Thermal Enhancements for Separable Thermal Mechanical Interfaces (STMI)

Matthew Flannery (ACT)
James Schmidt (ACT)
Jens Weyant (ACT)
Kevin Thorson (LM-ATL)

Presented By
William G. Anderson

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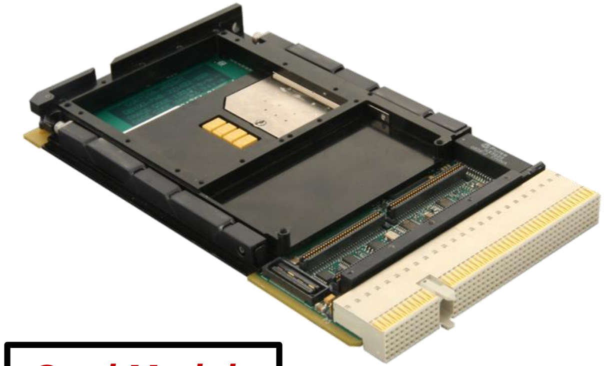
Program Background

Objective: Develop an easy to manufacture, low thermal resistance Separable Thermal Mechanical Interface (STMI) to be used in space and aircraft electronics applications.



Card Module

Standard Wedge Locks

Chassis Assembly

- High-power electronics, card-mounted, rack-installed, sealed cabinet construction with conduction-link to external cooling.
- The card assembly is designed to be easily replaceable by mechanical clamping. As a result, a weak thermal link exists between card and cooling.
- Wedge Lock clamps are preferred for this application but are poor thermal conductors.

http://www.cwcembedded.com/assets/images/product_images/124P-CC.jpg

Technical Approach

❑ Wedge Lock Design

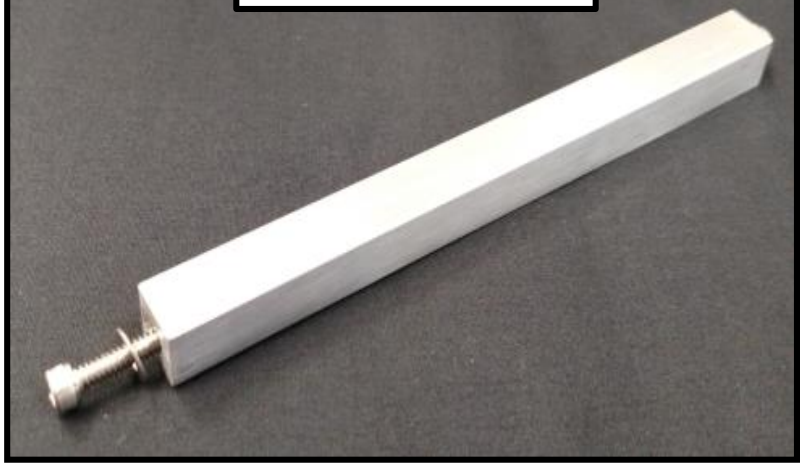
Current commercially available card retainers only expand in one direction, limiting the heat paths from the card to the heat sink

Wedge Lock

❑ Spiral Lock Design

Spiral Lock design reduces thermal resistance by increasing surface area for heat transfer and maximizing contact pressure. With two directions of expansion, the Spiral Lock uses brackets to contact all four sides of the thermal interface.

Spiral Lock



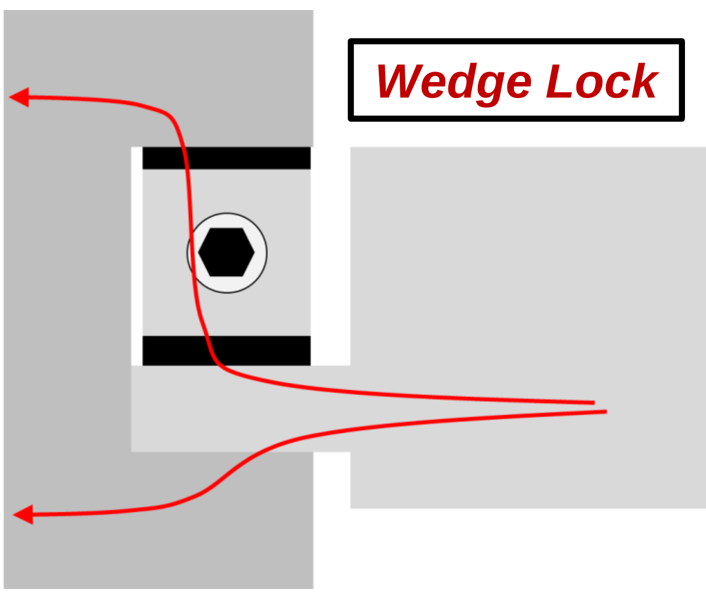
Theory of Operation

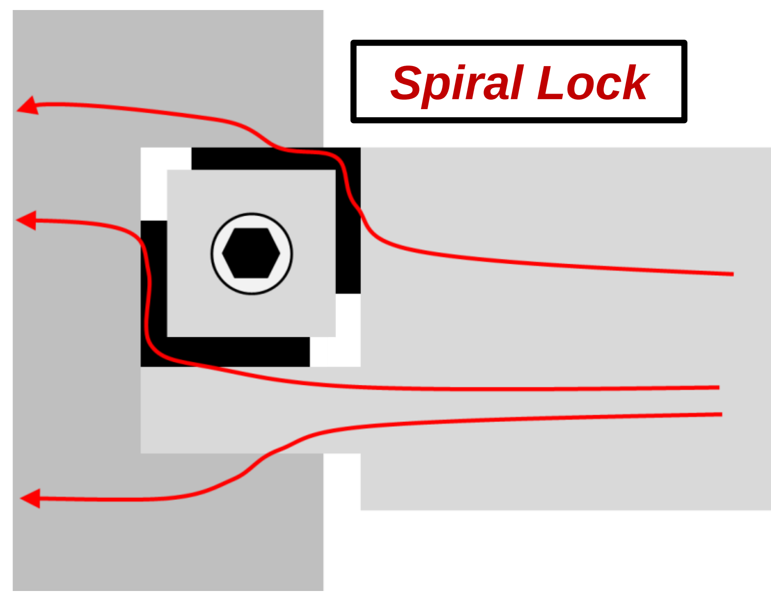
Wedging Action:

- Wedges provide method of redirecting axial bolt loading to perpendicular bracket movement.
- Compound angled facets allow for four DOF wedge movement.
- Wedge number, geometry, and surface conditions determine force output, and mechanical advantage.

