SAND2007-4729C

Fabrication of a Mini-SAR Antenna Array Using Ultrasonic Consolidation and Direct-Write

Brent Stucker

Christopher Robinson
Utah State University, Logan, UT, USA

Karen Coperich Branch, Jeremy Palmer & Bernd Strassner
Sandia National Laboratories, Albuquerque, NM, USA

Misael Navarrete, Amit Lopes, Eric MacDonald, Francisco Medina & Ryan Wicker
University of Texas at El Paso, El Paso, TX, USA

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Purpose of My Talk

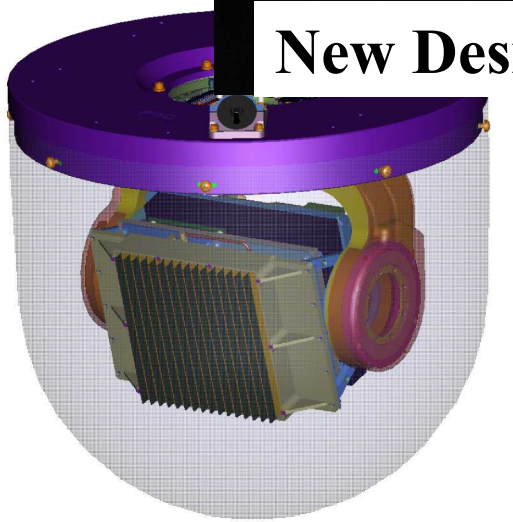
- Introduce the audience to Ultrasonic Consolidation
- Demonstrate one of the unique projects we have done using Ultrasonic Consolidation
- Help you to think outside traditional DFMA guidelines
  - Forget about old design rules – create new ones!
- Show how knowledge of and appropriate application of Rapid Manufacturing Techniques can revolutionize product design & manufacture

Project Motivation

- Investigate whether we can make a better mini synthetic aperture radar (miniSAR) using rapid manufacturing
  - Reduce mass
  - Create an easily reconfigurable, scalable design
  - Reduce fabrication time

