



Friction Stir Welding and NASA

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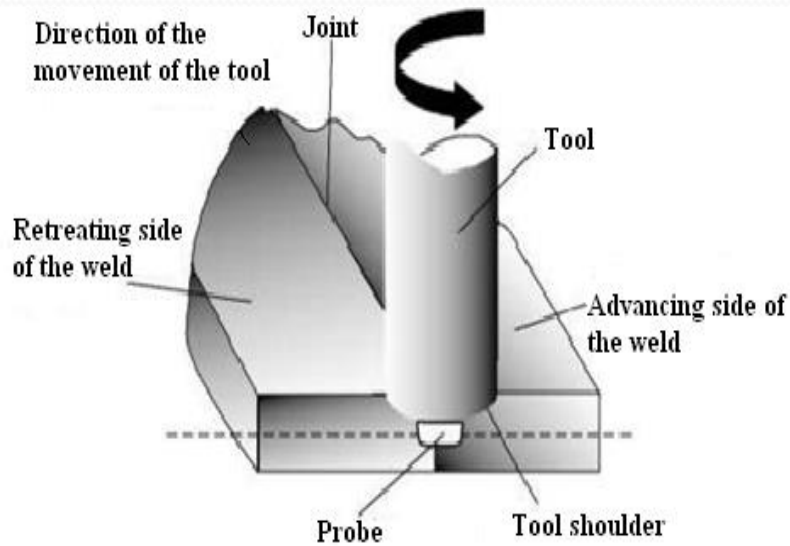
Friction Stir Welding

- Friction Stir Welding (FSW) is a solid state process with potential advantages for aerospace and automotive industries dealing with light alloys.
 - Avoids problems of hot cracking and porosity
 - Very flexible; joining one, two and three dimensions
 - Provides excellent mechanical properties¹
- Conventional Friction Stir Welding (C-FSW)
 - Has been studied and reviewed in literature since it was developed in 1991 by The Welding Institute.

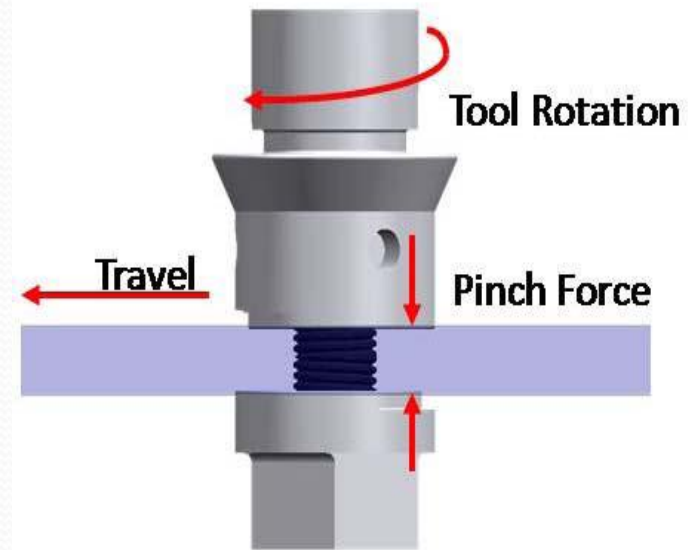


Self-Reacting Friction Stir Welding

- In SR-FSW there are two rotating shoulders: one on the top (or crown) and one on the bottom (or root) of the workpiece.
- In this case, a threaded shaft protrudes from the tip of the pin to beyond the back surface of the workpiece
- The opposing forces balance, simplifying the backup tooling used along the inside length of the weld.
- The main axial force exerted on the workpiece by the tool and front shoulder is reacted through the back shoulder and the threaded shaft, back into the FSW machine head, so that a backing anvil is no longer needed (Nabors, 2006).



(Somasekharan, 2005)



Pin tool used in self-reacting FSW
(J.A. Schneider, Nunes & Brendel, 2008)



Objective

- To understand the fundamental interaction and possible failure mechanisms, under static loading conditions, associated with a FPW in a SR-FSW.
- The weld zones in a SR-FSW of AA 2014/2219 alloys exhibit a distorted weld seam trace within the nugget region whose microhardness is comparable to that of the parent material. The formation of this zone and the role that this zone plays in the mechanical behavior of the welds is examined in this study
- The interaction between the FPW and the SR-FSW results in a greater strain area around the plug under static tensile test conditions in smaller samples than in wider samples. At the same stress level, the strain behavior, strength, and interaction of the parent material, weld zone and plug are very important discriminators used during the development process to accept or reject materials for design.
- The FPW/SR-FSW interface is a critical region to understand. The overall welding process may need to be optimized to obtain the desired behavior at the interface.



Results and Discussions



Initial Weld

- NDE
- Metallography
- Fractography
- Macros and Hardness Profile
- Tensile Test

