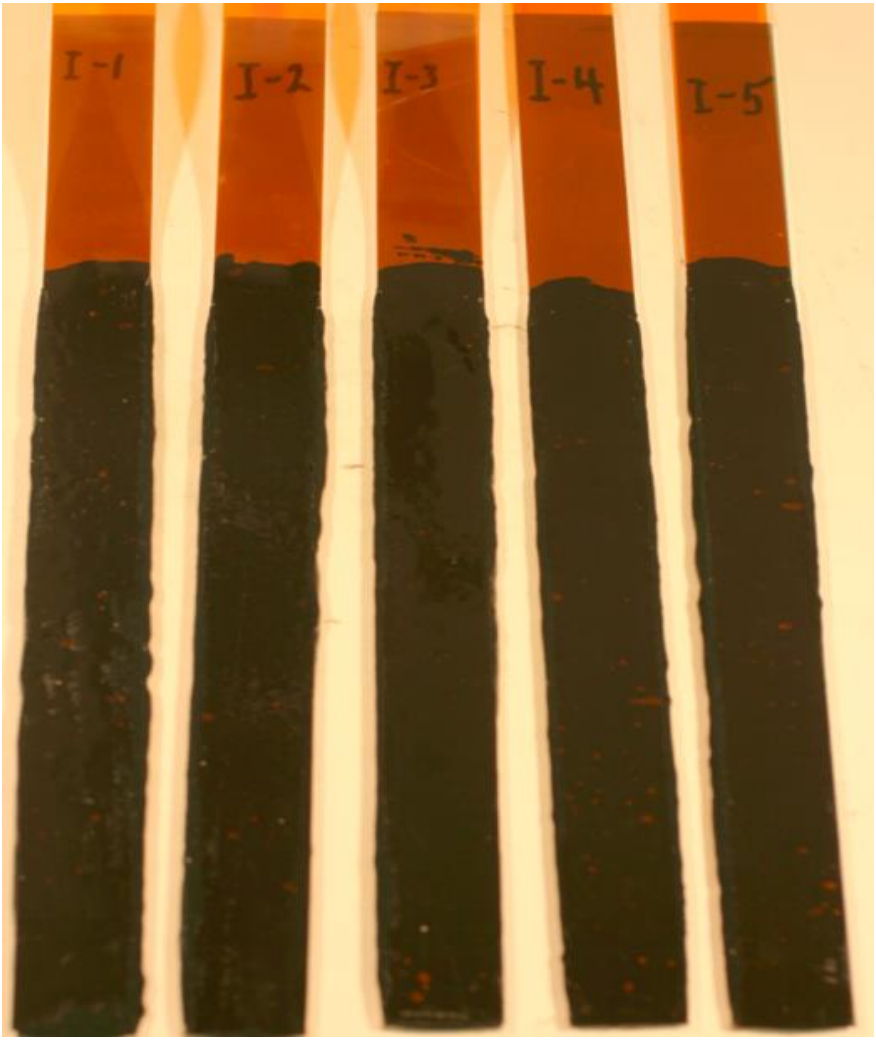
The substrates used were in accordance with ASTM D903 and ASTM D1002.

Sample Preparation and Fabrication





Above: Lap shear fixture assembly per ASTM D1002.
Below: Peel test fixture assembly per ASTM D903.



Peel test samples (Stycast 2850FT)

Test process

Control for each adhesive

No exposure

Thermal Cycle Only

10 hot cycles from RT to 195 C,
10 cold cycles from RT -230 C
Ramp 3-5 C/min
5E-5 Torr vacuum
Peak dwell time: 30 minutes

Radiation Only

Radiation exposure (TID)
- 100 Mrad
- 60 Mrad
- 40 Mrad

Radiation and Thermal Cycle

Radiation exposure (TID)
- 100 Mrad

10 hot cycles from RT to 195 C
10 cold cycles from RT to -230 C
Ramp 3-5 C/min
5E-5 Torr vacuum
Peak dwell time: 30 minutes