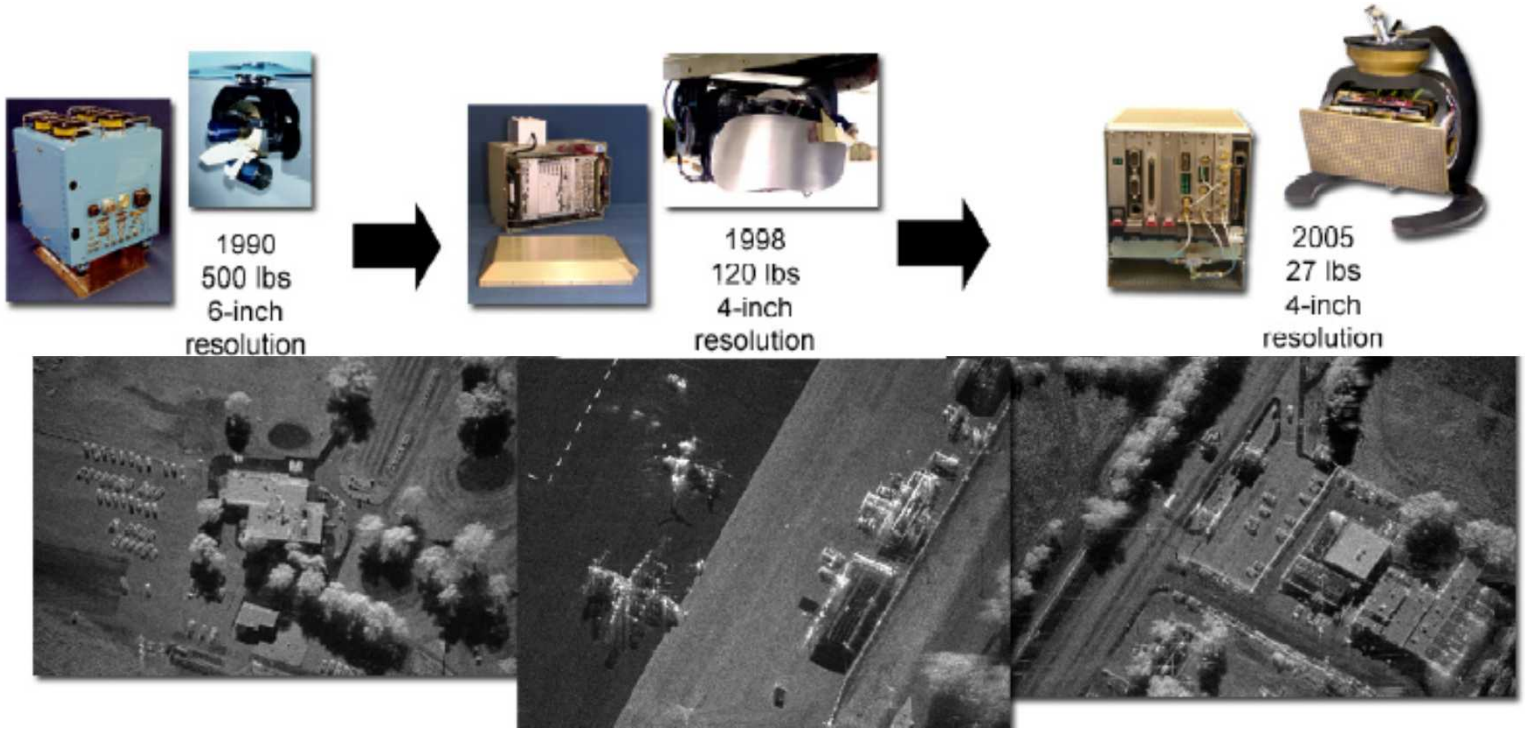
Original Design

New Design Concepts

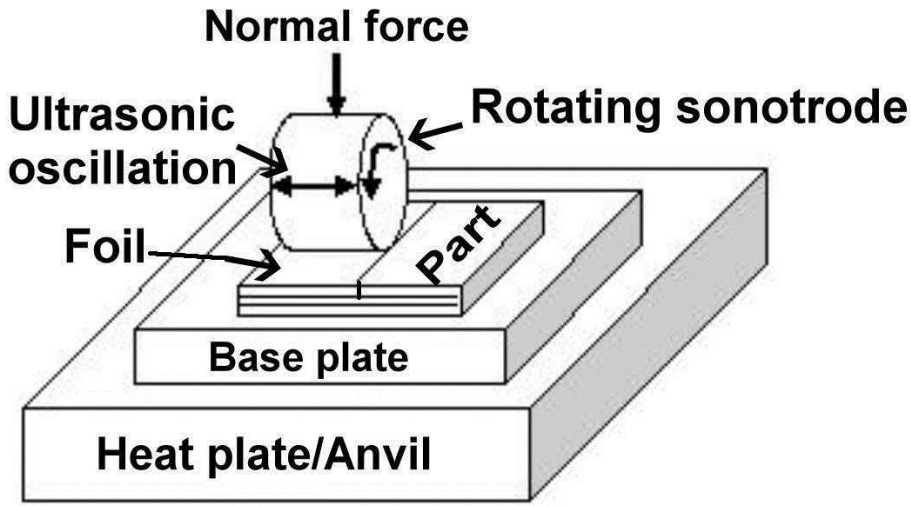


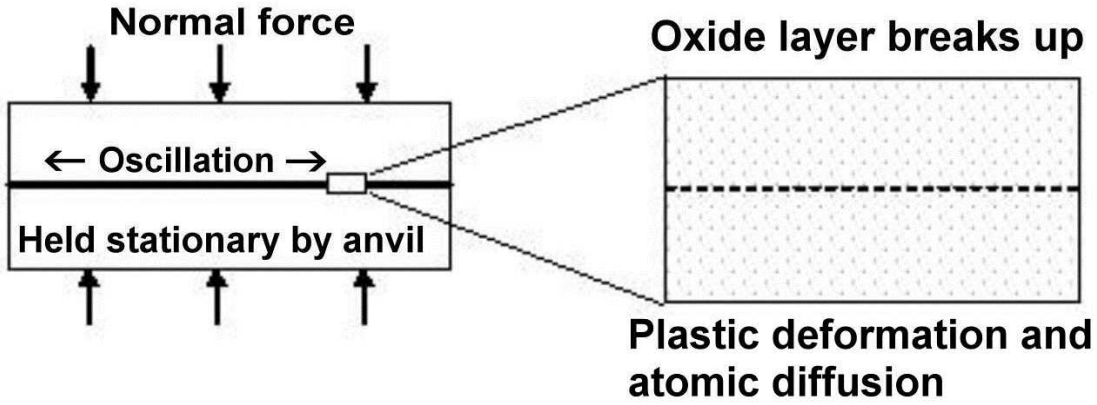
SAR

- Radar needs a large aperture for usefulness
- Synthetic Aperture Radar (SAR) reduces mass and size
- SAR scans a “line” while movement of aircraft creates the 2D image
- Sandia’s MiniSAR has a 10cm resolution at a 10,000 meter standoff distance with only 20-25% of the mass of a Standard SAR