Hardness Profile

- C-FSW
- SR-FSW

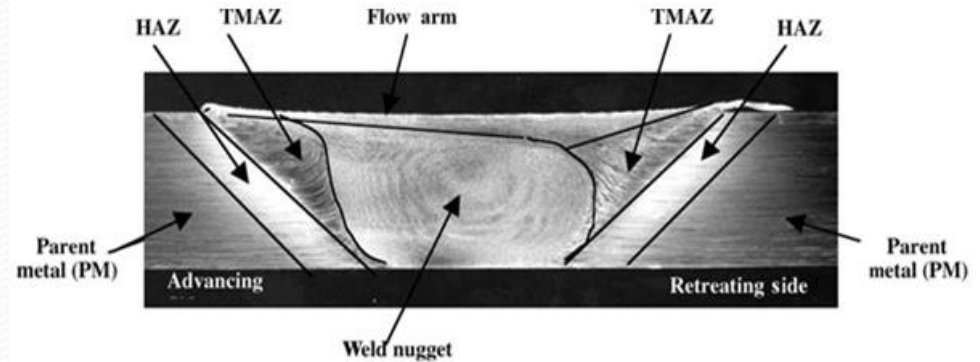
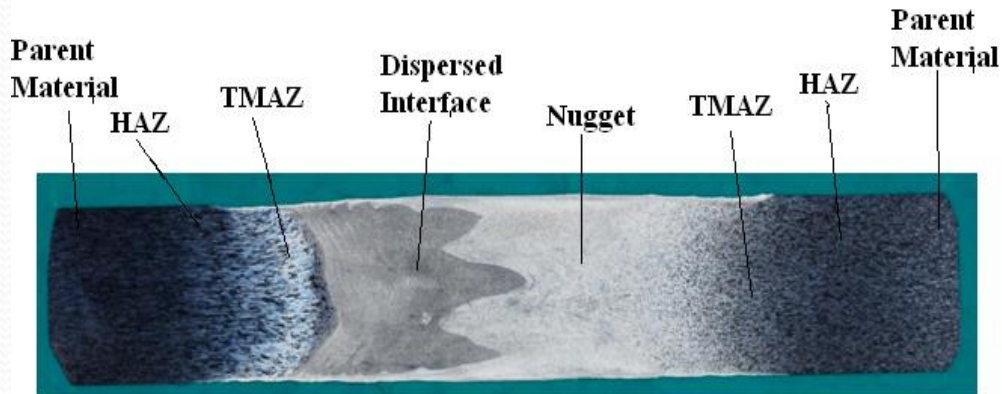
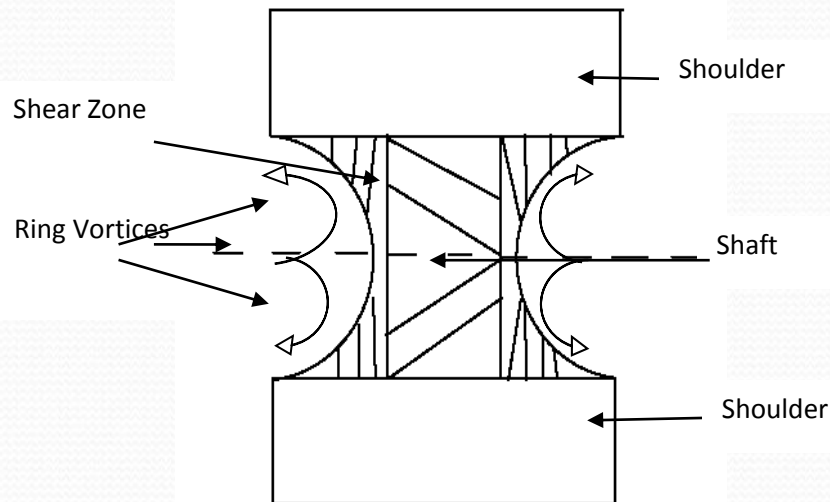


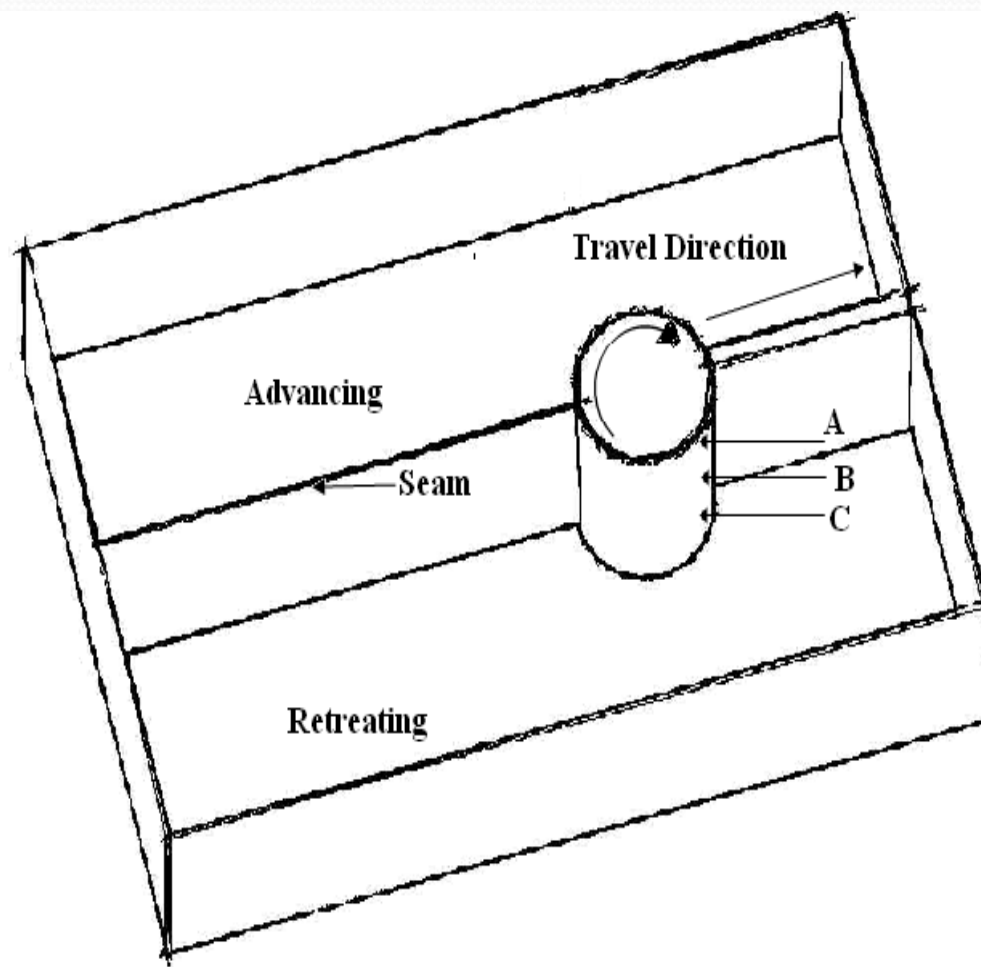
Figure 11 Image showing the distinctive zones in a C-FSW. Parent material is also referred to as base material (Mahoney et. al. 1998)



- The threading in the pins pushes the material up and down creating a ring vortex circulation (RVC) which has local creeping motion.



- There are three ring vortices, one at the top, one in the middle and one at the bottom. Each vortex plays a role in the development of the weld zone.