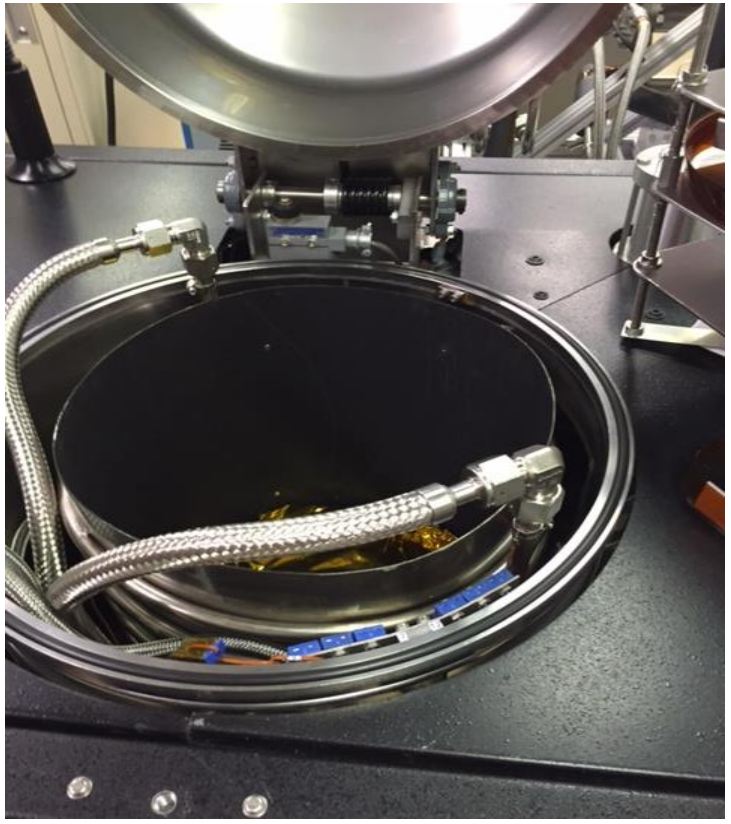
Evaluation

- Physical
  - Peak Stress/Peel Strength
  - Visual

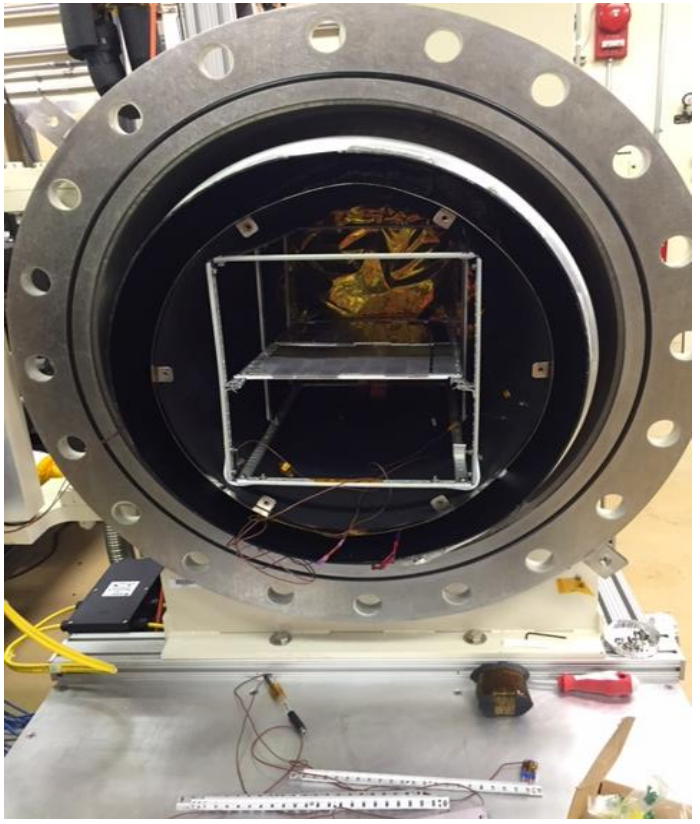
Sample size of 5 for each adhesive and test group

