# Non-Destructive Inspection of Adhesive Bonds in Metal-Metal Joints

*USAMP/NDE601*
*Agreement 15013*
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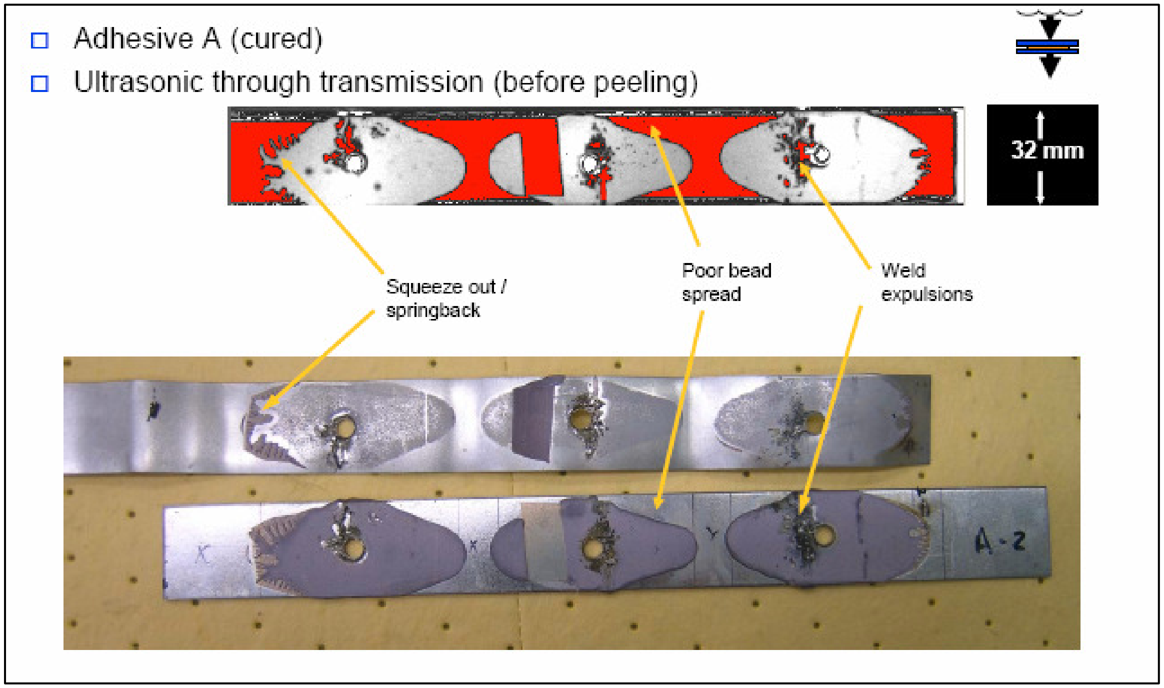
*This presentation does not contain any proprietary or confidential information*

# Outline

- ❑ Purpose of work
- ❑ Address Previous Review Comments (if applicable)
- ❑ Barriers
- ❑ Approach
- ❑ Performance Measures and Accomplishments
- ❑ Technology Transfer
- ❑ Publications/Patents
- ❑ Plans for Next Fiscal Year
- ❑ Summary

# Purpose of Work

- ❑ Develop non-destructive inspection methods to verify adhesive bonds in automotive metal-metal joints
- ❑ Nondestructively assure the strength of adhesive bonds



# Barriers addressed

- Adhesives increasingly being used because they
  - Increase body stiffness - without significant mass increase
  - Increase body strength – without significant mass increase
  - Enable dissimilar materials, e.g. steel + Mg, or composite + steel to be used next to each other
- Reduce cost of light-weight materials.
- Adhesive bonding is a critical technology
  - Present in ~95% of the Mg Front End joints
  - Present in all the Composite Underbody joints
  - Allows less expensive sheet product to be used instead of castings or extrusions
- Spread strain for more brittle light-weight materials, especially around joints.