Enabling Technology
Ultrasonic Consolidation



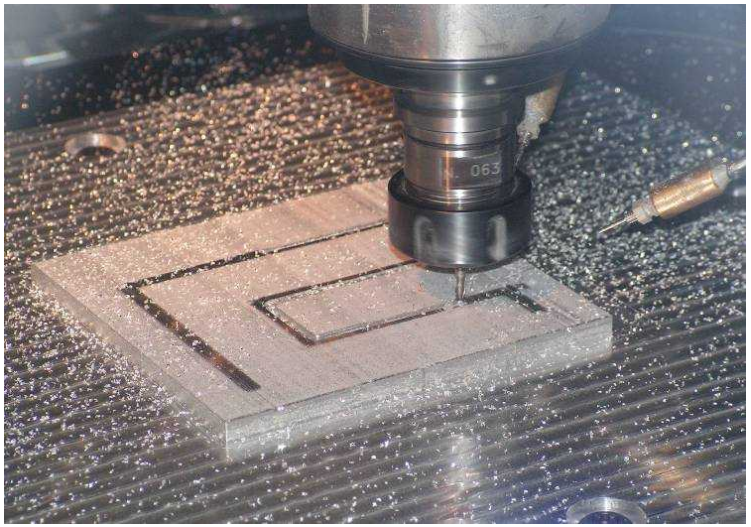


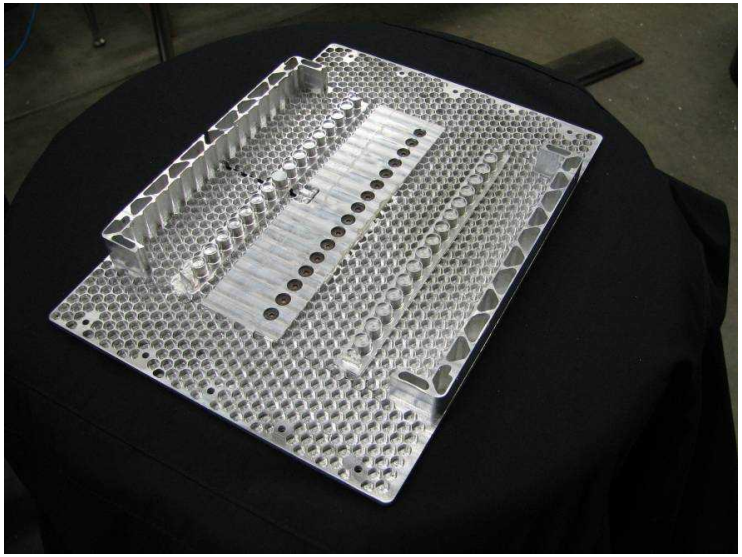
- Ultrasonic Seam Welding in a layer-by-layer fashion, when combined with CNC milling, enables the creation of unique structures.

SOLIDICA

Benefits of UC

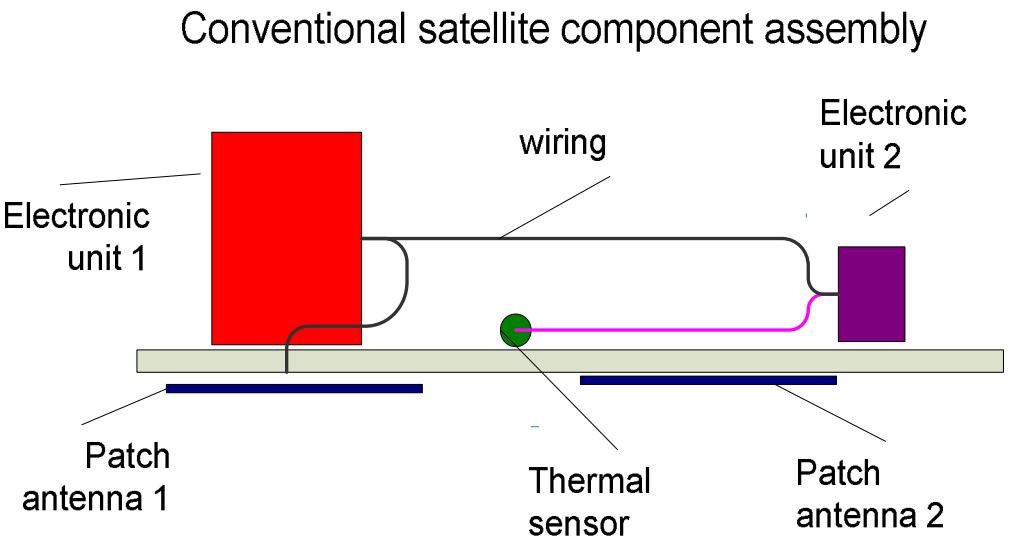
- Built Directly from CAD
  - –Digital Reconfiguration
- Additive + Subtractive System
- Internal Channels Possible
  - –Cooling Channels & Heat Pipes
- Internal Support Structures
  - –Honeycomb, Ribs and Trusses
- Built at Low Temperature
  - –Room Temperature to 300ºF
- Embedded Components Possible
  - –Electronics & Wiring
- Multi-Material Structures
  - –Fiber-reinforced MMC's
  - –Dissimilar material structures