Test Equipment: Thermal Cycling

- **Used two separate chambers at APL Space Simulation Lab (SSL)**

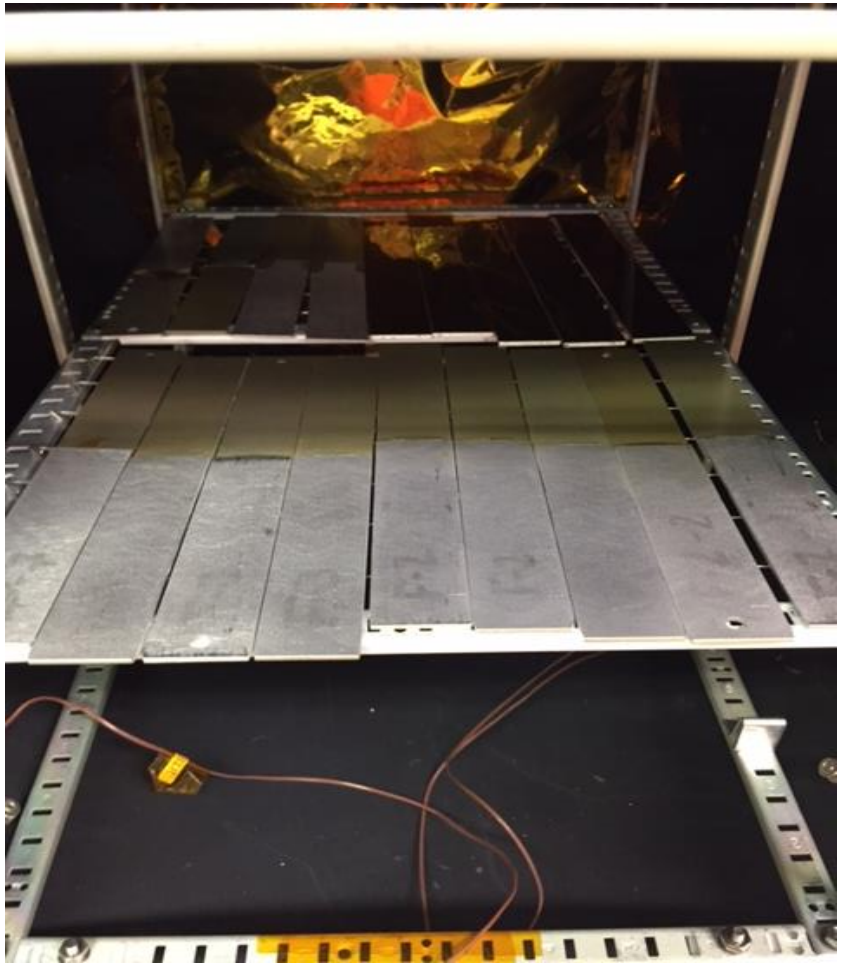


High temperature: Temescal bell jar chamber
- Thermal shroud
- Heated w/ GN2

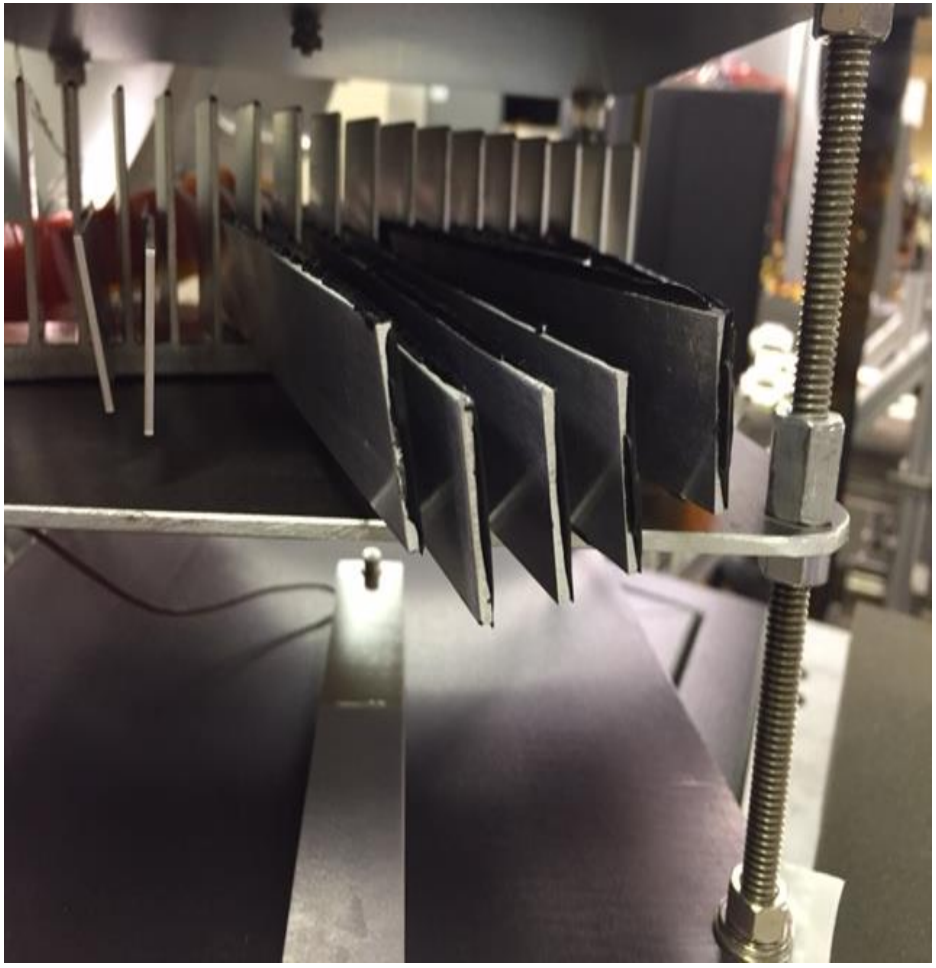


Low temperature: Cryogenic Automated Test System (CATS)
- Helium injected shroud
- Cryogenic pump