Brackets:

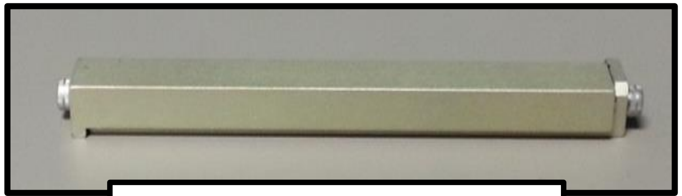
- Brackets spread clamping load, add extra surface area for heat transfer, and capture retainer parts to prevent FOD in the event of failure.
- Multiple paths for heat transfer from the card module frame and the chassis reduce thermal resistance.



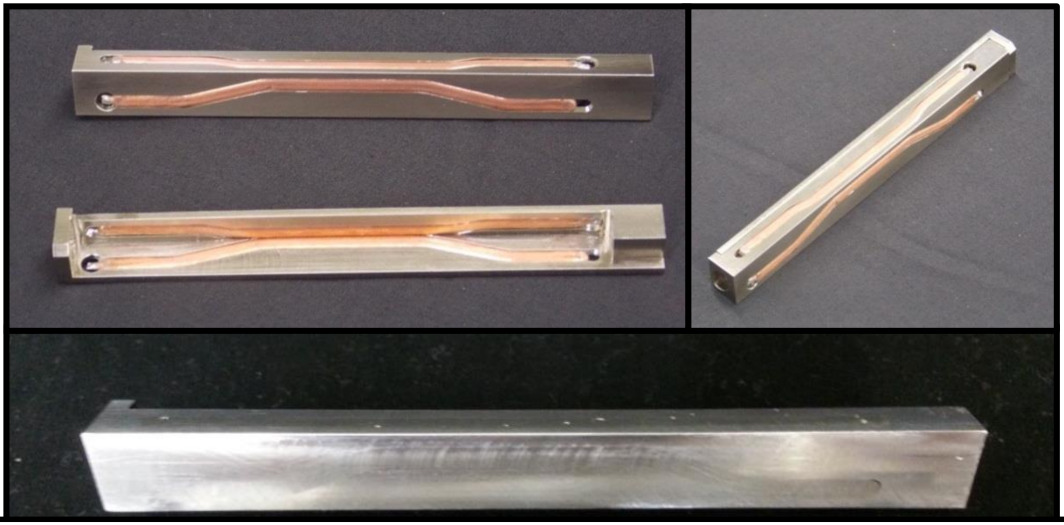


Original Spiral Lock Design

- **SBIR Phase I to improve the heat transfer of current wedge locks:**
  - ACT worked with Lockheed Martin to model and design prototype Spiral Lock card retainers.
  - Methods of improved thermal enhancement were sought, including integration of heat pipes into the L-brackets of Lockheed Martin's (LM) Spiral Locks to improve conductivity of the brackets
  - The prototype card retainers were tested for thermal performance using an apparatus which simulates a conduction card and liquid cooled chassis.

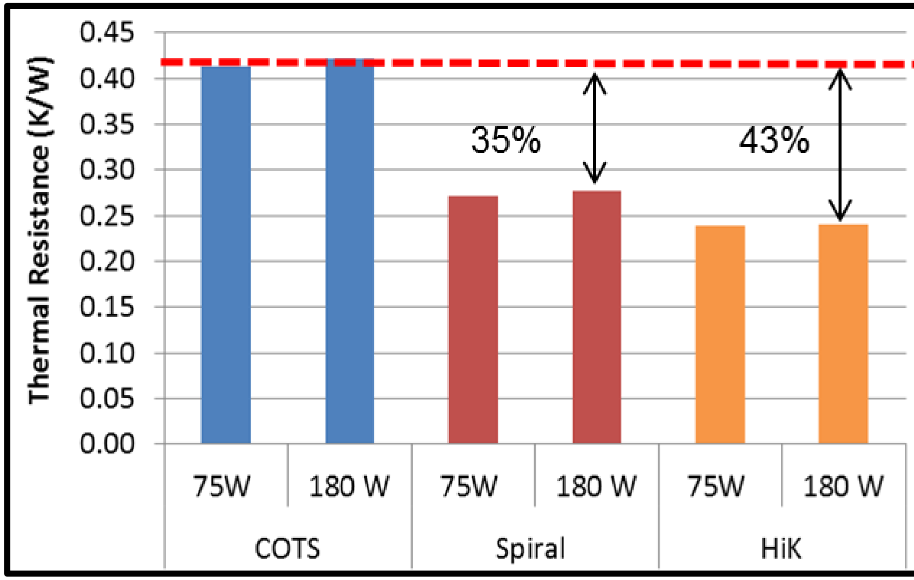


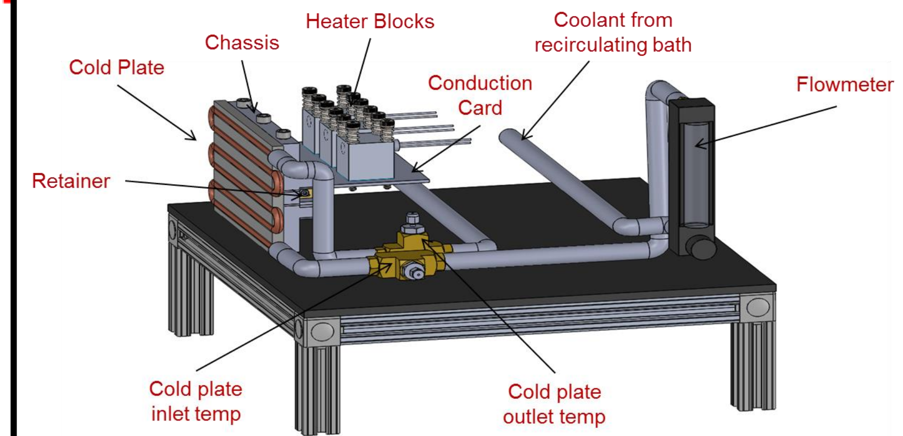
Original Spiral Lock produced with LM



ACT HiK™ Spiral Lock with embedded heat pipes before (top) and after(bottom) soldering and machining