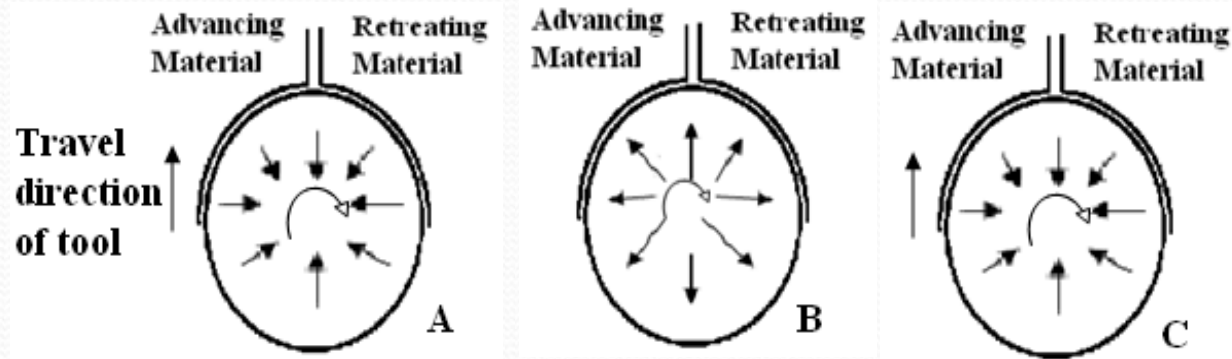




- The pressure during the SR-FSW process caused the material to stick along the shaft.
- As the pintool travels down the weld, material from the advanced side is captured and is buried under additional material from the advance side, then further buried by material on the retreating side.
- As the pintool rotates, the retreating material is re-deposited followed by the advancing material. The material that passes through the ring vortex circulation is subjected to the shear zone.



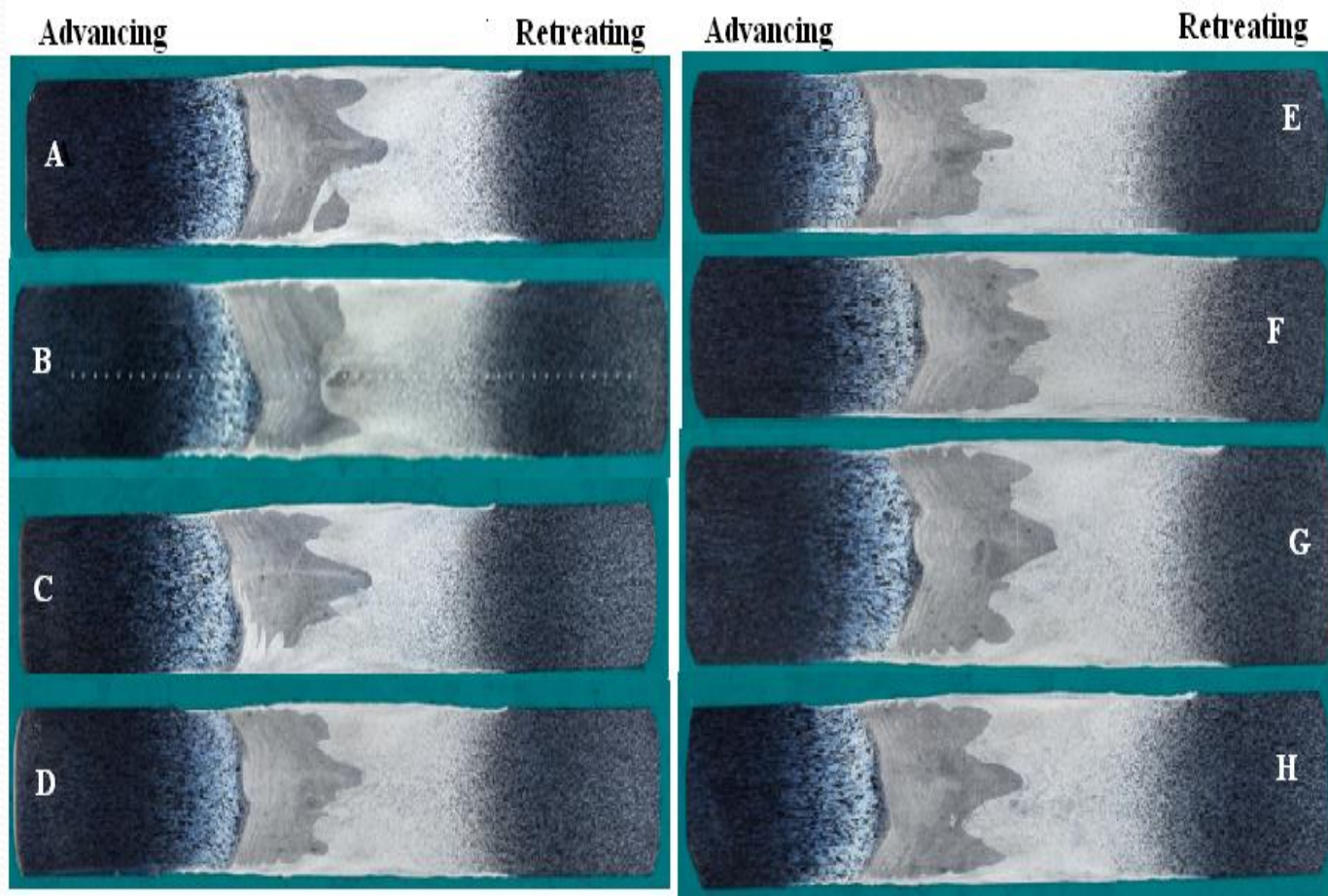
- The material closest to the pintoole produces fine grains in the nugget.
- As you move toward the outside of the ring vortex the material is subjected to the heat produced by the annihilation of the dislocations and the movement of the pintoole in the TMAZ area.
- Beyond the RVC the material is subjected to heat creating the HAZ.



- The RVC-A creates an inward motion allowing the material from the retreating side to stay on longer allowing for a greater mixture of the two materials.
- The stream line is moved further into the retreating side.
- RVC-B creates an outward motion which deposits the retreating material earlier than material from RVC-A.
- The advancing material is deposited sooner than the material that is deposited from the RVC-A.
- RVC-C produces an inward circulation identical to RVC-A.



- The dispersed interface advancing material is extremely fine material that has passed through the shear surface.
- This material is buried deep under the retreating material and is deposited further into nugget region.
- The grains in the TMAZ are small and elongated grains.
- The grains in the HAZ are coarse grains that haven't been affected by the shear zone of the pintool.