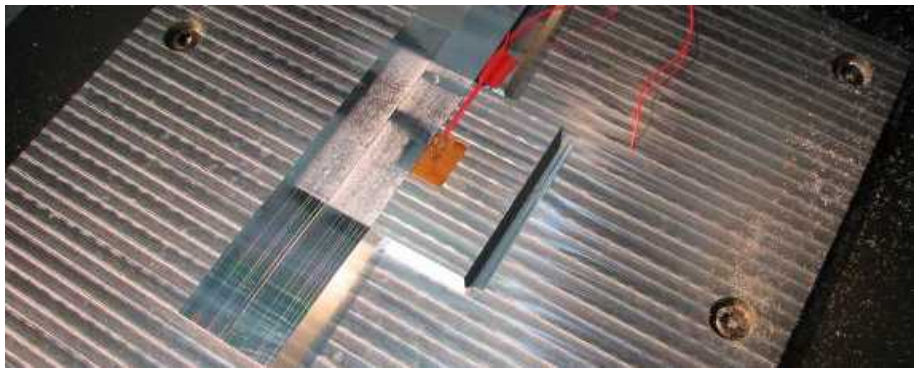




Embedded Electronics Using UC

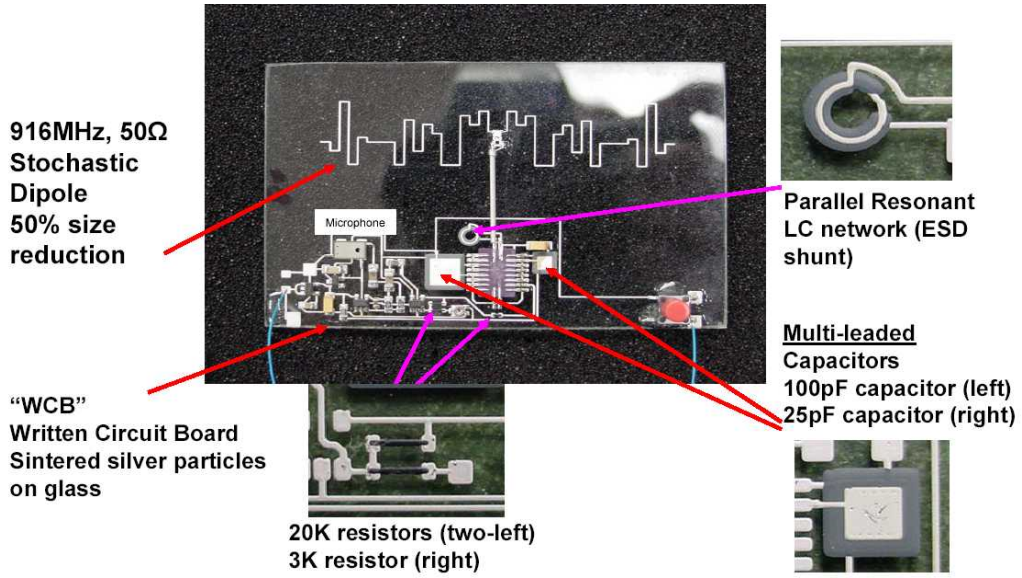
- Pockets can be left for devices during construction
- Devices are inserted into machined cavities and potted in a support material or directly welded over



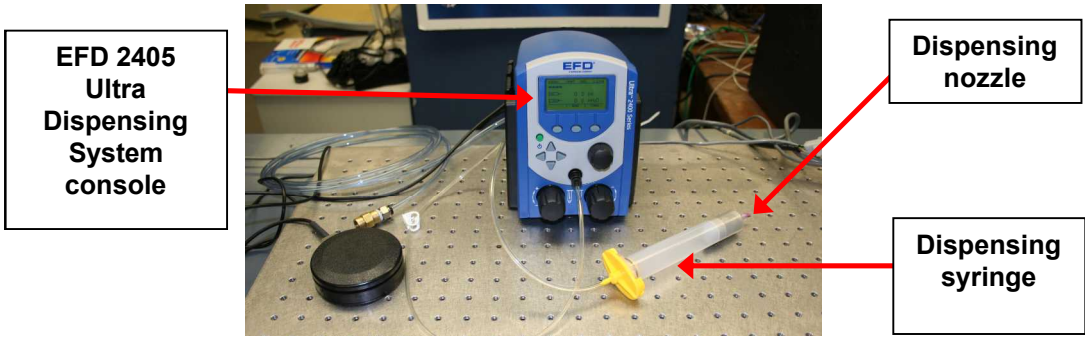


Direct-write Technologies

- Write traces of conductors, insulators, capacitors, batteries, etc. onto freeform surfaces
- Enables complex circuitry to be written onto internal layers of aluminum while under construction
- Automated or Manual Operation