Original Spiral Lock Performance





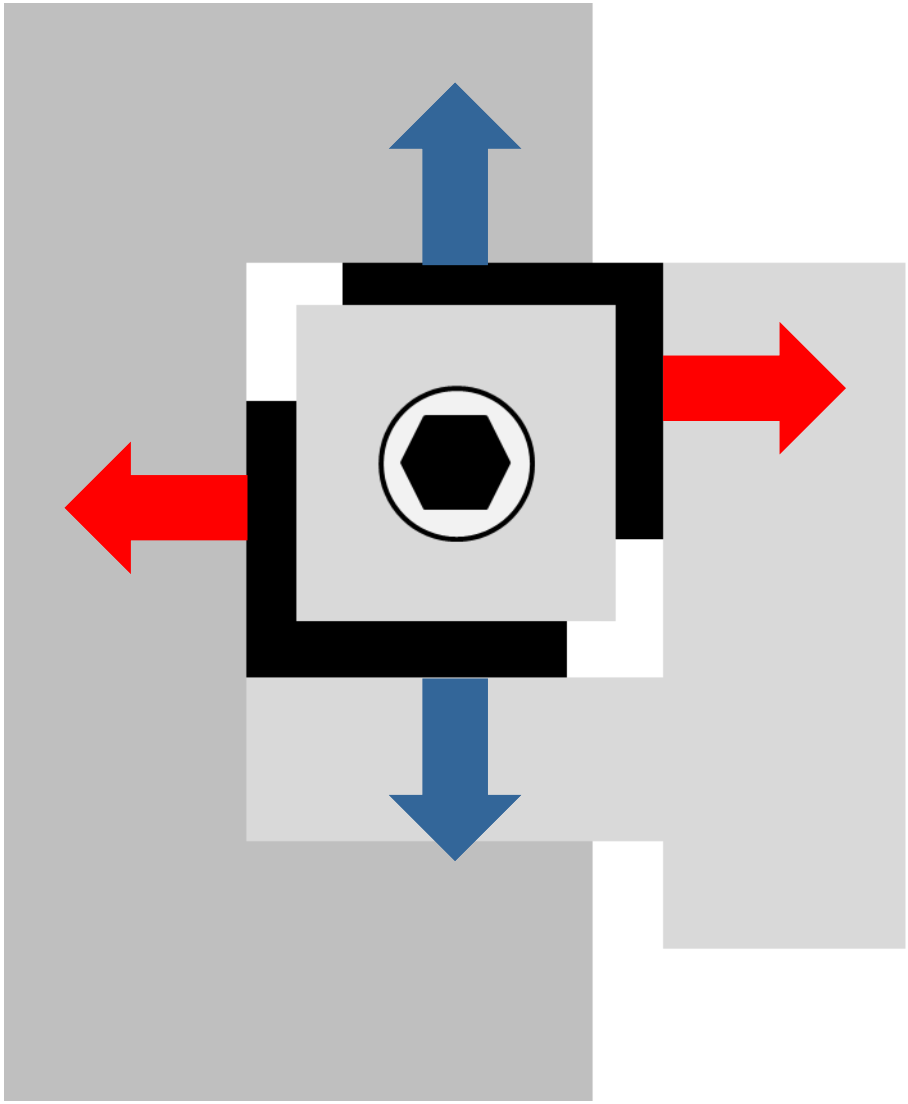
Thermal evaluations of the spiral lock design exhibited a 35-43% reduction in thermal resistance compared to the current COTS Wedge Lock design.

The thermal test apparatus consisted of an aluminum conduction card (half), a liquid cooled chassis wall, and temperature controlled recirculating liquid loop.

- **In future development, maintain performance while:**
  - Converting the dual-bolt design to enable integration into current chasses
  - Maximizing outward applied force, improving uniformity of contact
  - Improving manufacturability to compare favorably with existing devices
  - Identifying any other factors influencing performance to maximize performance gains

Integration Requirements

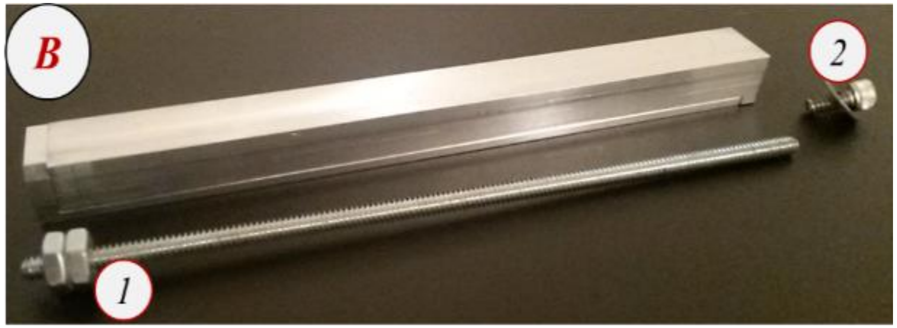
- **Actuation Mechanism:**
  - All current applications require the retainer to be actuated when only one side of the device is accessible.
  - The original Spiral Lock design works best when actuated using two screws, with equal actuation from both sides.



- **Chassis Deflection:**
  - Current thermal chasses are not designed in anticipation of outwardly applied loading.
  - Deflection of thin-walled chassis, such as in liquid-jacket cooled designs, could cause assembly issues or possible deformation.

Bolting Mechanism:

- Spiralock must be redesigned to eliminate one of the screws used to actuate the wedge/bracket mechanism.
- Previous tests showed that when bolted only by one-bolt, the Spiral Lock performed similar to the two-bolt design.
- The Spiral Lock wedges were redesigned to allow a single actuating screw to pull the wedges.
- Pulling the wedges removes the contact between the, previously pushing, screw and end wedge.