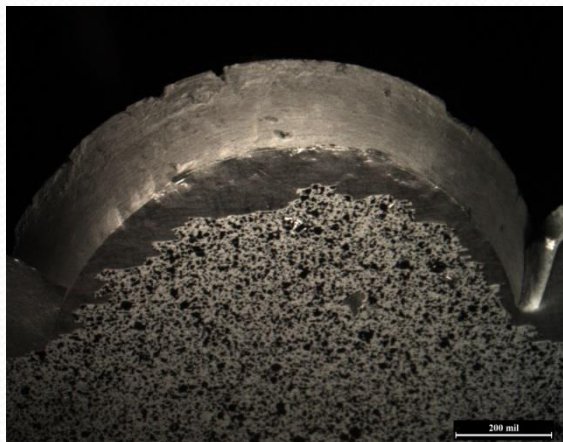


(A) CB-179, (B) CB-180, (C) CB-181, (D) CB -182,
(E) CB-183, (F) CB-184, (G) CB-185 and (H) CB-186.



Plug Weld

- NDE
 - Liquid penetrant
 - Eddy current
 - Phase array
- Fractography
- Hardness Profile
- Tensile Data
- Strain Data
- Finite Element Model of Friction Plug Welds



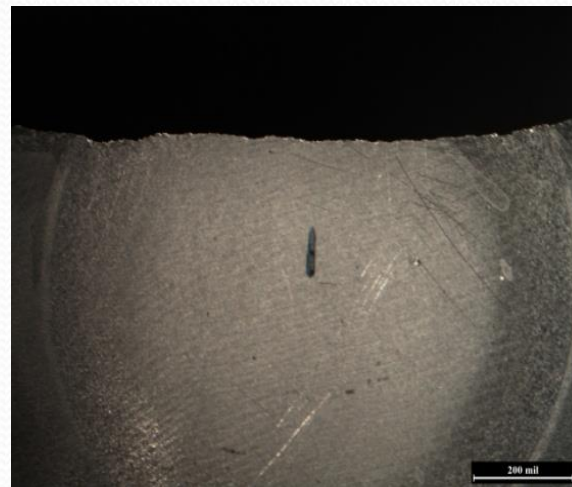
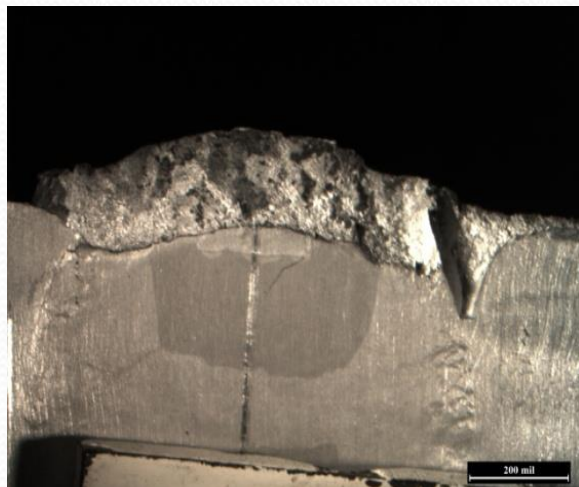
Fracture surface around plug with little or no bond to weld



Microscopy of bonded surface of weld and FPW



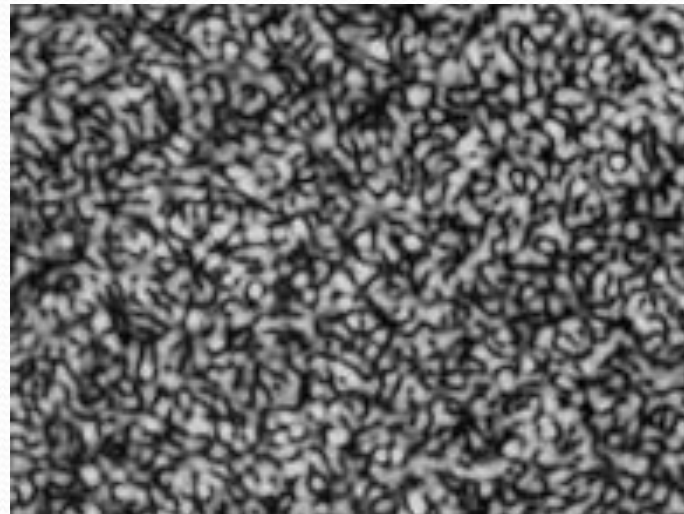
Very rough ductile surface on the surface of the plug fracture area of sample that failed through the plug.



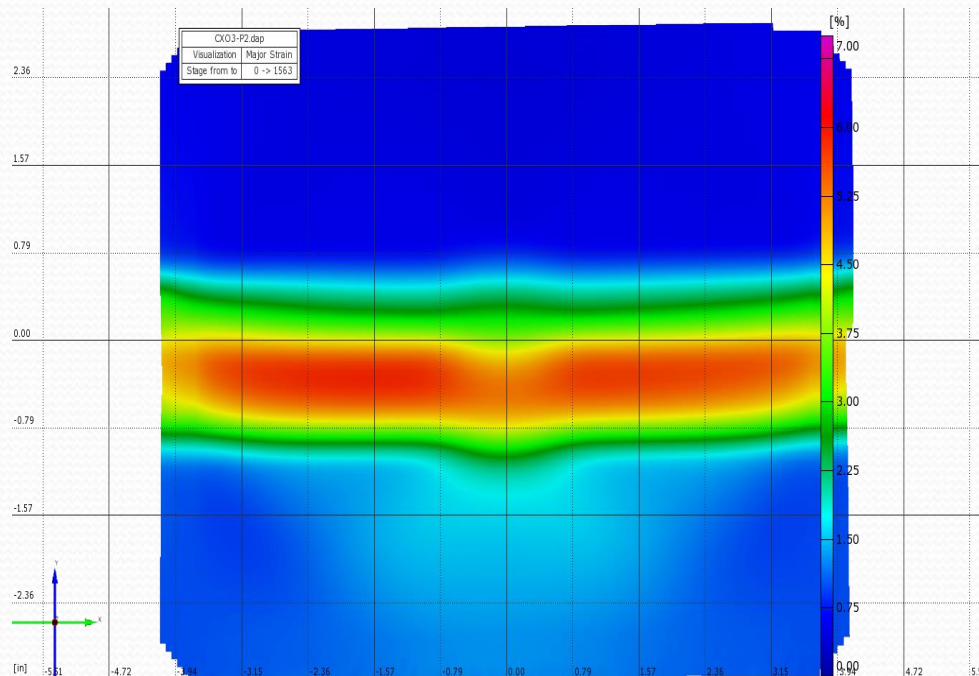
Rough fracture surface (a) ragged fracture with partial plug and (b) ragged fracture through the plug