# Approach

- ❑ Work with adhesive suppliers to identify key features that determine the adhesive bond strength quantitatively

- ❑ Work with NDT experts, especially from aerospace, to identify leading NDT technologies to measure these properties in vehicle structures

- ❑ Verify targeted methods on coupons (NDT prediction vs. quantitative strength measurements)
  - Skips, bond-thickness and -width variations, 3 adhesives, 2 substrates, cure state, welds
  - Kissing bonds (intimate, but weak)

- ❑ Test performance of methods on production vehicle bodies

Dow

Henkel

LORD

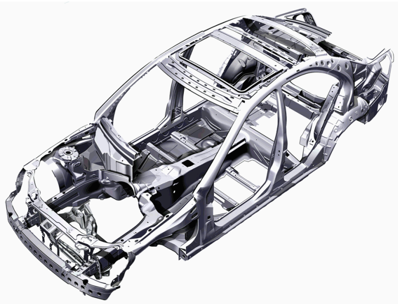
Sandia National Laboratories

Inteligent Optical Systems

IOS

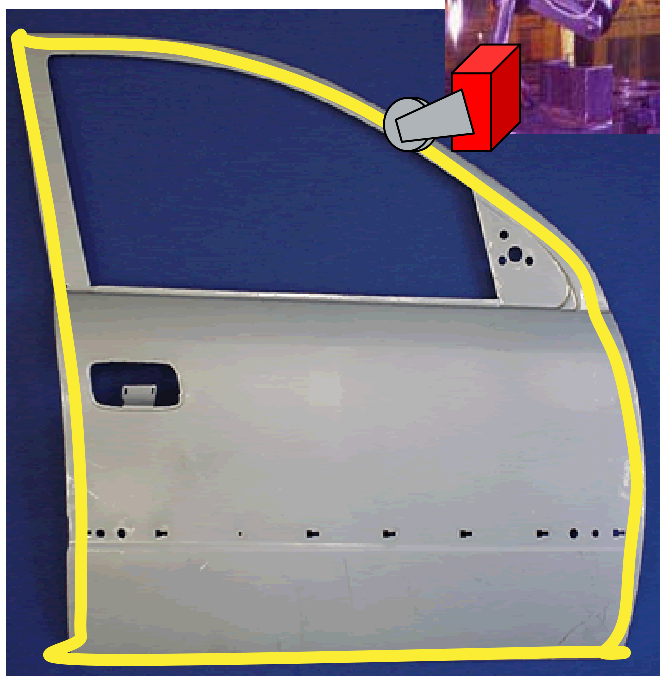
OLYMPUS

Thermal Wave Imaging
THE ART OF INSPECTION



# Technical target: demo flange following tool

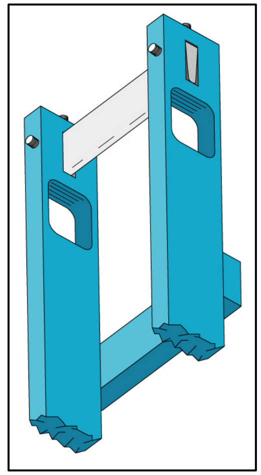
- Requirements
  - Lap joints with 2-t & 3-t stackups
  - Single-sided inspection
  - Hand or robot capable
  - 25-mm wide flange
  - <1 mm resolution
  - >1 m/min (off line)
  - Cured or uncured