Legend

(1) Actuating Screw
(2) Capturing Screw

Thermal Testing

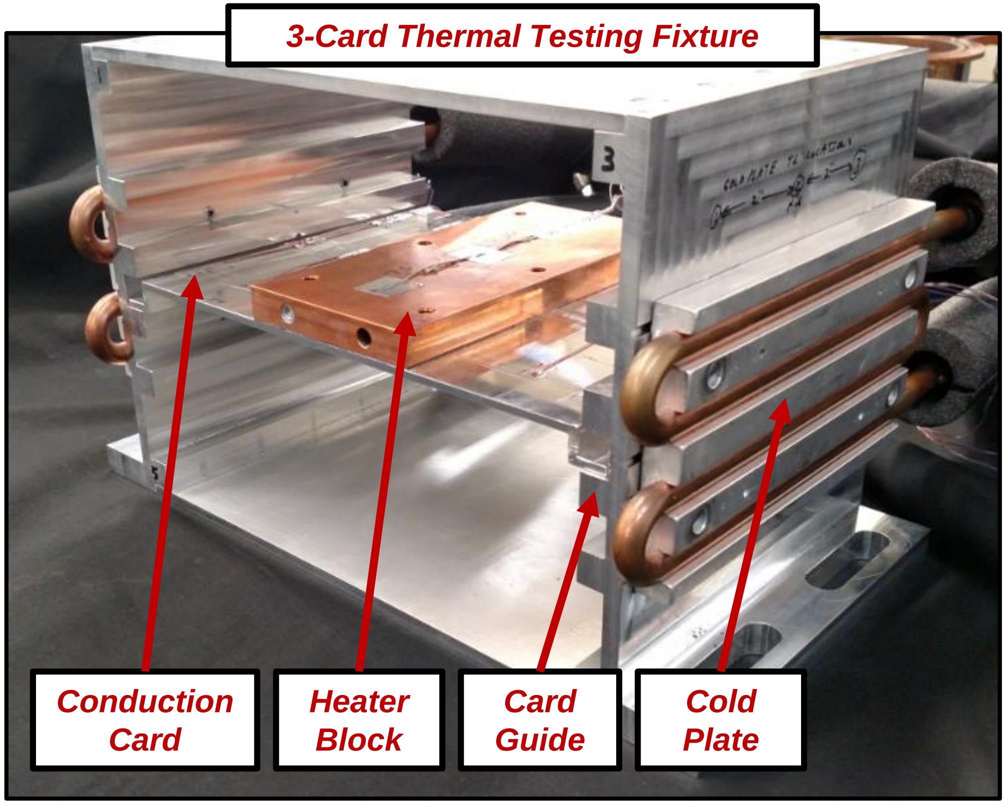
- **ACT built a three card, 6U-sized, VITA 48.2 compliant chassis for testing:**
  - Aluminum cards with a heater block were used to simulate a conduction card with electronics. The card is instrumented with thermocouple array for STMI thermal resistance measurement.
  - Water temperature and flow rate are used to calculate the total power removed from the system

$$Q_{in} = Q_{removed}$$

$$Q_{removed} = \dot{m}_{water} c_p (T_o - T_i)$$

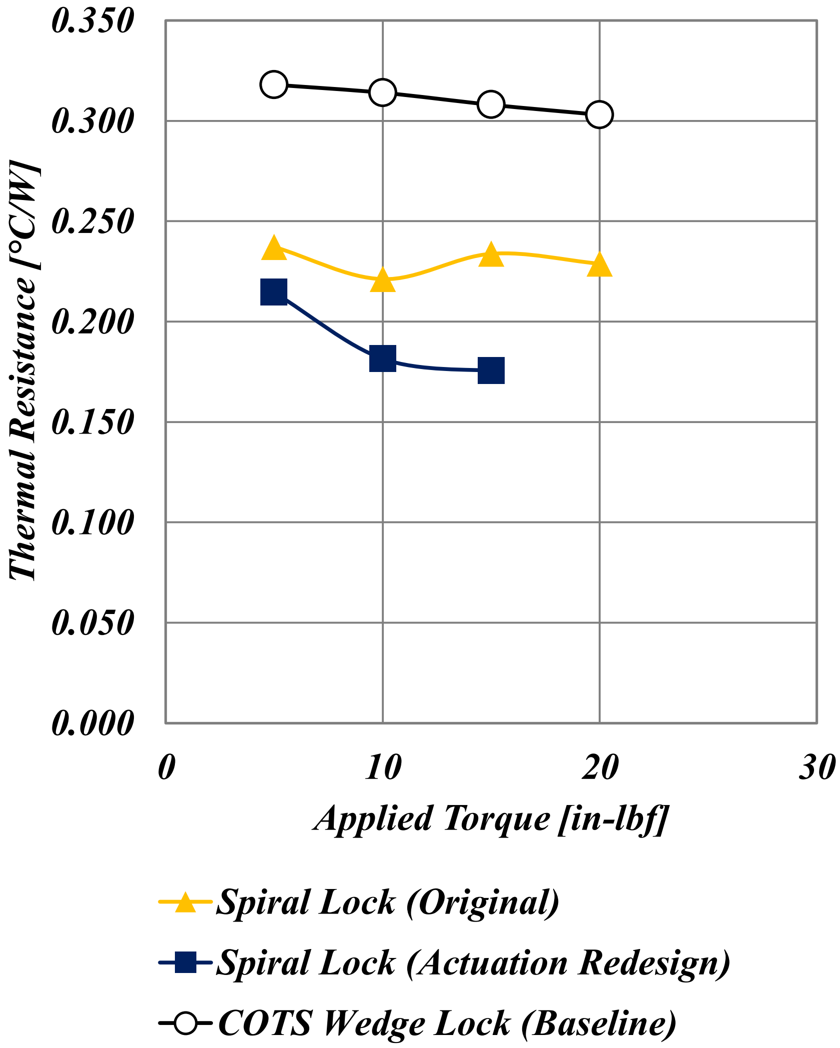
  - Temperature measurements on the card edge and chassis wall were used to calculate the thermal resistance of the Spiral Lock

$$R = \frac{(T_{card\ edge} - T_{chassis\ wall})}{Q_{removed}}$$



Thermal Performance

- **Testing Parameters:**
  - **Installation Torque:** 5 to 20 in-lbs
  - **Heating Load:** 75 to 200 W_{th}
  - Testing was performed with commercially available wedge lock for 6U-sized cards, the original Spiral Lock retainers, and the redesigned Spiral Lock retainers.



- **Conclusions:**
  - The prototype is successfully operated using the new actuation methodology
  - Performance observed is similar to original Spiral Lock, indicating no loss in performance.
  - Relative to COTS device, a 40% reduction in thermal resistance is observed. ΔT of 10°C at 100W_{th}/STMI