Thermal Cycling Test Fixtures



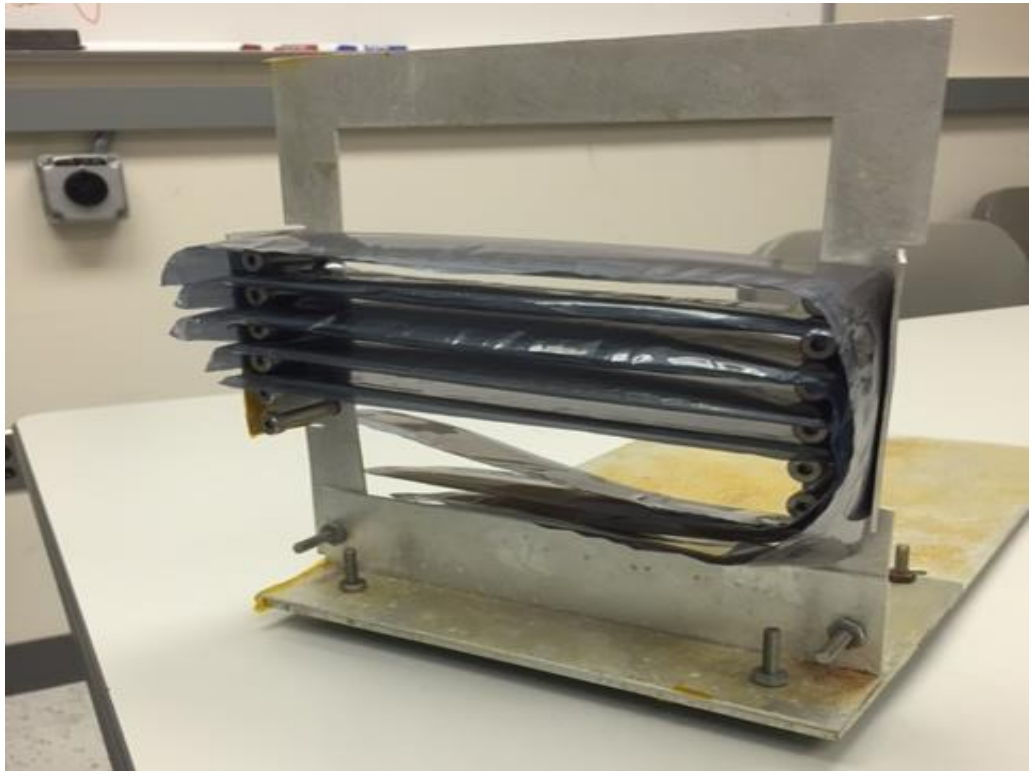
Left: Lap shear samples over wire frame test stand



Right: Peel test samples in aluminum grid test stand

Radiation Exposure

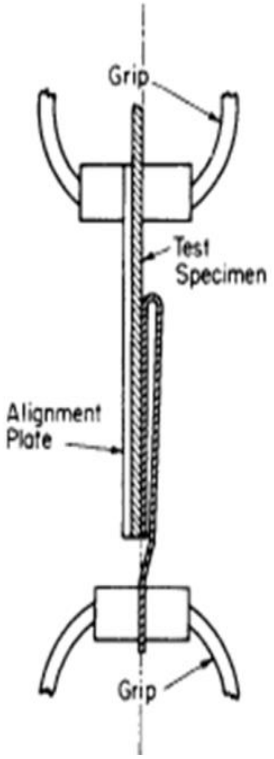
- **Seal adhesive samples in Kenlam bagging material through APL purge vacuum sealing system**
  - **Remove oxygen and moisture**
- **Irradiate in APL Space Department Cobalt-60 gamma radiation chamber**



Test fixture for peel test adhesive samples (set of 5). Goal was to uniformly expose all samples to the "center" of the radiation beam flux