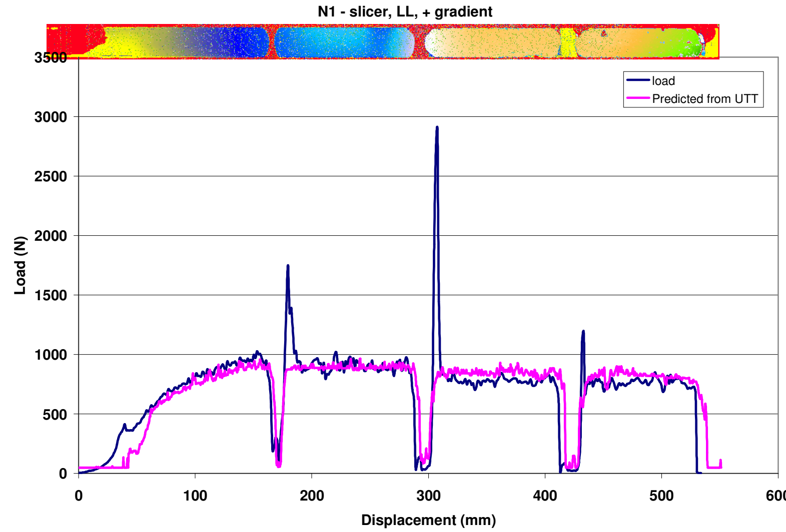


- Detect
  - Area wetted
  - Location on flange
  - Thickness
  - Adhesion strength
  - (Cure state)

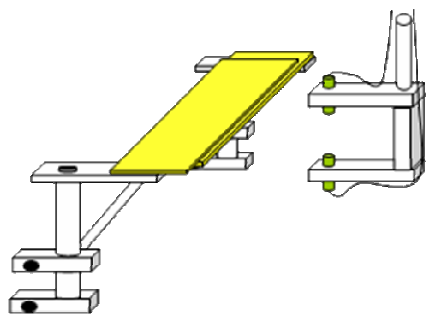
# Accomplishments – demonstrated that requirements are sufficient

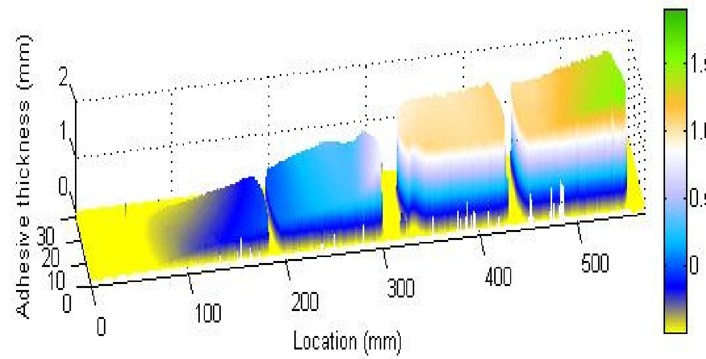
- After testing three alternatives, developed new wedge peel method to obtain high-resolution strength map





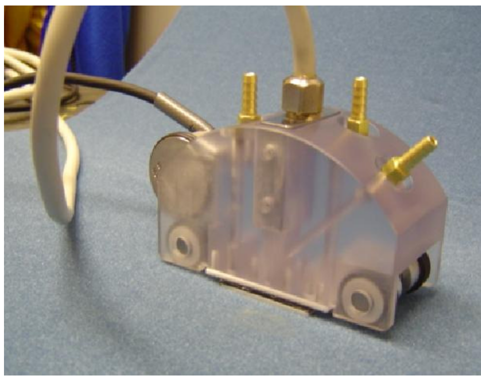

- Developed gold-standard NDE method (ultrasonic through transmission in immersion tank) to predict strength