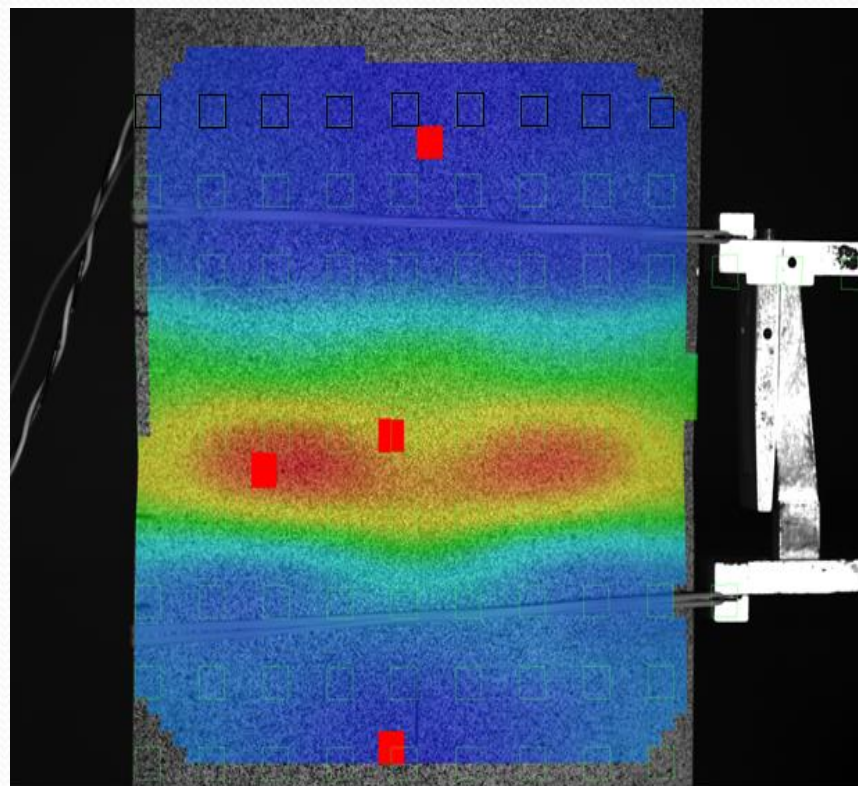
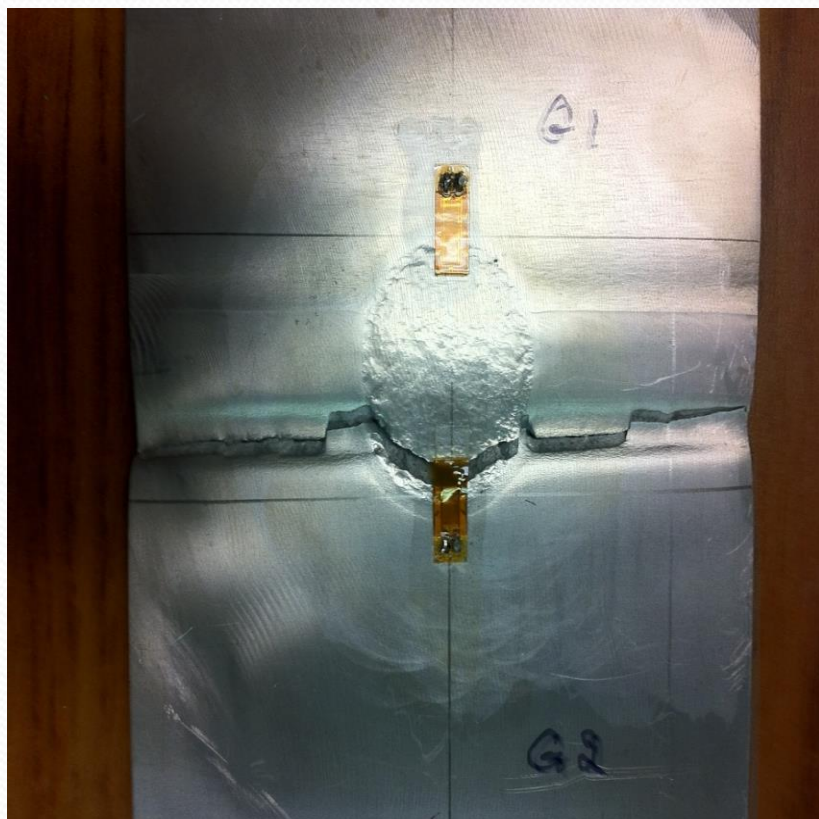
ARAMIS Calibration.

- Two camera images are taken simultaneously during the testing.
- To ensure reliability of the images captured, calibration of the system must be completed before each test.
- The cameras were calibrated for a distance of 140.868mm (5.546 in) and 140.843mm (5.545 in)
- Calibration deviation was 0.017 pixels, a camera angle of 14.4°

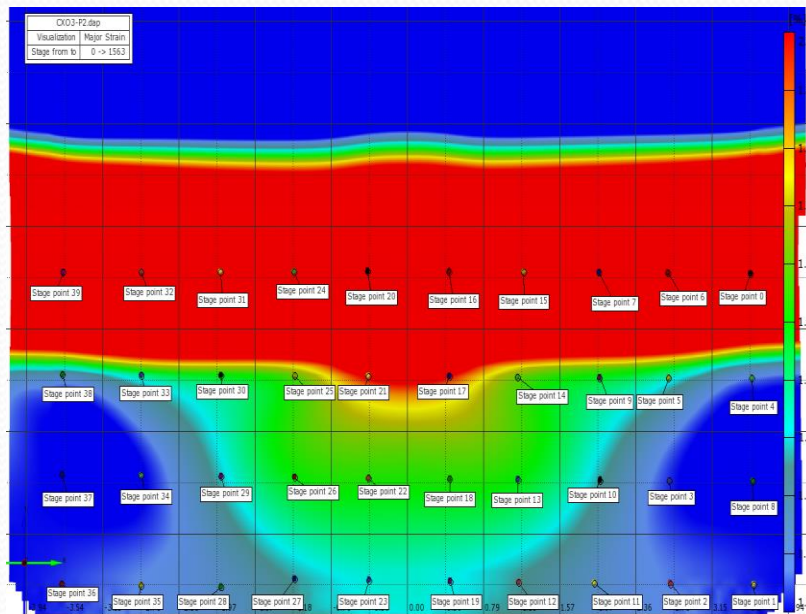


- The strain images from ARAMIS provide a look at strain development during testing with the visual representation of strain.
- Representation of an original strain gage length of 6.55 mm.
- There is an excess of strain located along the retreating side of the panel with delineation around the plug. Panel failed through the weld and through the plug.