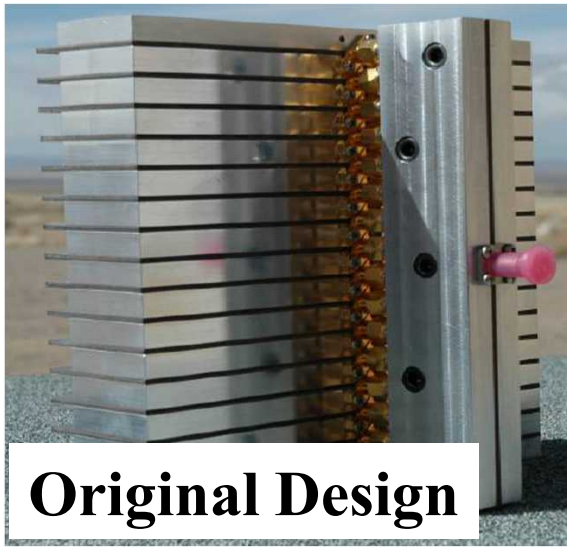
Example nScrypt-Produced Circuit



Simple System Used for This Project

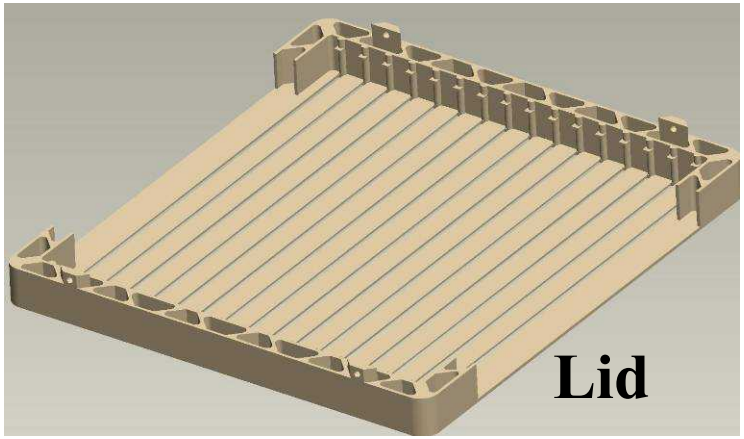
Design Goals

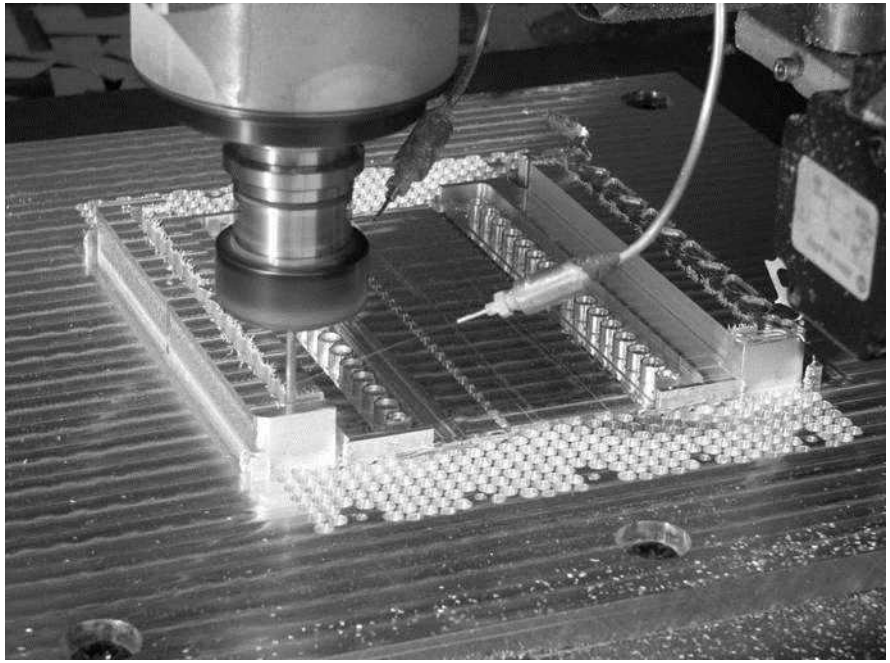
- Reduce Mass
  - Use honeycomb and truss structures as much as possible
- Improve circuitry layout
  - Use DW to connect the antenna cards to the power divider card to avoid mass of wiring and manual assembly operations
  - Use DW to ground the antenna cards to the enclosure
- Make it possible to assemble and disassemble easily
  - 2-part assembly to minimize assembly steps
  - Automatically account for tolerance stack-up
- Properly support the antenna cards
  - Keep them from flexing during vibration
- Embed the power divider card

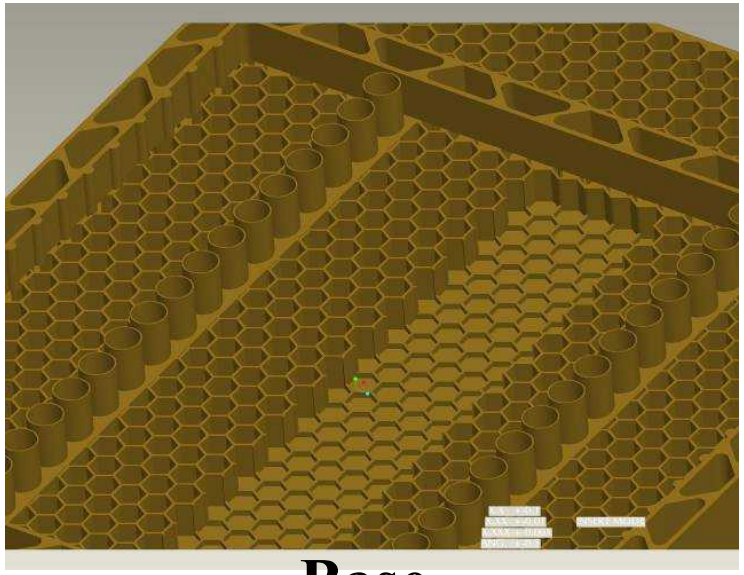


Mass Reduction

- Honeycomb Base
- Truss Walls
- Remove Unnecessary Enclosure Walls







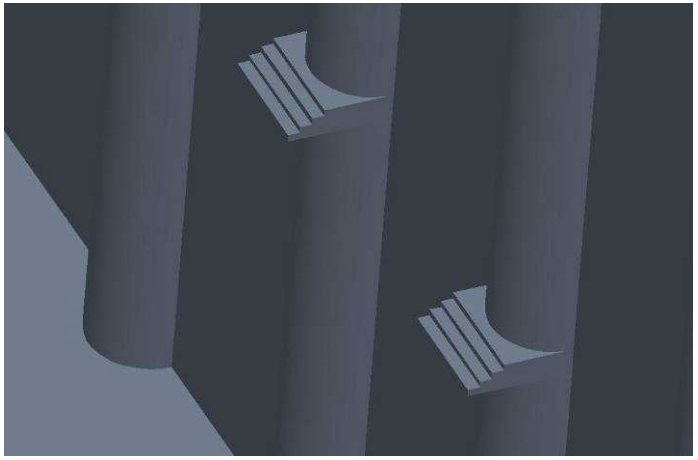
Base

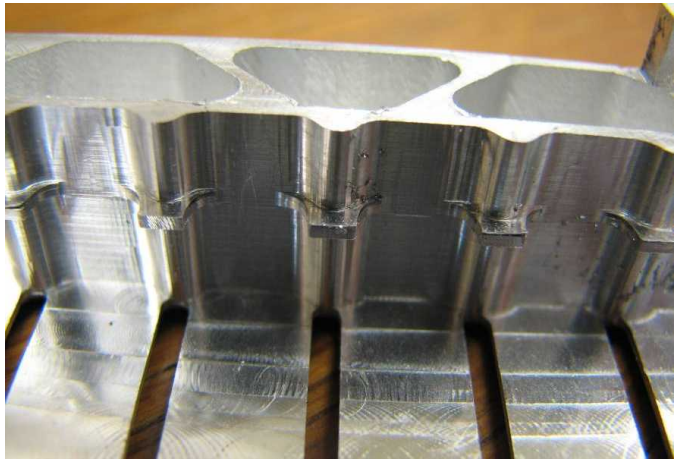
Antenna Card Supports

- Airy support Design
  - Minimize Free Deflection
  - Does not Introduce Stress
- Cylinder Supports
  - Line Contact on sides of cards
  - Minimize material by hollowing
- Triangle Simple Supports
  - Point Contact
- Half Cylinder Supports
  - Line contact card ends