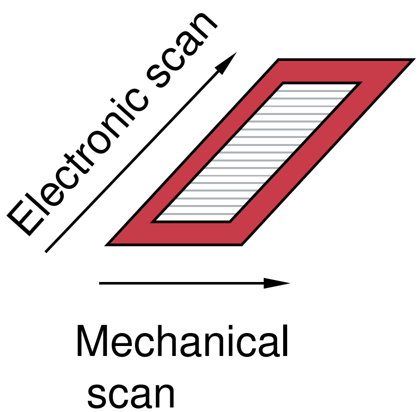


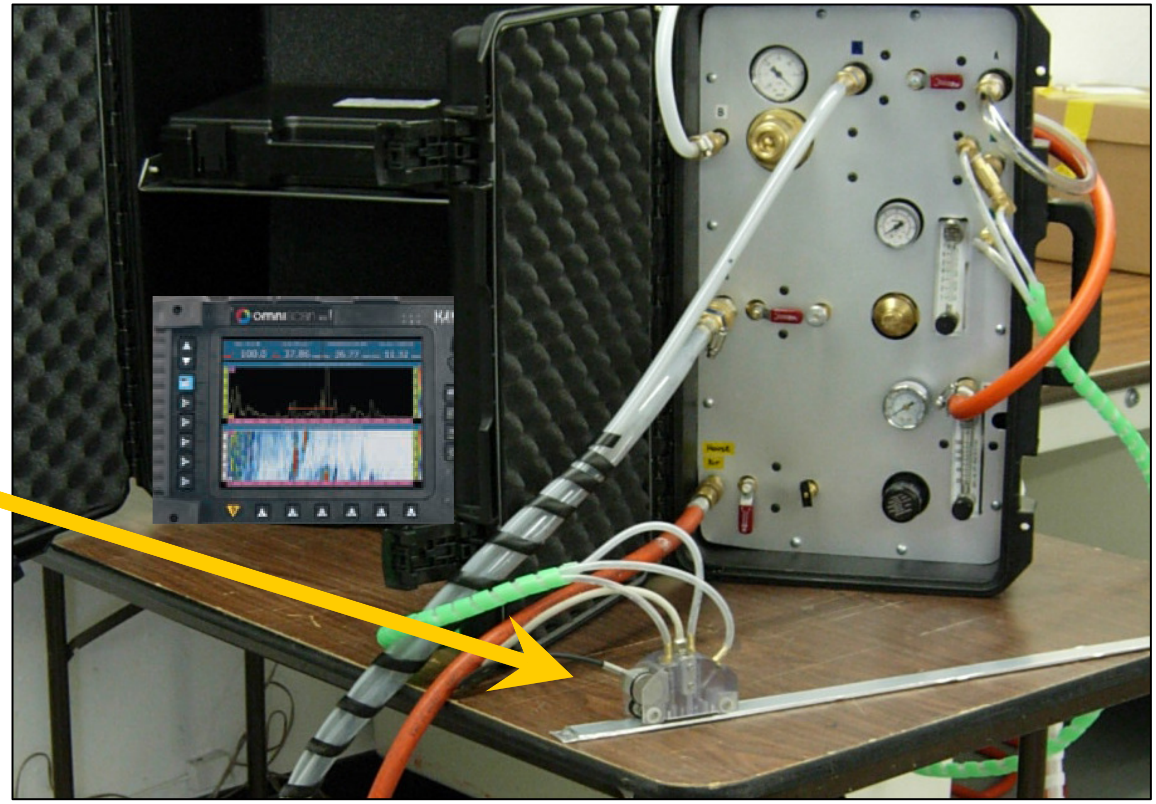


# Accomplishments – designed & built unique high-frequency ultrasonic phased array probe

- Manual
- Portable – closed loop water
- Water use: <1 cup/100 m
- Resolution: 0.5 mm
- Speed: 5 m/min

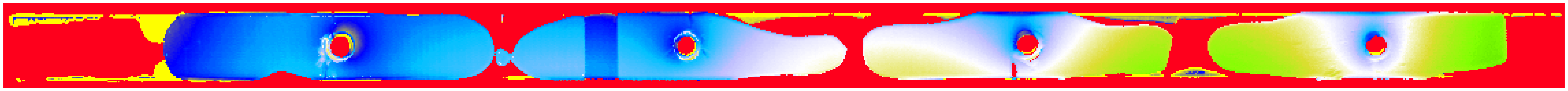
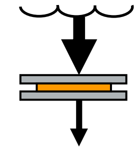




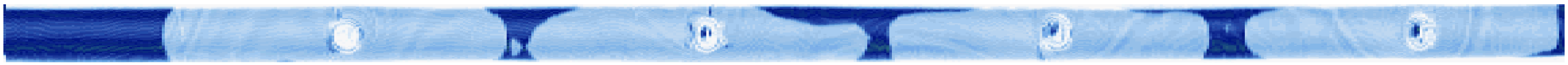
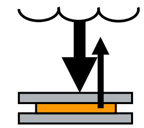