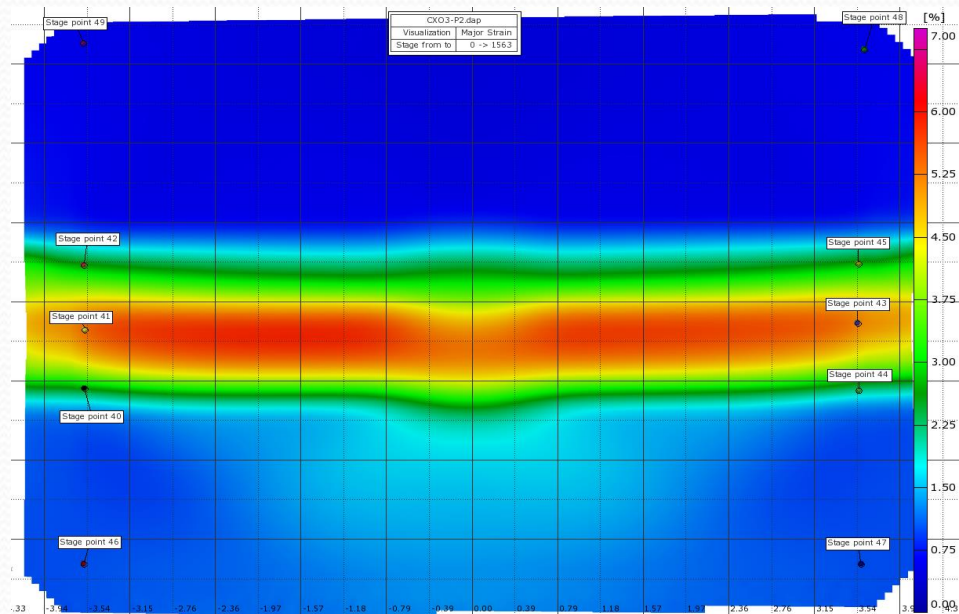




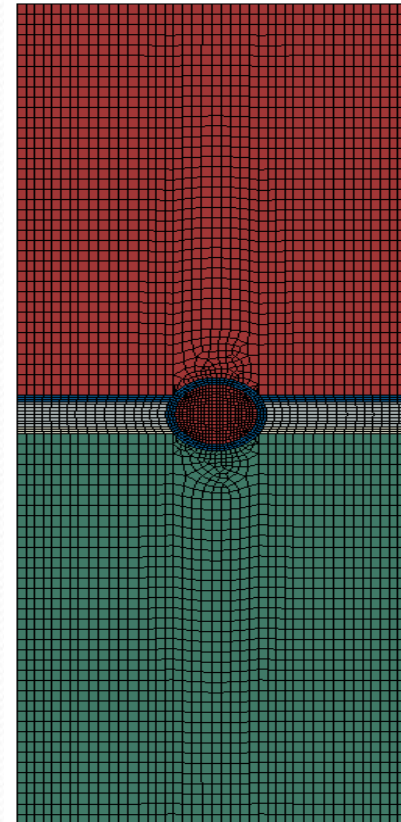
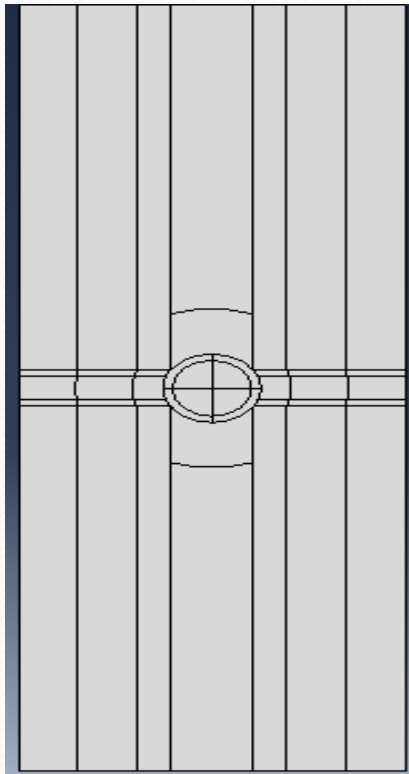
Initial fringe plot to determine less effected stress points