Test Equipment and Method: ASTM D903-98

Standard Test Method for Peel or Stripping Strength of Adhesive Bonds

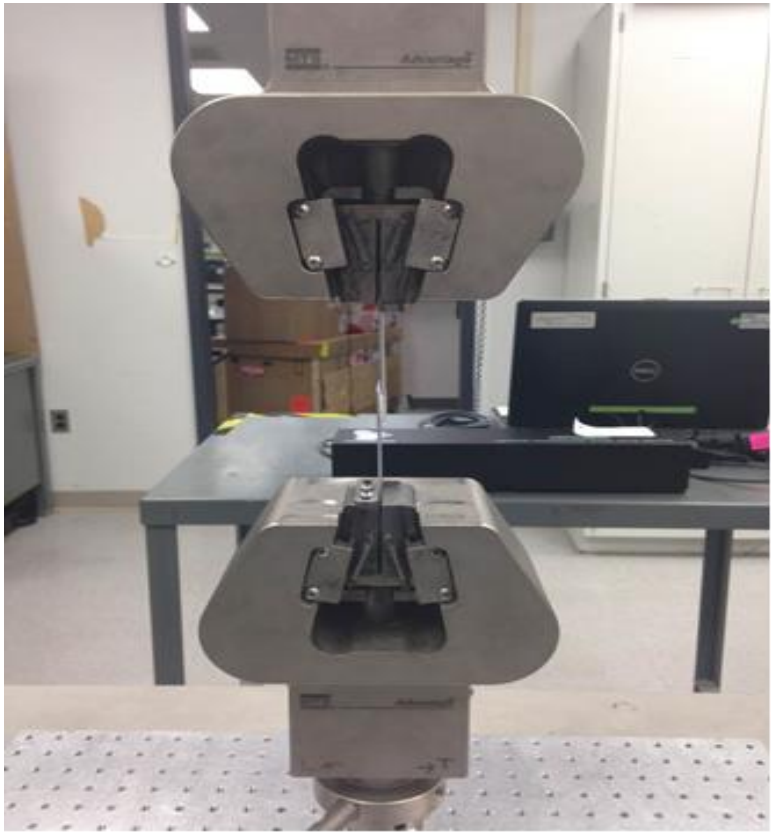


Left: Specimen under test configuration called by the ASTM test method

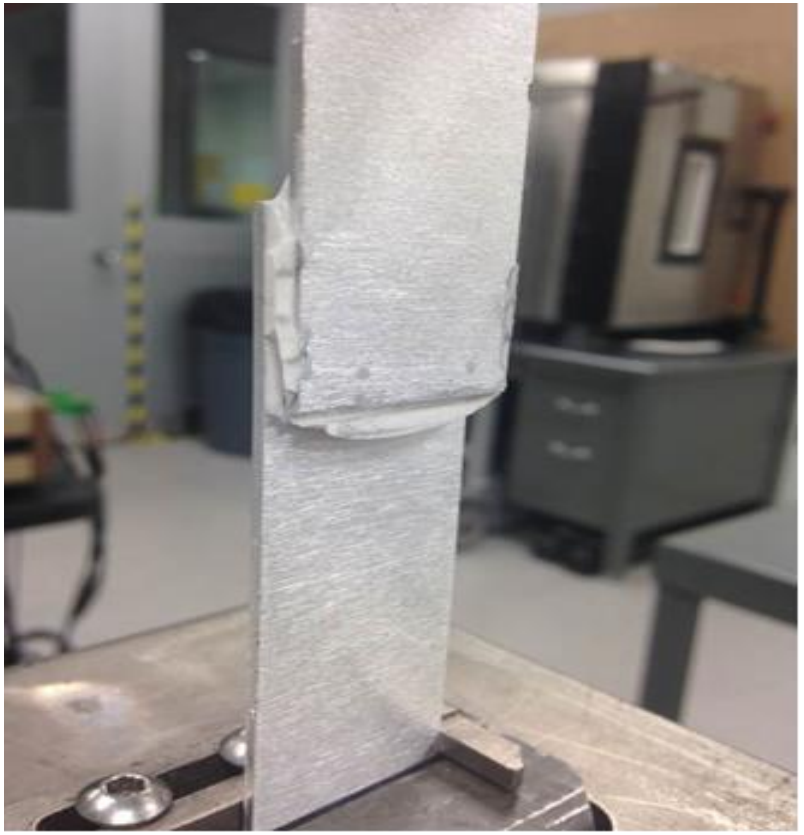
Right: APL testing machine

Test Equipment and Method: ASTM D1002

Apparent Shear Strength of Single Lap Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal to Metal)