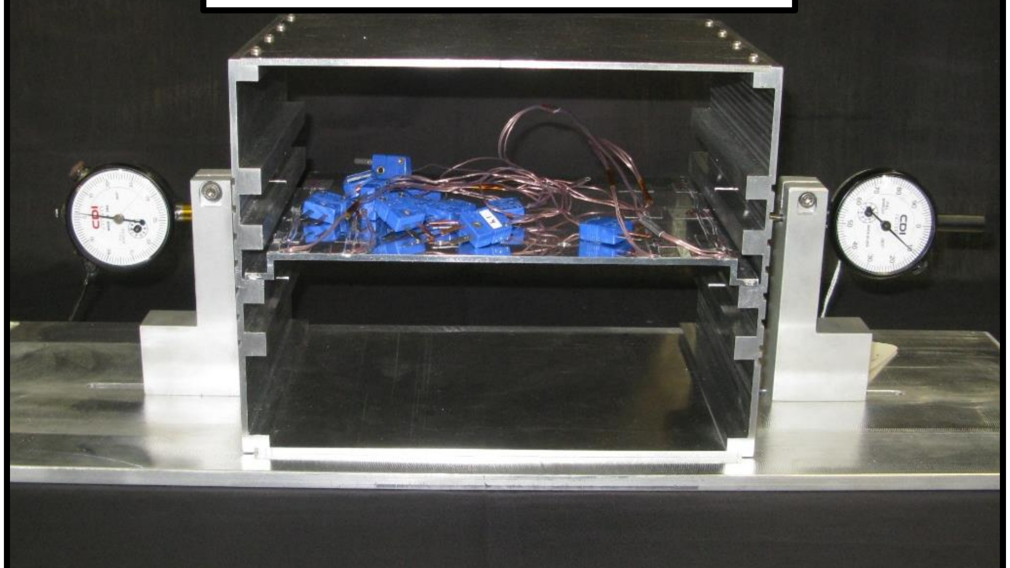
Deflection Testing

Chassis Deflection:

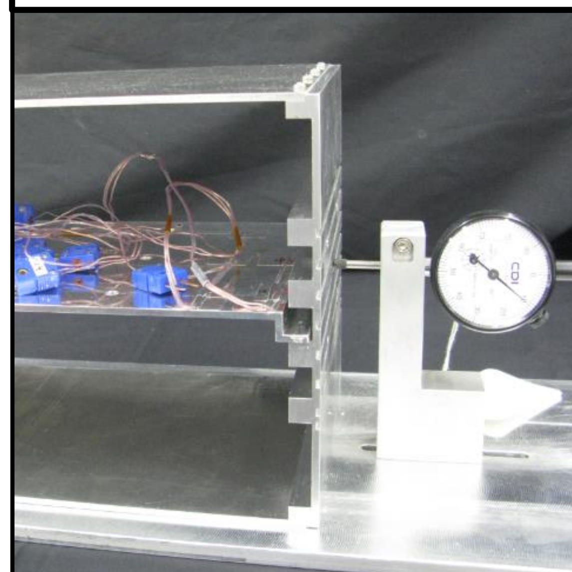
- Current thermal chasses are not designed in anticipation of outwardly applied loading.
- Deflection of thin-walled chassis, such as in liquid-jacket cooled designs, could cause assembly issues or possible deformation.

Test Apparatus:

- A thin-walled, easily deflected, chassis is utilized for mechanical characterization.
- Dial indicators and chassis are fixed to a stiff base plate. They can read outward movement of walls due to applied card retainer loads.



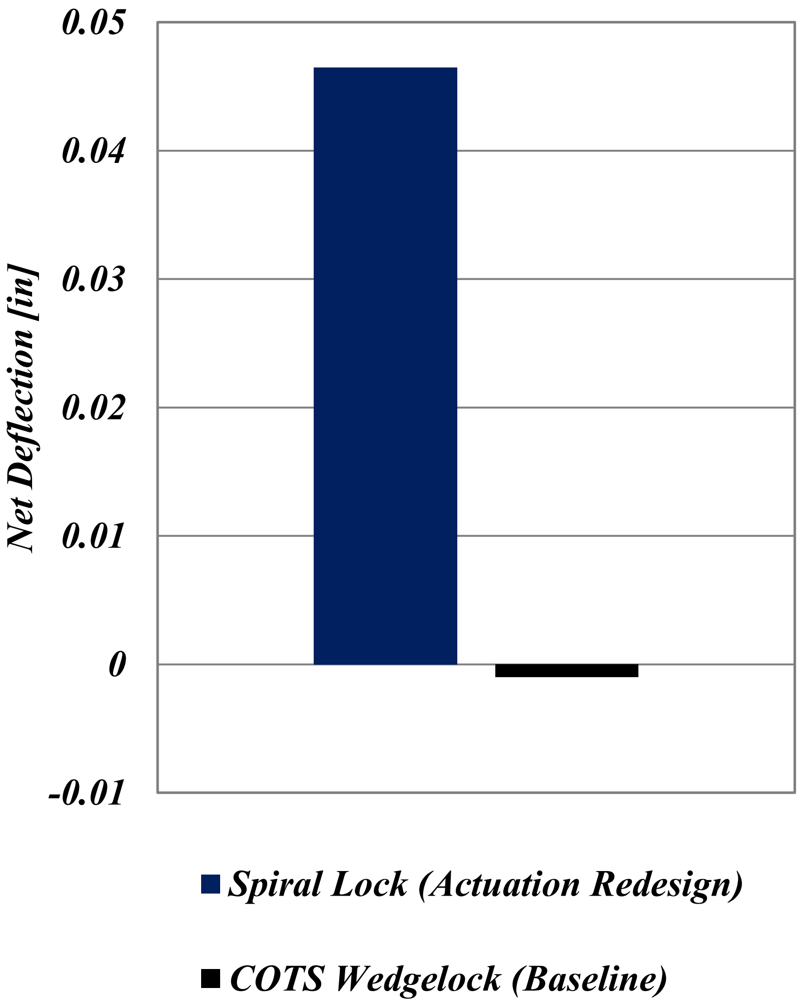
Deflection Testing Fixture



Dial Indicator Positioning

Deflection Performance

- **Testing Parameters:**
  - **Installation Torque:** 10 in-lbs (if possible)
- **Conclusions:**
  - The Spiral Lock is able to continuously deflect chassis walls until deformation occurs.
  - Torque does not build due to elastic deformation of the chassis, so contact pressure cannot build.
  - The COTS wedge lock works as expected and produces nearly zero displacement.