Tolerance Compensation Details

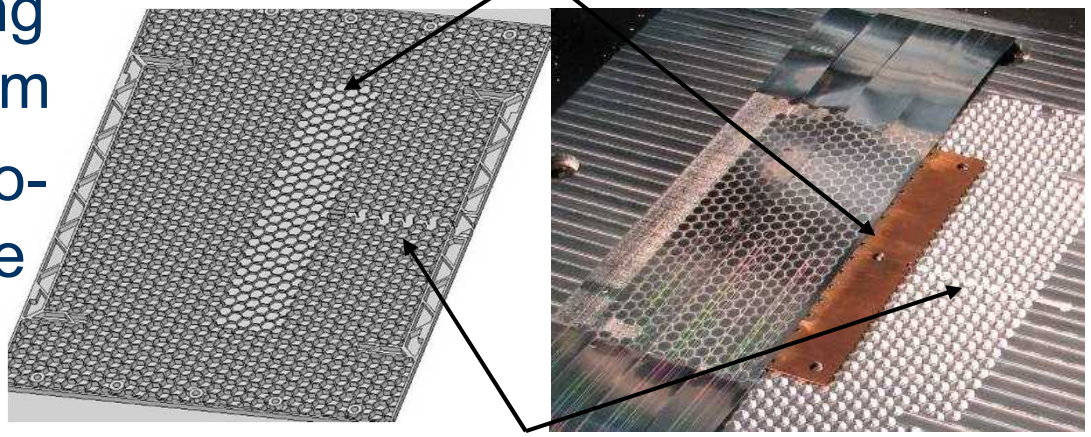
- In UC the Z direction is the least accurate (0.006” layers)
- Overhanging Tabs are used to press tabs on antenna cards (which flex without breaking to hold the cards tightly in place)
  - These types of overhangs are nearly impossible to machine from a block.