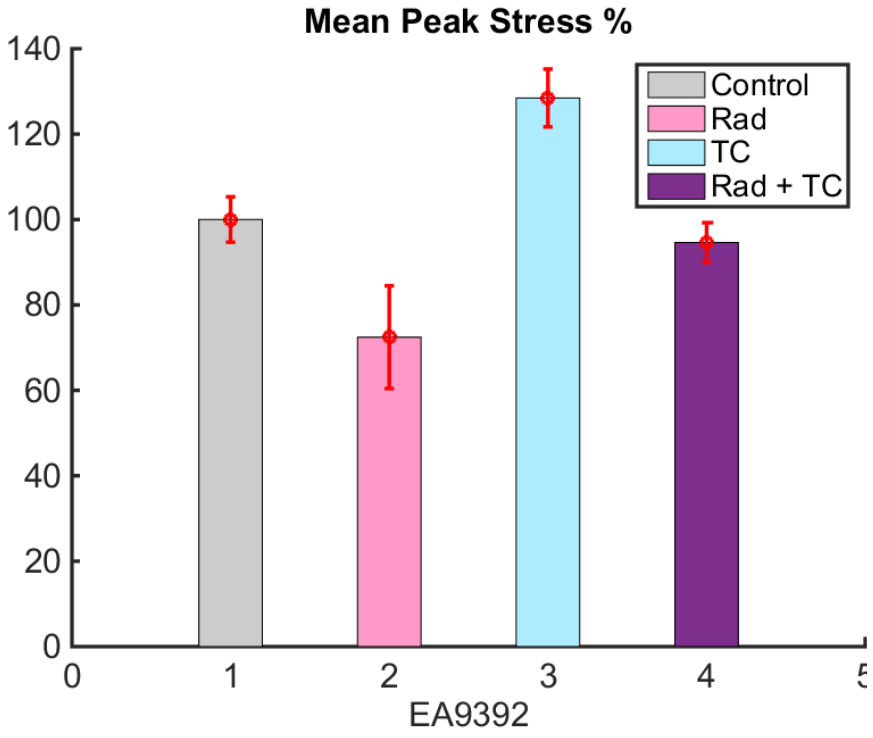


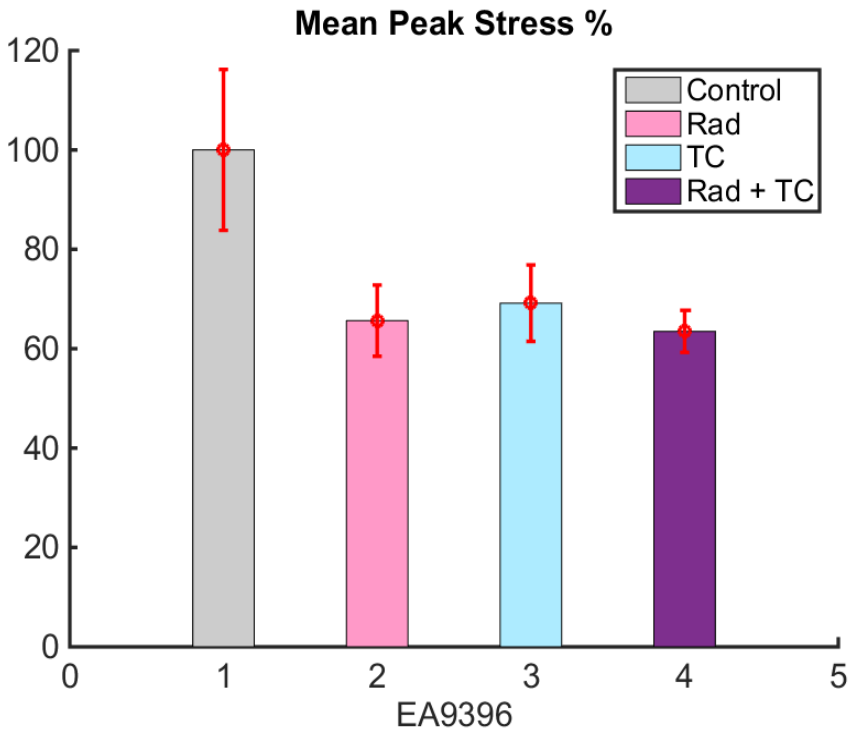
Left: Test Apparatus loaded with sample, conforming to ASTM test methods



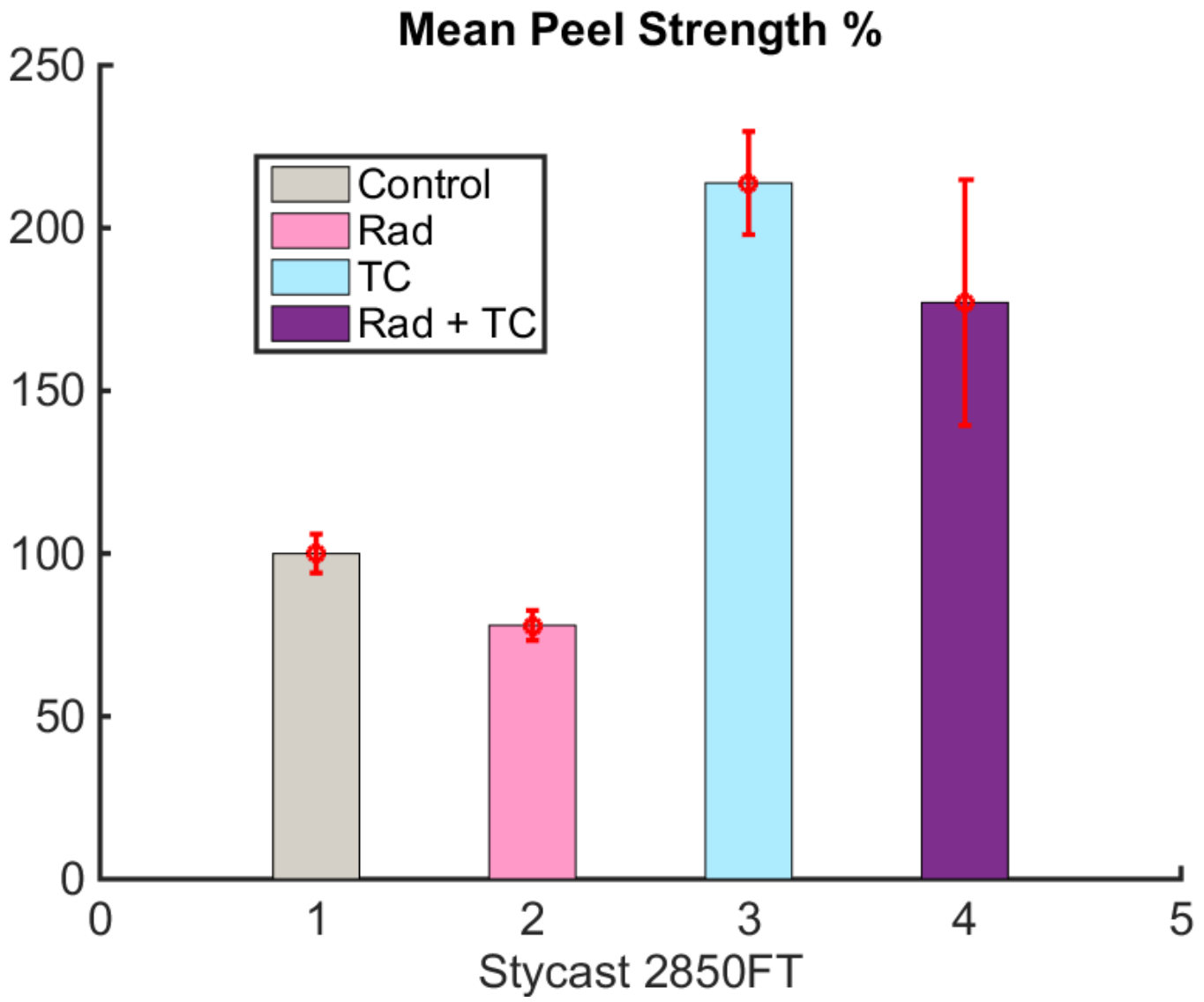
Right: Typical adhesive lap shear sample loaded into test apparatus