# Accomplishments – four technologies evaluated on steel & aluminum (shown) coupons with good bonding

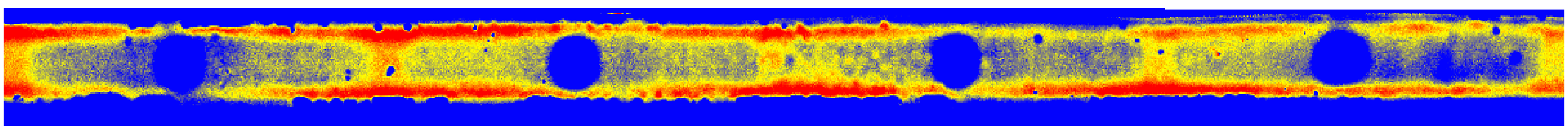
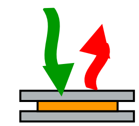
- ❑ Immersion tank

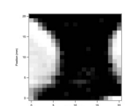
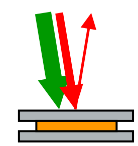
- ❑ Ultrasonic phased array

- ❑ Pulsed thermography

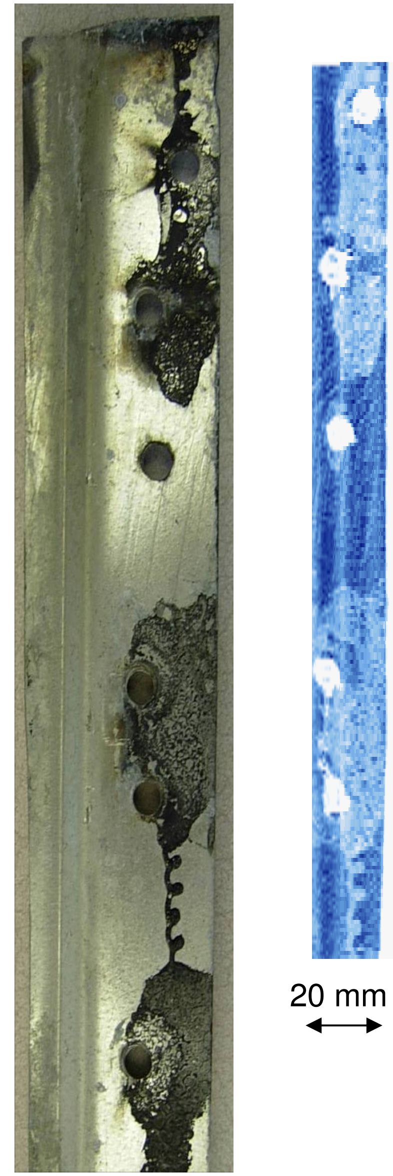



- ❑ Laser ultrasonics (steel sample shown)