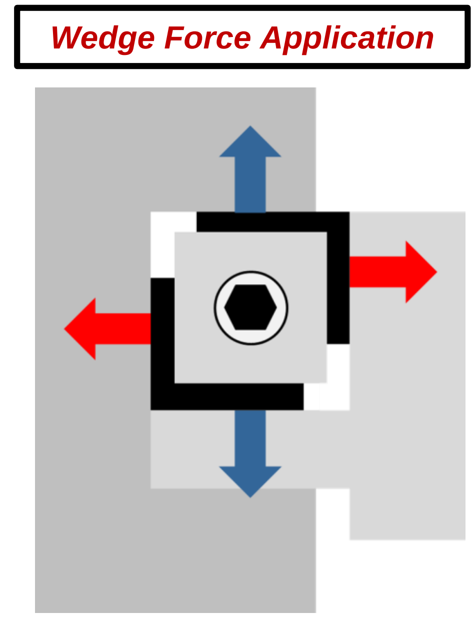


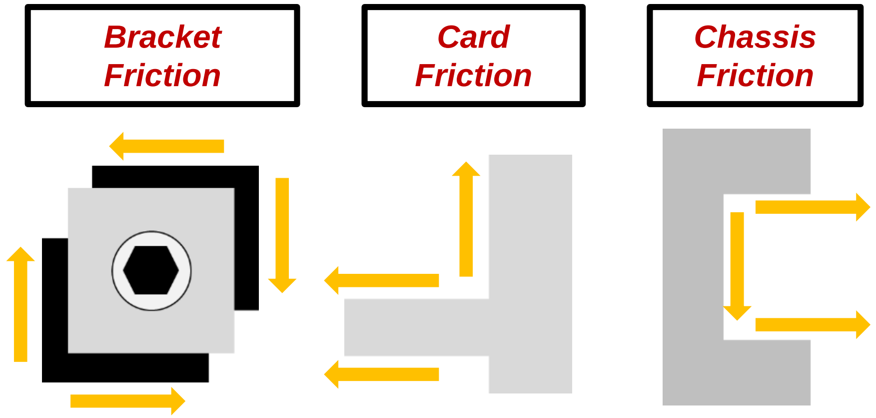
"Friction Locking" Concept:

- The Spiral Lock exerts a vertically applied, and a horizontally applied outward force upon its brackets; it is this latter component which causes deflection of the existing chassis side-wall.

- The vertically applied forces create friction between the bracket faces and the card-guide/conduction card. If the friction forces developed by the Spiral Lock exceed the forces applied horizontally, by a critical ratio, then the card and the chassis cannot move relative to one another, locking the card to the chassis.

- By friction locking the card to the chassis, the card tab is used as a tensile member. This greatly stiffens the chassis.





Second Spiral Lock Redesign – Addressing Deflection

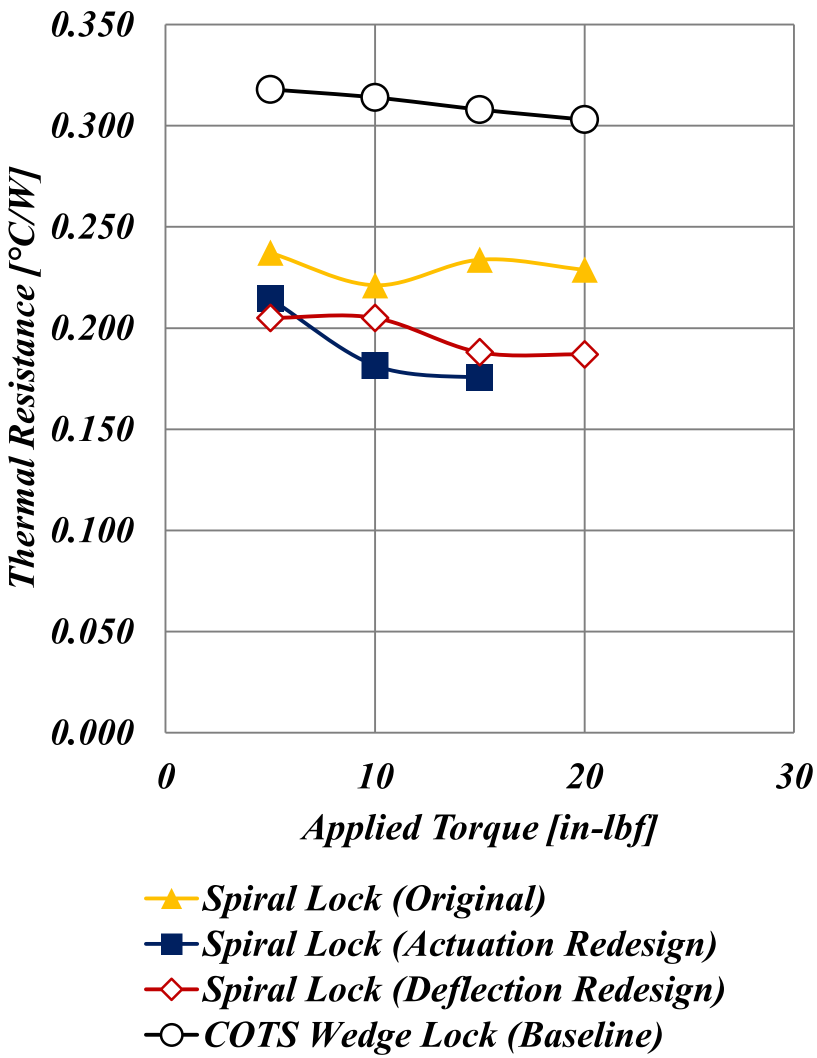
- **Design Parameters:**
  - Large ratio between wedge apparent side-angles (φ) and (θ) produces a more stable locking, but also can impact other important aspects of design

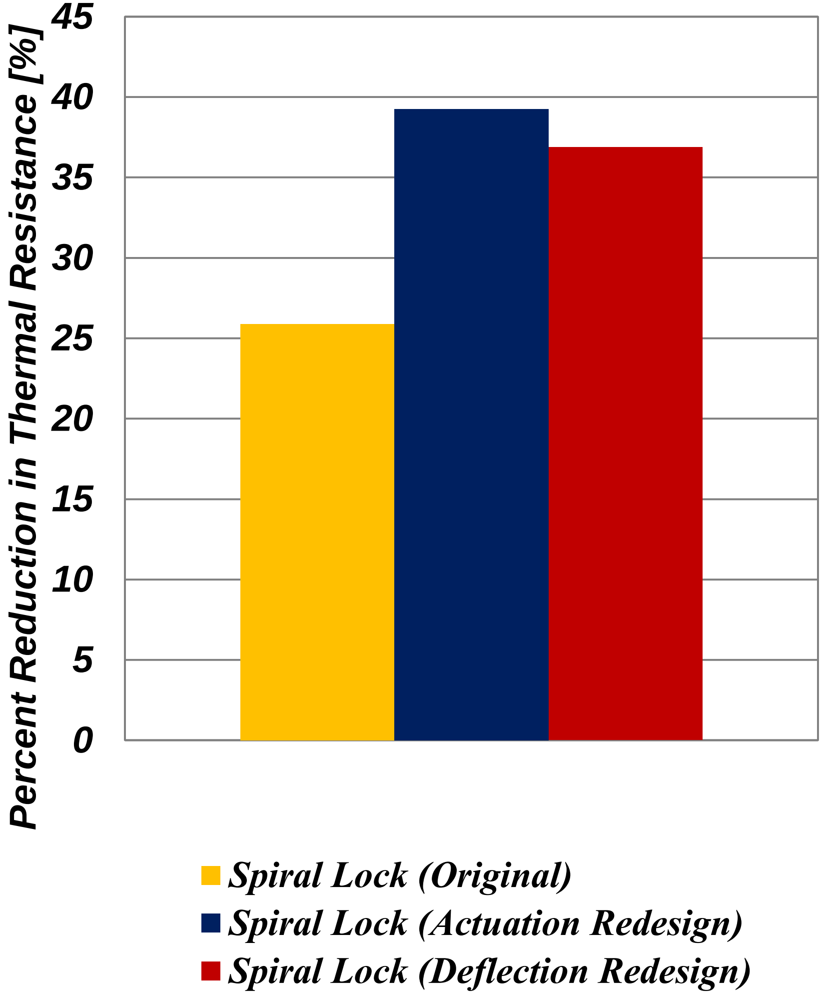
Stability (↑), Number of Wedges (↓), Mechanical Advantage (↓), Bolting Loading (↑), Actuation Range (↓)