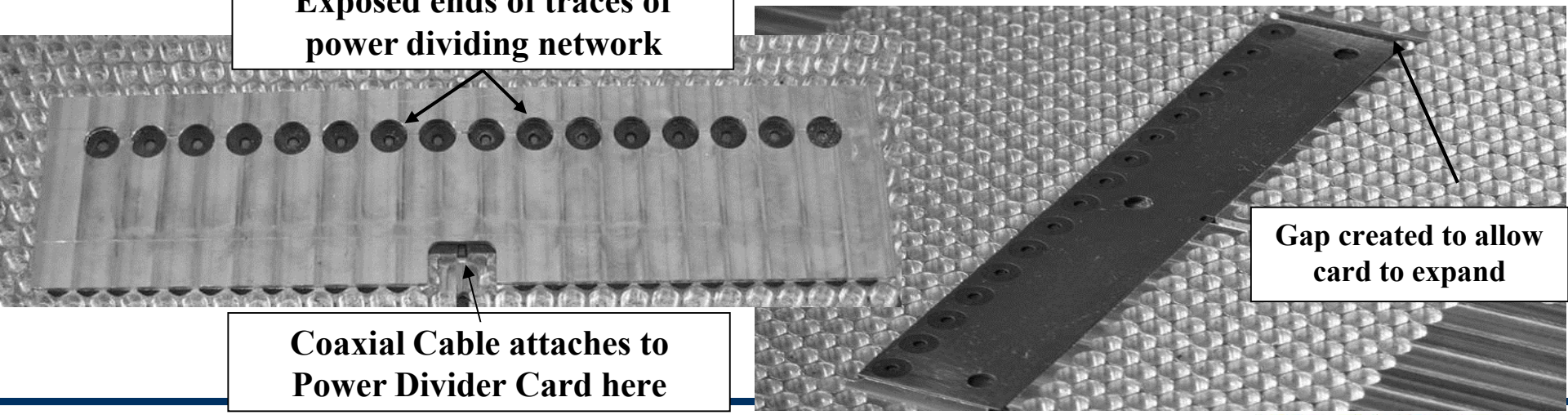




Embedded Power Divider Card & Co-ax Cable

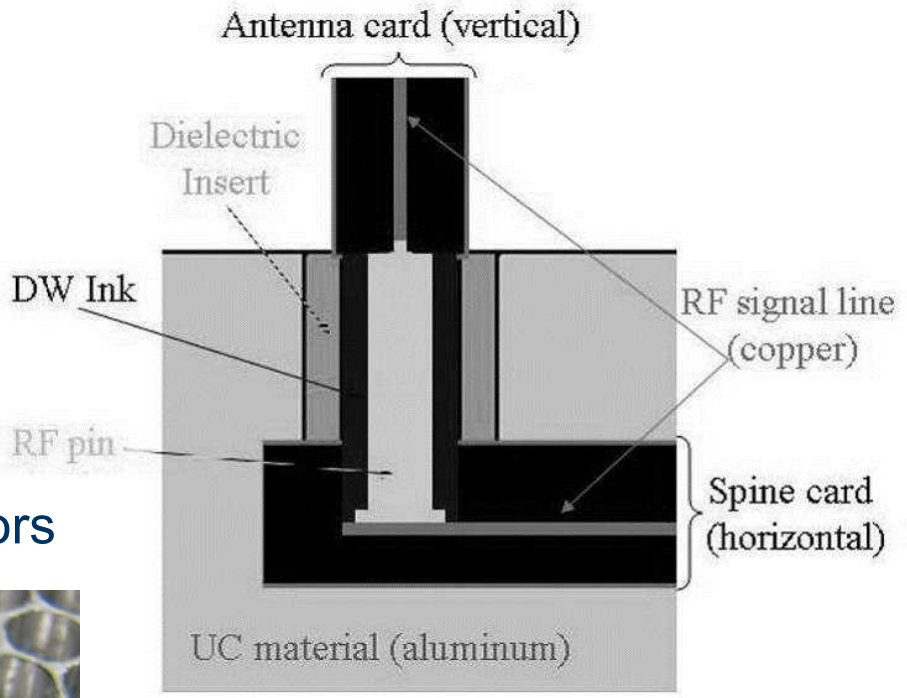
- All connections are exposed after embedding using CNC milling system
- Empty channel left for co-ax cable to run out to the side of the assembly

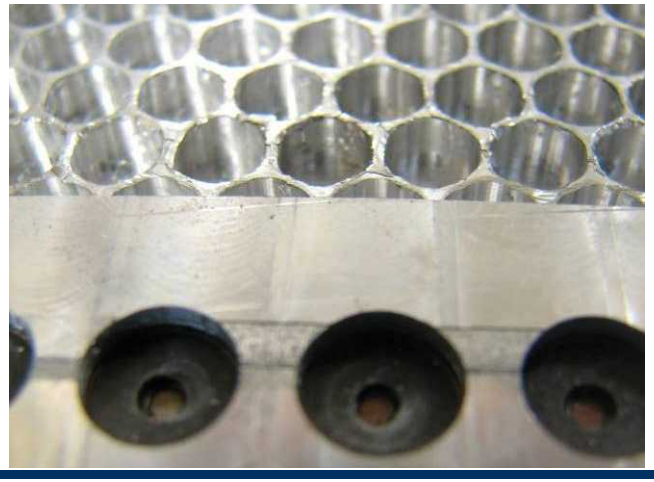




Interconnects

- High frequency RF signals experience losses through bends and connections
- Created a custom pin design
  - DW ink well surrounded by dielectric
  - Compensates for assembly errors

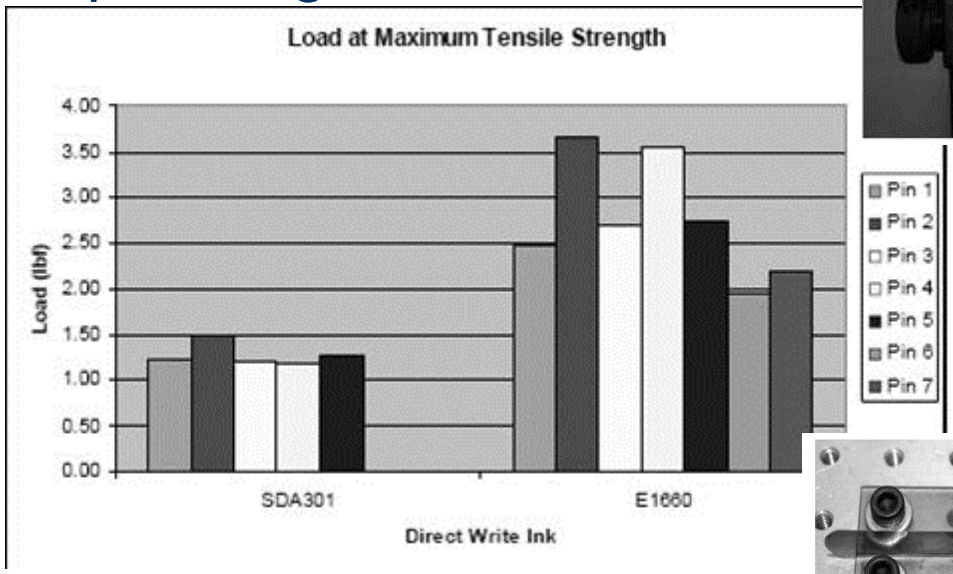


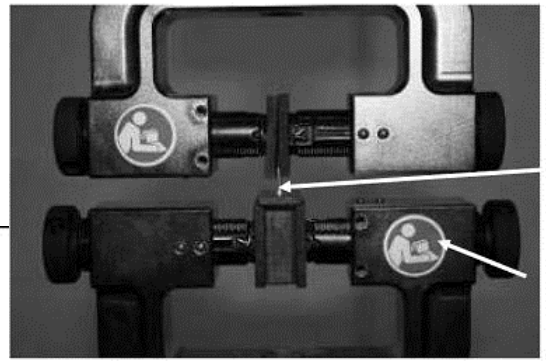


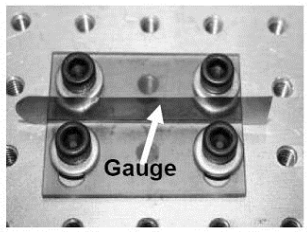
DW Ink Testing

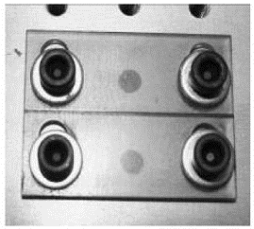
- Mechanical testing of DW ink
- Seep testing of DW ink