Lap Shear Results – 100 MRad level

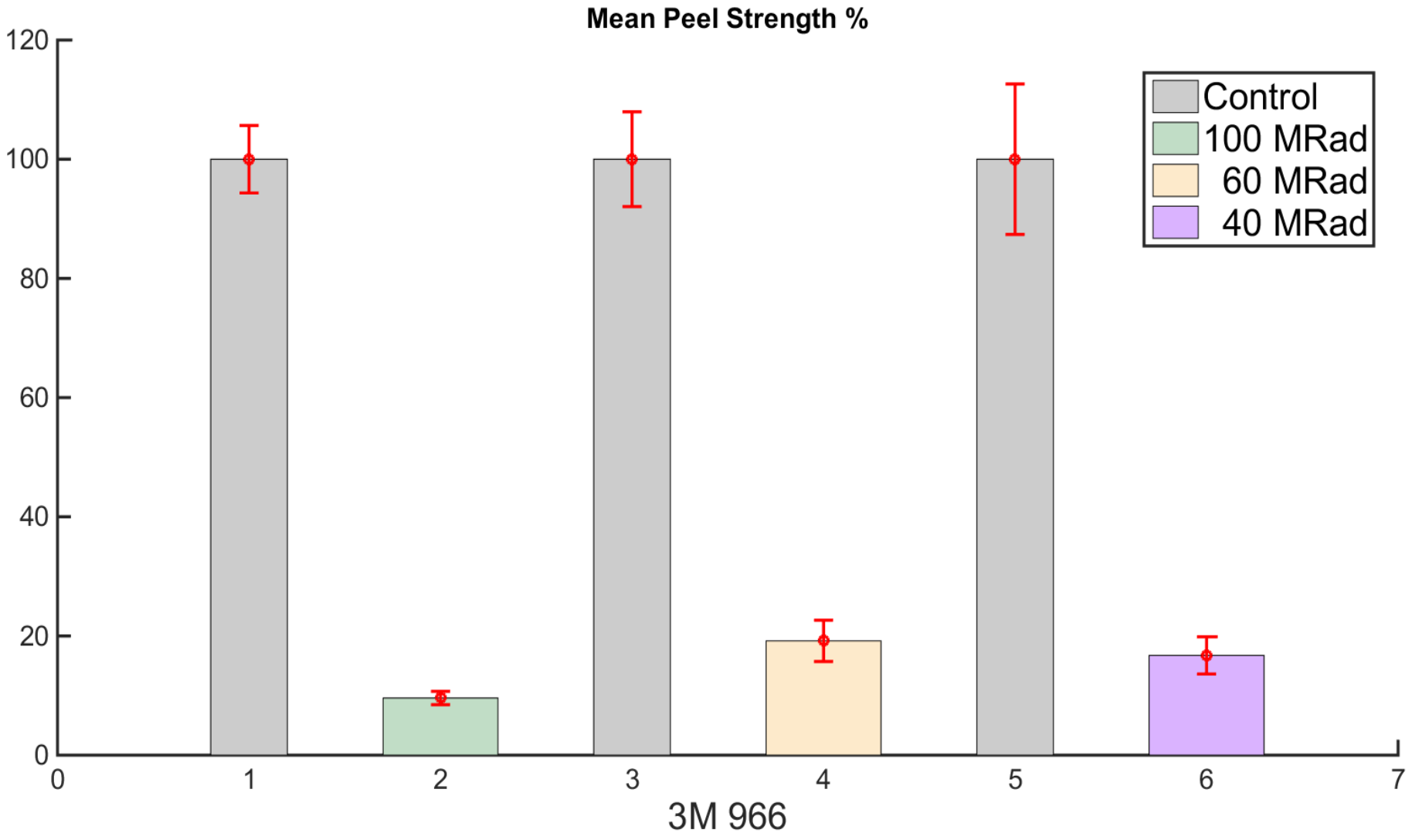




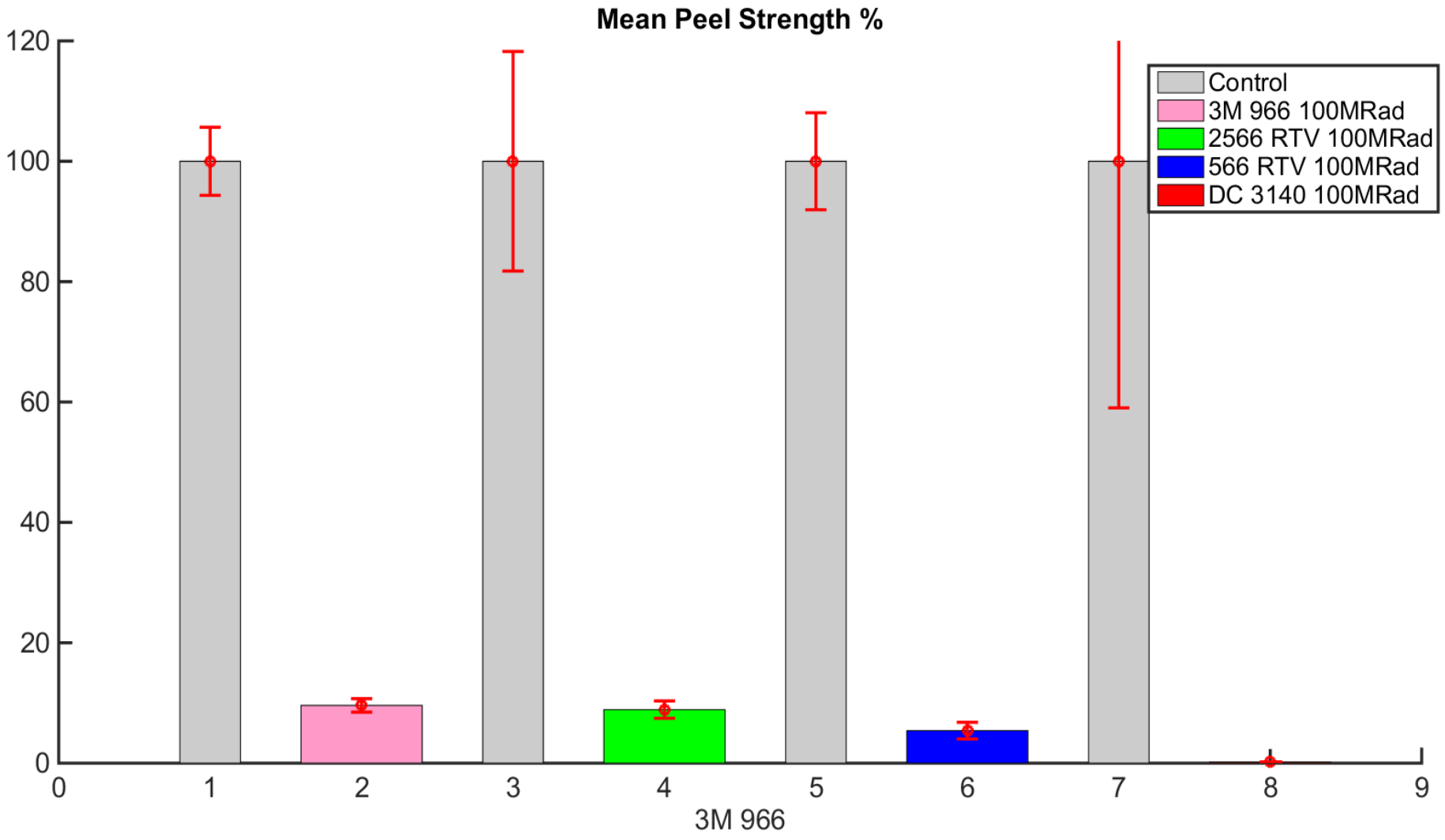
Peel Strength Results- Stycast 2850FT



Peel Strength Results- 3M 966



Peel Strength Results



Conclusion and Path Forward

- **Preliminary risk reduction adhesives testing in simulated Jovian environment**
- **Results show that epoxy adhesives degrade after exposure to 100 MRad, but still show structural capability**
- **Acrylic and silicone adhesive peel strengths degrade significantly after tens of MRad exposure**
  - **Recommendations**
    - **Further application specific testing of adhesives may be necessary**
    - **Employ additional or alternate means for mechanical attachment**
- **Future plans**
  - **Conduct follow-on adhesive radiation testing**
  - **Review developing design specific application information for adhesives from across project**
  - **Prioritize candidates for evaluation**
  - **Anticipated follow-on test to include the following:**
  - **Commonly used commercial tapes used for spacecraft applications**
  - **Lower radiation dose**
  - **Alternate thermal cycle parameters**
  - **Include effects of PP HMR exposure as appropriate**

Special Thanks!

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