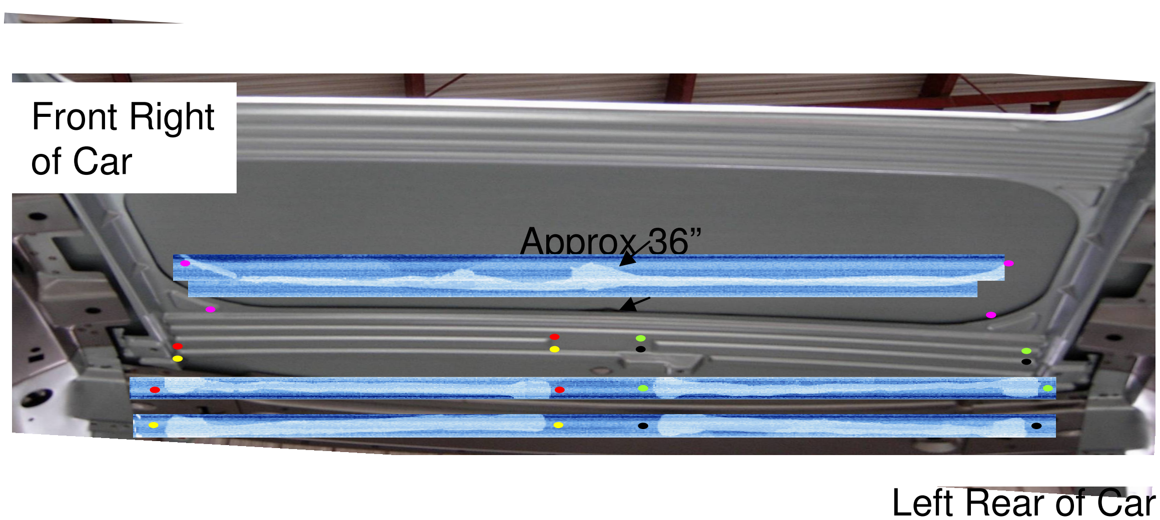
# Accomplishments – Body in white inspections