  - The final design was chosen to meet theoretical force output of previous prototype while maintaining bolt load, actuation range, and obtaining a stable "friction lock".

Prototype Friction Locking Spiral Locks

Thermal Performance

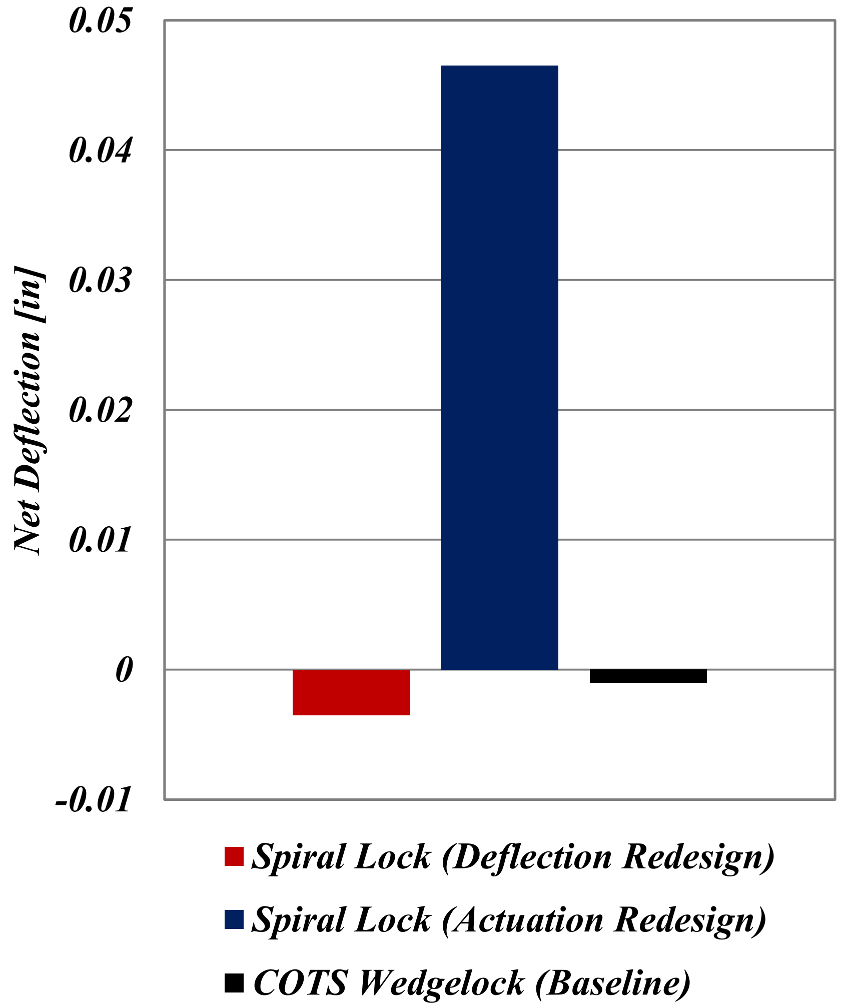




Deflection Performance

Conclusions:

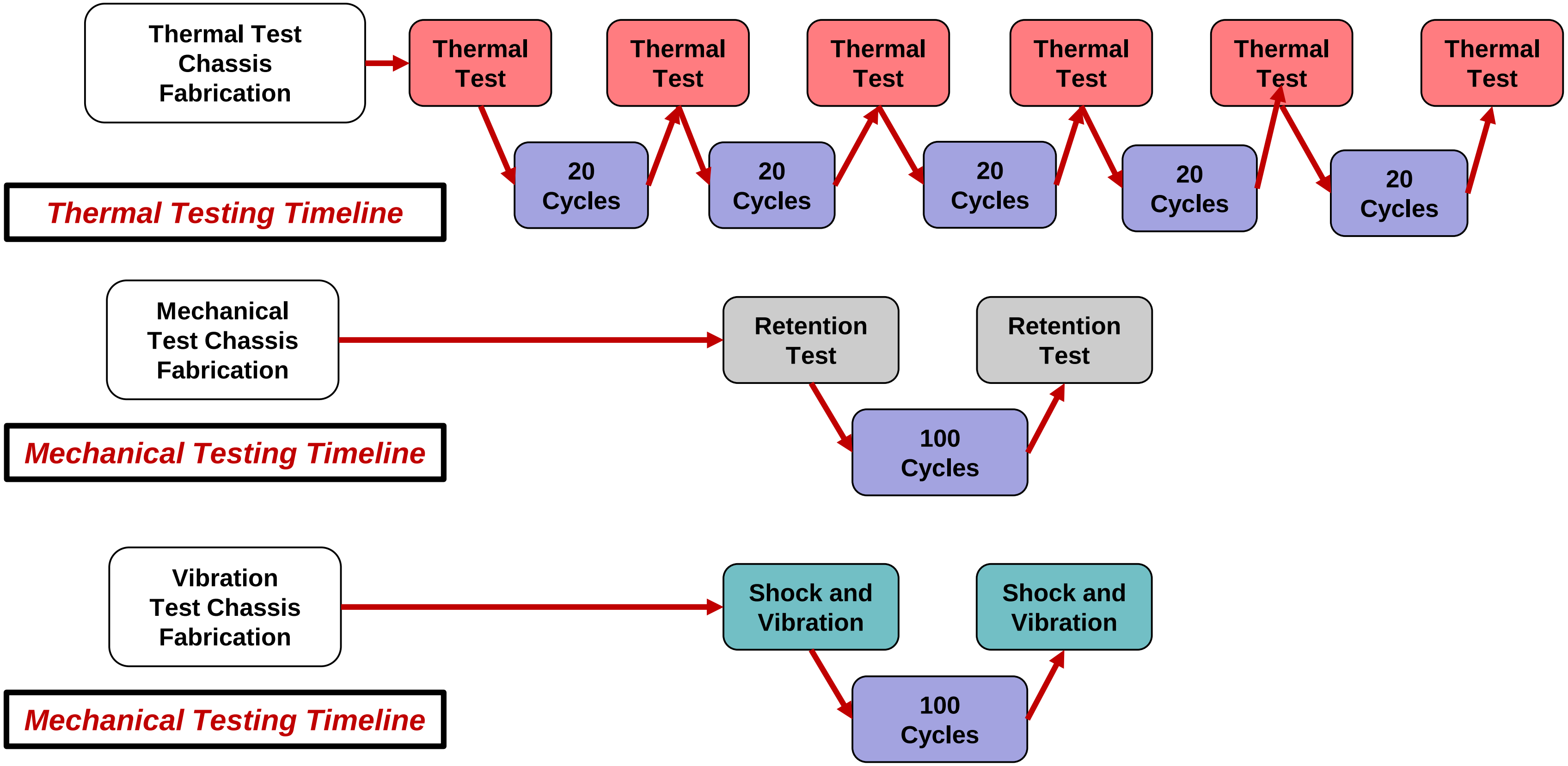
- Good thermal performance from the friction locking concept confirms that similar outward forces were obtained when compared to original prototypes
- New friction locking concept produces deflection similar to wedge lock devices, thus it can be safely used in current chasses.