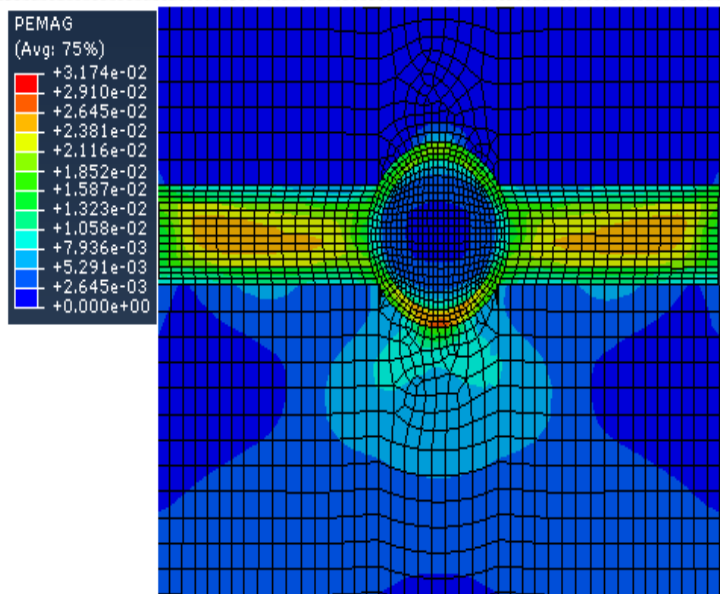


Fringe points of selected points for FEA model

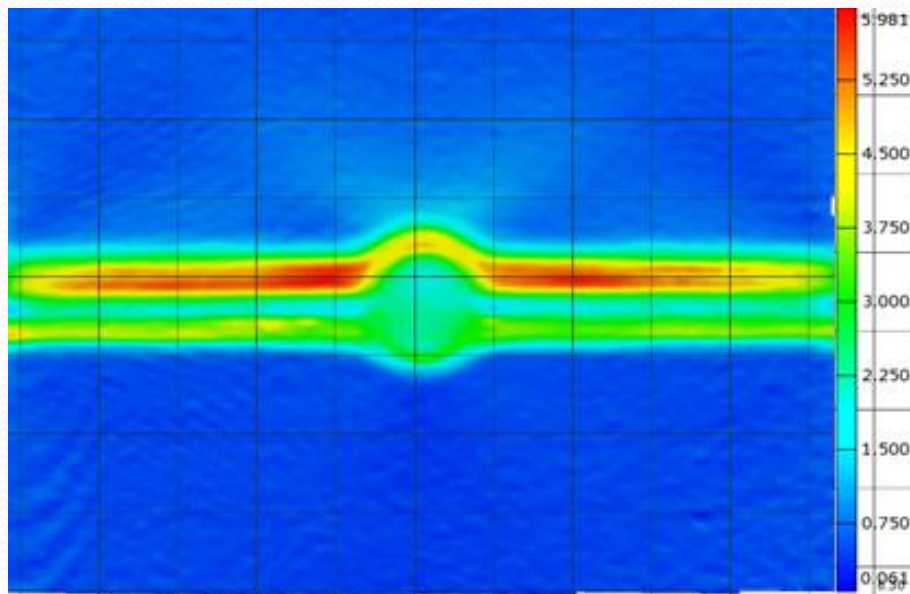


- The model is a simplistic representation of a complex material system.
- It is divided coarsely into seven material regions: 2219plate, 2219HAZ, weld, 2014 HAZ, 2014 plate, 2219 plug, and plug weldHAZ.
- Elastic plastic material property assignments are shown (by color code)in the next figure The use of seven regions (rather than more or less) is an adaptation of previous modeling practices for un-plugged welds, in which weld, HAZ, and plate regions were defined.