- Floor flange




- Hem flanges


- Row bows - uncured

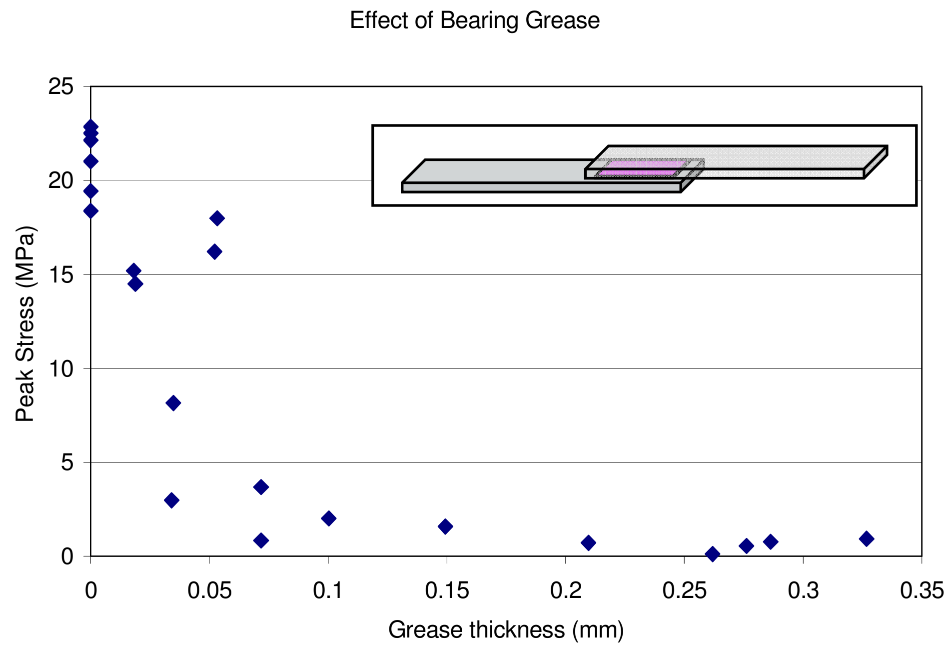


# Accomplishments – four technologies with good bonding

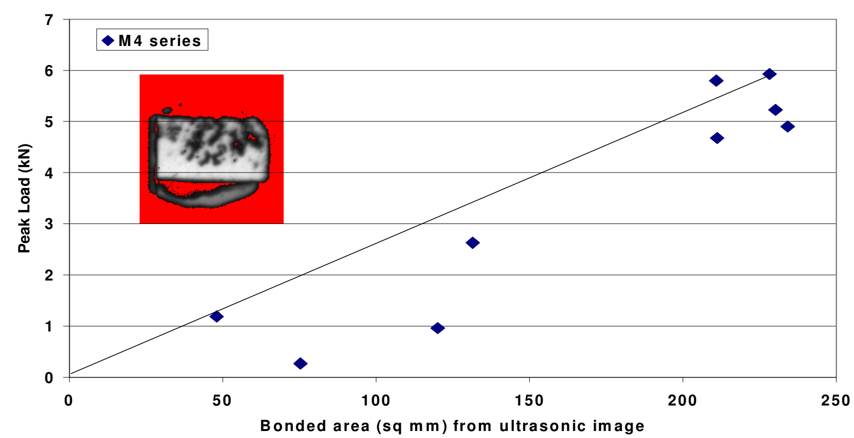
| **Technology** | **Resolution** | **Speed** | **On vehicle** | **Status** |
|---|---|---|---|---|
| Target | <1 mm | >1 m/min | | |
| Ultrasonic immersion tank | ✓ 0.5 mm | ✓ 5 m/min | No | Gold standard on flat coupons |
| Ultrasonic phased array | ✓ 0.5 mm | ✓ 5 m/min | Yes | Best near-term, needs thickness |
| Laser ultrasonics | ✓ 1 mm | 0.3 m/min | Not tested | Under development for in-line inspection |
| Pulsed thermography | 5 mm | 0.3 m/min | Yes, with coatings | Dropped |

# Accomplishments -Weak ("Kissing") Bond Detection

- Prepare carefully controlled lap-shear coupons with repeatable amounts of grease contamination




- Inspect contaminated interface with conventional ultrasonics



# Technology Transfer

- ❑ Ultrasonic phased array has been used to answer engineering questions on OEM pre-production and production vehicles
- ❑ Working with NDE vendors to commercialize the phased array and laser ultrasonics technology
- ❑ Working with Automotive Composites Consortium (ACC)
  - Ultrasonic through transmission has been used by ACC Energy, Focal Projects 3 & 4 to verify plaques and components
- ❑ Working with AMD 603/604 Mg Front End
  - Apply to Mg Front End joints as they become available (riv/bond)
  - Applied to corrosion tests of Mg bonded lap joints

# Publications, Presentations, Patents

- Record of invention filed for phased array probe

- Presentations/extended abstracts

  - K. Lazarz, C. Dasch, and R. Agarwal, "Correlating adhesive bond strength with non-destructive test methods", The Adhesive Society Annual Meeting, Austin TX, Feb. 2008.

  - C. Dasch, K. Lazarz, and R. Agarwal,"Inferring Adhesive Bond Strength for Automotive Applications from Quantitative Nondestructive Testing", The Adhesive Society Annual Meeting, Austin TX, Feb. 2008.

# Activities for coming fiscal year

- Miniaturize / productionize phased array
  - Reduce size by 50%, articulated
    - 18 mm flanges, smaller confines
    - 95% of vehicle should be accessible
  - Use commercial circulation system
- Ultrasonic signal processing – adhesive thickness
- Kissing bond evaluations
  - Phased array performance on grease bonds
  - Access requirements of other kissing bonds
    - Dry lube
    - Mold release

# Summary

- ❑ Adhesives (with good bonding) are a light weight material enabler
  - Allow reduced gauges and reduced # of welds or rivets – reduced costs
  - Adhesives are critical technology for composites, Mg, AHSS where brittleness is a limit
  - Adhesives provide corrosion barrier in dissimilar metal structures

- ❑ Aug. 2006-Dec. 2007: Tasks 1-9 completed on time; Gates 1 and 2 passed
  - Demonstrated that strength (when adhesion is good) can be predicted quantitatively from NDE bond width and thickness measurements
  - Demonstration of NDE performance using commercial technology on steel and aluminum flat coupons
  - Demonstration of NDE performance on production bodies-in-white
  - Demonstration of grease kissing bond sample prep and detection

- ❑ Technology transfer is well in hand
  - Commercial vendors involved in development
  - Engaged in production and related USAMP Mg and composite problems

- ❑ Plans for Next Year
  - Productionize phased array and laser ultrasonic technology
  - Methods to inspect kissing bonds

# Questions?

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