Future Work

❑ Detailed, “Qualification-Like” Testing

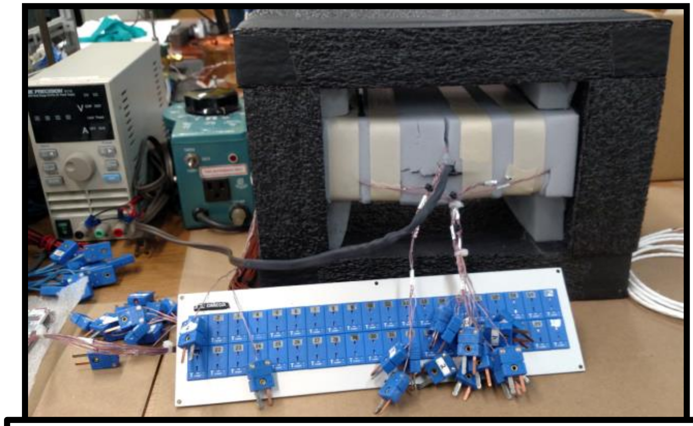
- ACT has developed a testing plan to provide the detailed performance metrics needed for design evaluation by end-users.



Thermal Characterization

- Thermal performance must be measured as both a function of mechanical cycling and altitude.
- ACT will use the thermal test chassis to perform testing over the considered simulated altitude range of 0-65,000 ft. above sea-level, test conditions will also include low-vacuum (10^{-5} Torr) for simulating space conditions.
- Thermal testing will be done at 20 mechanical cycle intervals until end-of-life (EOL) testing which will occur after 100 mechanical cycles.

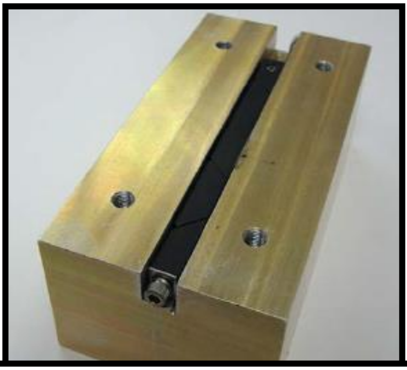
ACT thermal vacuum chamber for testing at lower than atmospheric pressure and for simulation of spacecraft conditions.



ACT, 3 card thermal test chassis with insulation installed for testing

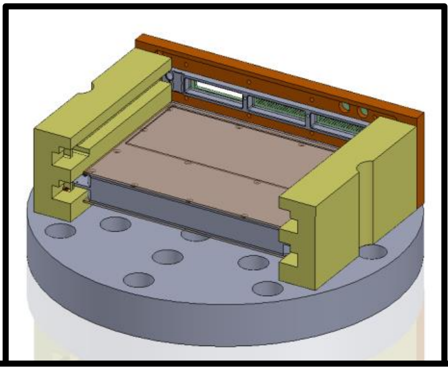
Mechanical Characterization

- Mechanical testing will consist of retention testing and shock and vibration testing.
- Retention of the card under an applied for of 300lbf is necessary for qualification. ACT will test card retention on a dedicated chassis, then send the chassis for shock and vibration testing. Retention will be tested after shock and vibration. (MIL-STD-810G Shock, MIL-STD-883 Vibration)
- Three pieces of test hardware have been fabricated for detailed performance testing:
  - (1) Fixture for shock and vibration testing.
  - (1) Fixture for deflection testing, and (1) fixture for mechanical cycling



Lockheed Martin test setup for mechanical cycling of a card lock device.

Retention testing apparatus with linear actuation and control box for clamp testing



Vibration test fixture for simulating vehicle environments

State of Technology and Future Development Needs

Thermal and Mechanical Performance:

- The Spiral Lock has been successfully redesigned to meet current industry integration requirements, while maintaining superior thermal performance to baseline wedge lock devices.

Further Technical Development:

- ACT will continue developing the Spiral Lock in future by further optimizing the retainer geometry and the choice of coating.

Manufacturability:

- Much work still should be done to enhance the manufacturability of the Spiral Lock by identifying processes for scaling the manufacture of devices.
- Due to the similar use of material and similar number of machined parts, it is anticipated that the Spiral Lock will be comparable in price to current wedge locks when manufactured at scale.

Thank You!

Questions/Concerns/Ideas

Matt Flannery
Lead Engineer, Defense Aerospace Group
Advanced Cooling Technologies, Inc.
1046 New Holland Ave.
Lancaster, PA 17601
(717)295-6076
Matt.Flannery@1-act.com

James Schmidt
R&D Engineer, Defense Aerospace Group
Advanced Cooling Technologies, Inc.
1046 New Holland Ave.
Lancaster, PA 17601
(717)295-6062
James.Schmidt@1-act.com

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