ABAQUS representation of plastic strain

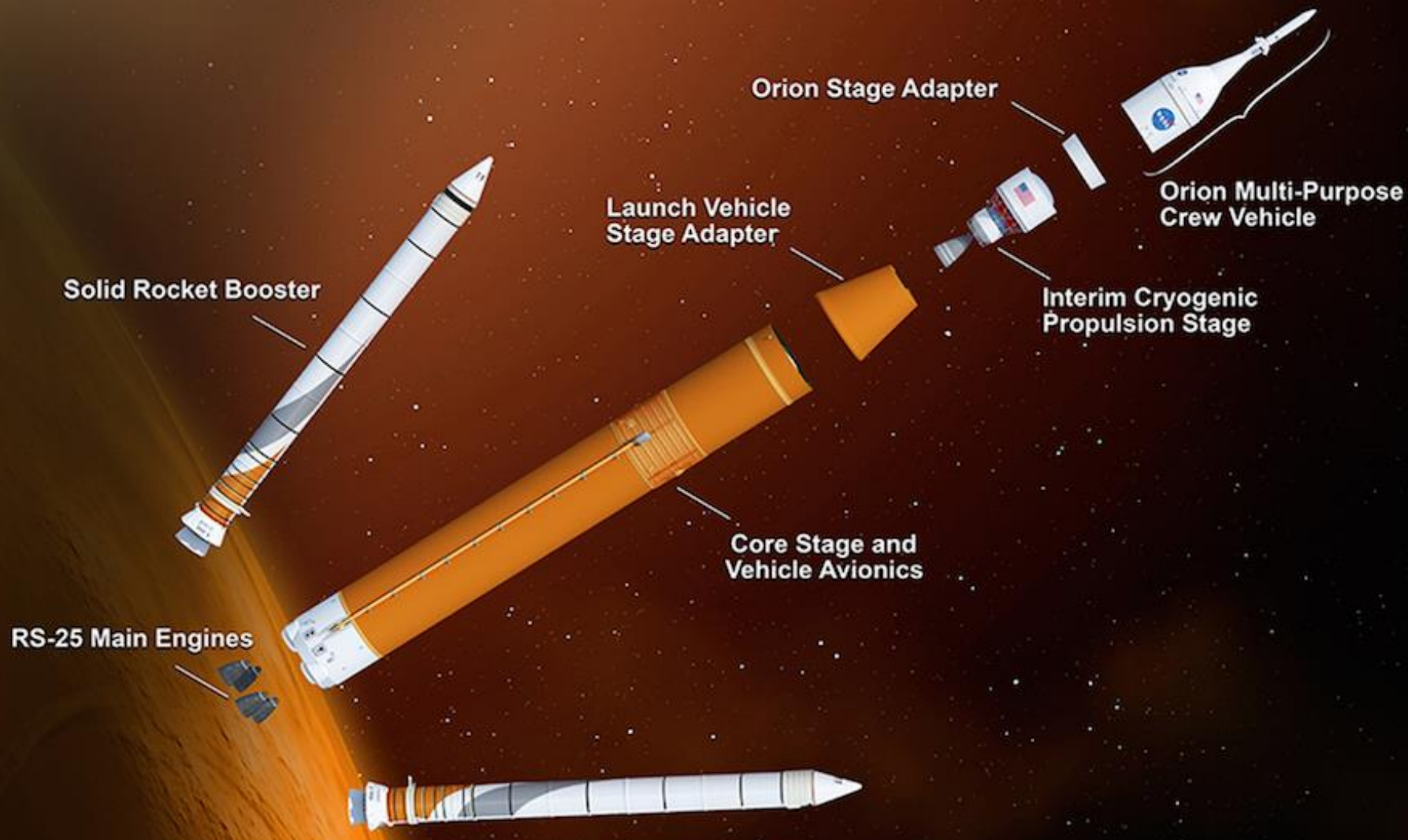


ARAMIS representation of plastic strain

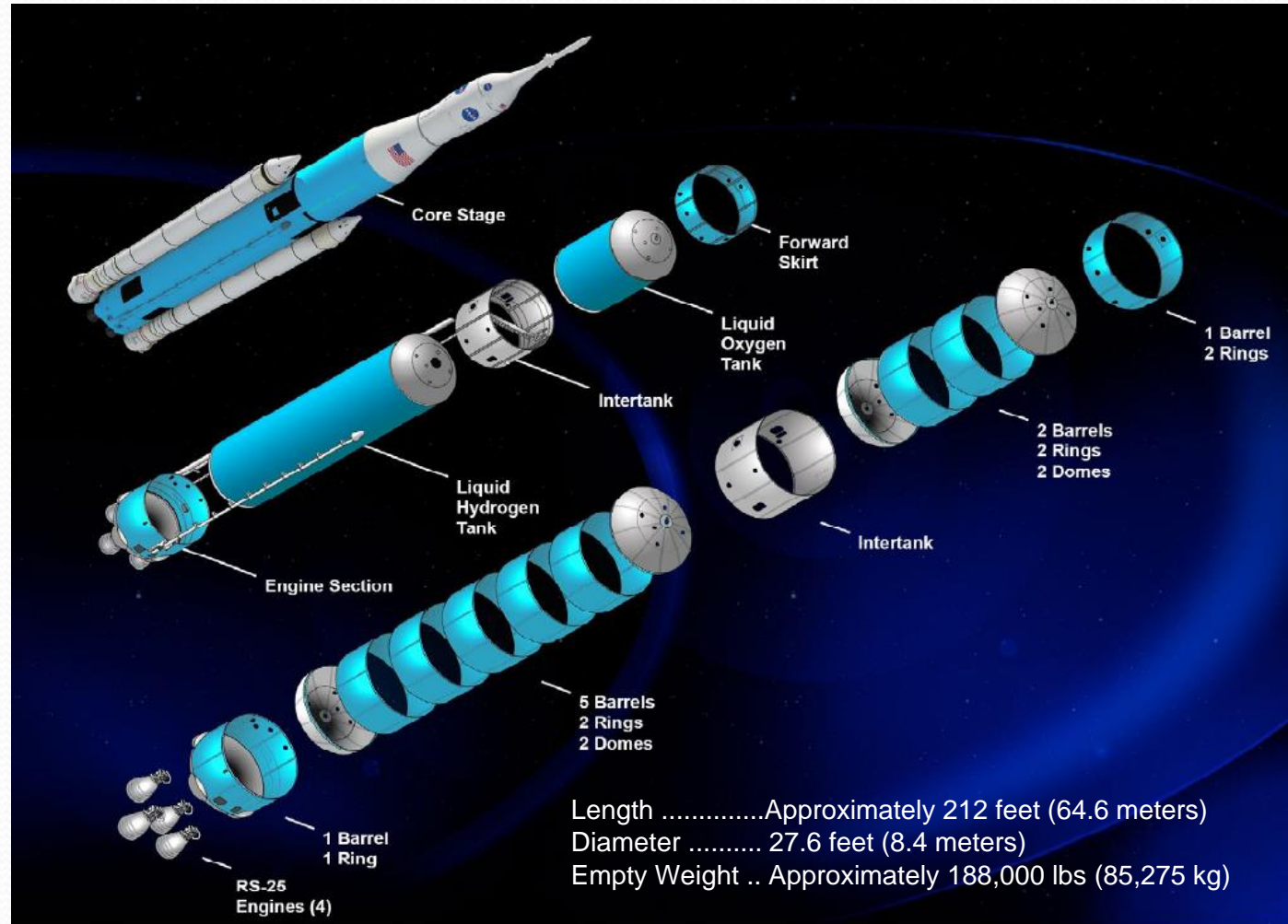


Where is this Used With NASA

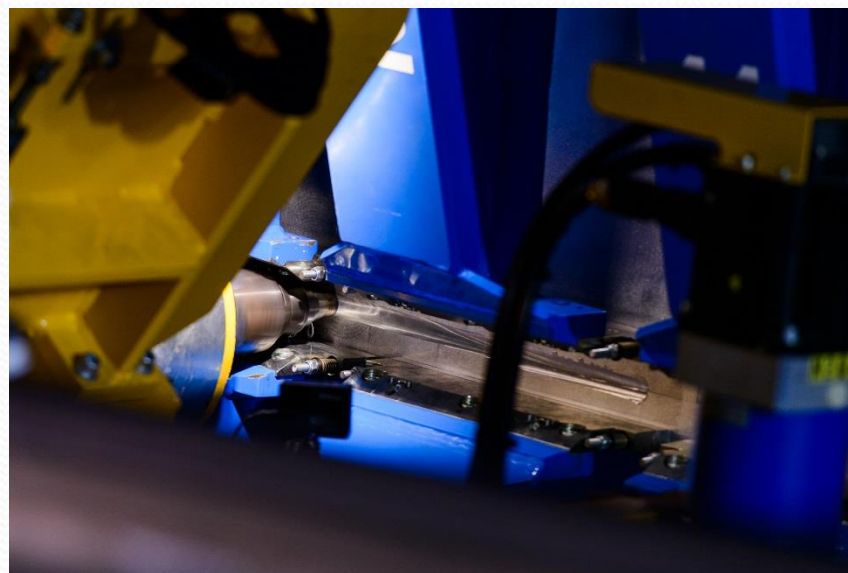
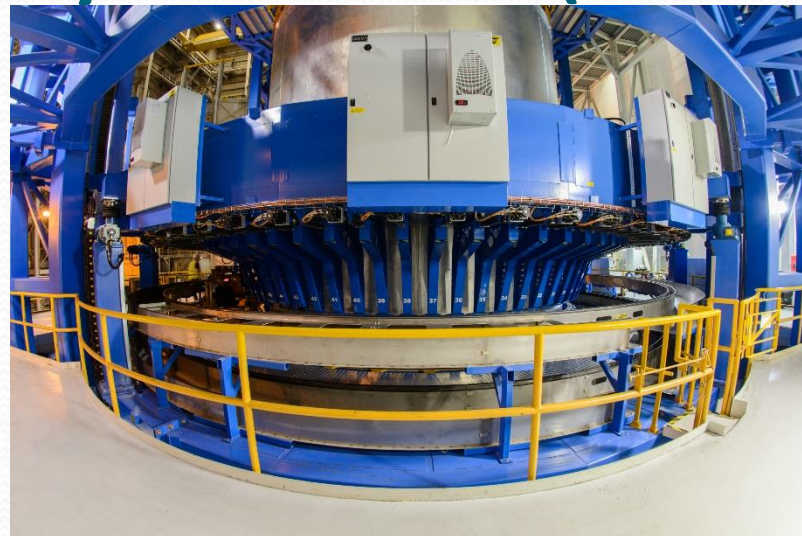
Space Launch System - Block 1 Expanded View



SLS Core Stage



Vertical Assembly Center (VAC)







<https://www.youtube.com/watch?v=QV7MO29BnME&feature=youtu.be>
<https://www.youtube.com/watch?v=mQLLXLN5Lx0&feature=youtu.be>



Questions?