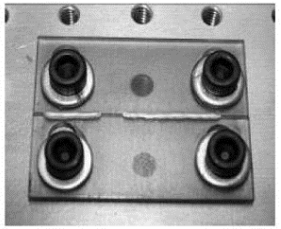
Tensile-test specimens







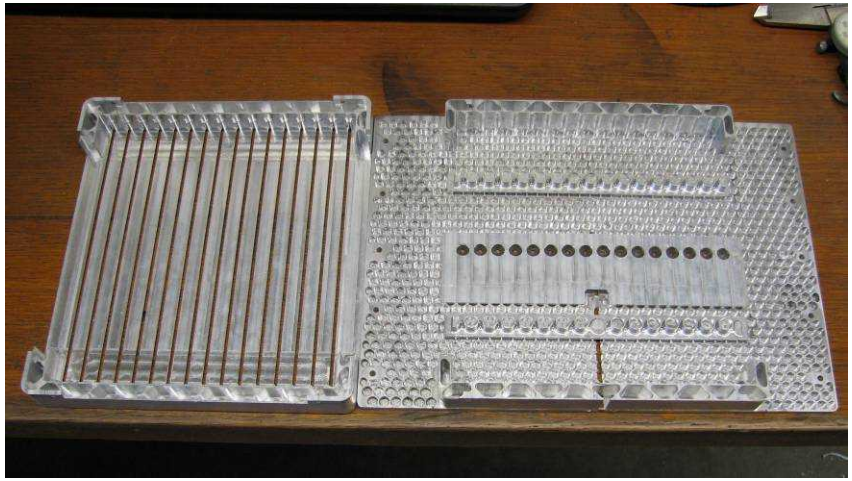


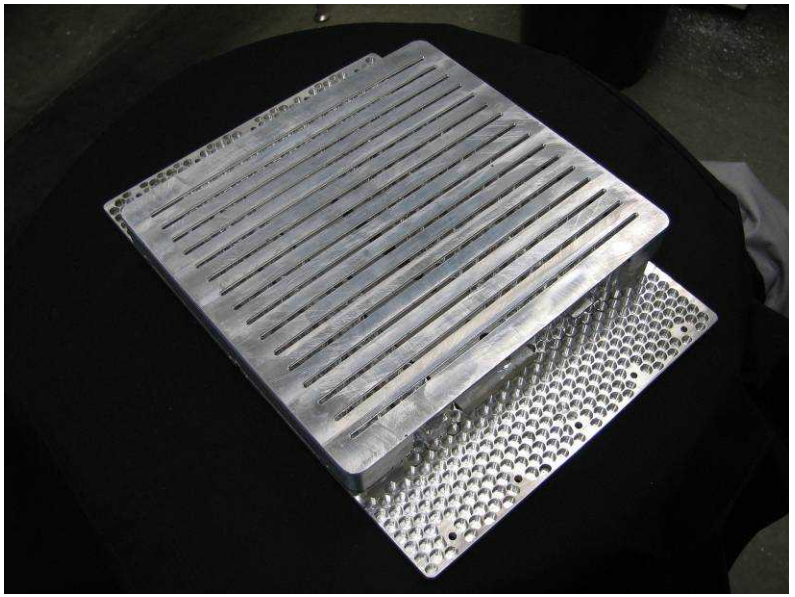


The E1660 ink had fewer voids after curing, could bridge gaps more effectively, and was the strongest, and thus was chosen

Final Enclosure

- Bottom
  - Embedded power divider card
  - Cylinder supports
  - Truss walls
  - Honeycomb base
  - Mounting holes for gimbal
  - DW interconnects between cards and to embedded co-ax cable
- Top
  - Reflector plane
    - DW used to ground edges of antenna cards to lid
  - Restrains cards in x, y and z directions
  - Truss walls which assemble over bottom for alignment & fixating
- Total weight approximately 1 lb
  - Not including antenna card weight





Future Work

- High frequency testing of DW ink is required to determine performance characteristics
- The Mini-SAR antenna cards will be assembled and tested to determine feasibility of the design
- The DW RF interconnects must be tested to determine suitability of the developed interconnect design
- Development of support materials for UC will make building a single, monolithic miniSAR antenna possible
  - This will make the antenna impossible to disassemble, however

Conclusion

- Rapid Manufacturing technologies present tremendous opportunities to consider new designs
  - Even for complex, integrated electro/mechanical systems
- UC as an additive + subtractive process gives considerable design flexibility for creating unique metal structures with embedded capabilities
- A UC/DW MiniSAR phased array antenna has been designed and built
  - The antenna enclosure is low mass, ~1 pound
  - Tolerance issues were avoided using creative design
    - Taking advantage of the flexibility of additive manufacturing
- Superior interconnects were created using UC and DW in concert

Questions?

Contact Info:

Brent Stucker

Mechanical & Aerospace Engineering

Utah State University

Logan, UT 84322-4130 USA

brent.stucker@usu.edu

Phone: +1-435-797-8173