JOINING CORE PROGRAM (JCP)

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DOE-VTO AMR

Project ID # MAT-145

Pacific Northwest NATIONAL LABORATORY

OAK RIDGE National Laboratory

OVERVIEW

Timeline

- Start: FY18
- Finish: FY20
- 25% Complete

Budget

- Total Project – $2.65M (ITD)
- 50/50 distribution PNNL/ORNL
  - FY17 - $400k
  - FY18 - $2.25M

Barriers

- Lack of mature technologies to join magnesium and carbon-fiber composites
- Limited scientific understanding of metal to composite joints
- High corrosion potential between Mg and CFRP

Partners

- Pacific Northwest National Laboratory
- Oak Ridge National Laboratory

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JOINING IS A CRITICAL CHALLENGE

Increasing Need for R&D

Increasing Impact on Reducing Vehicle Mass

Material	Critical Challenges				
Multi-Material Systems Enablers	High Volume Joining (Fusion, Mechanical, Adhesives)	Engineered Surfaces (Corrosion, Wear, Friction)	Predictive Modeling	NDE & Life Monitoring	Recycling
Carbon-Fiber Composites	Low-cost High-Volume Manufacturing	Low-Cost Fibers	Predictive Modeling	Joining, NDE, Life Monitoring & Repair	Recycling (OFFAL / Vehicle)
Aluminum	Low-cost Al Manufacturing Processes	Improved Alloys (Body/Powertrain) for Performance & Manufacturing	Joining Mixed Al Products	Recycling Vehicle	
Ultra High-Strength Steels	Improved Alloys for Room Temp Forming	Weldability for Dissimilar Steel Alloys	Predictive Modeling (Formability, Crash)		
Magnesium	Low Cost Feedstock, Low Carbon Footprint Production	Galvanic Corrosion Protection	Improved Alloys for Energy Absorption	Manufacturing (Sheet and Extrusions)	Recycling
Glazings	Low Cost Feedstock for Polymer Glazings	Low Temp Processed Chemically Toughened Glass	Durable, Scratch Resistant, UV Resistant Coatings		
Metal / Ceramic Composites	Feedstock Cost	Compositing Methods	Powder Handling	Compaction	Machining & Forming

Dissimilar materials joining recognized as most critical R&D need with highest impact towards vehicle lightweighting

USDRIVE Materials Technical Team Roadmap, October 2017
Summary of significant technological challenges to widespread use of lightweight materials

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RELEVANCE

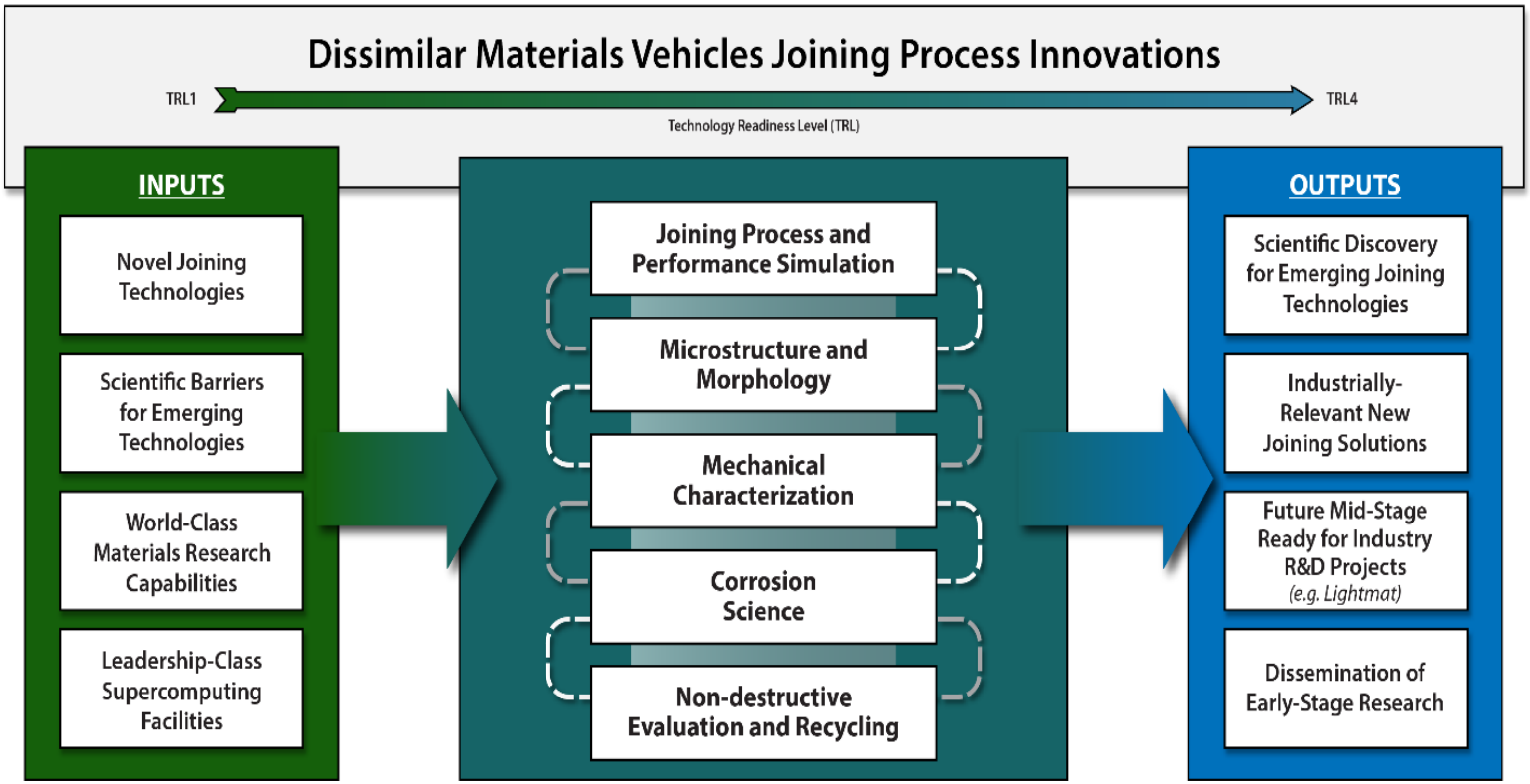
Joining Core Program is designed to deliver early-stage research for joining technologies, and understanding of the underlying science, that will enable increased use of lightweight mixed-materials in vehicles.

- **Project Objectives:**
  - Study the complex metallurgical, chemical and mechanical behavior associated with the formation of intermetallic compounds, electrochemical reactions and stress-strain states that exist in-situ and post-joining, to better understand and control detrimental effects;
  - Develop process technologies specific to joining combinations of magnesium and carbon fiber reinforced plastics (CFRP) to existing vehicle steel and aluminum components in a manner that ensures long-term durability and performance.

JOINING CORE PROGRAM: Scientific Thrusts

Advanced Joining Consortium to Enable Multi-Material Vehicles

Conducting Early-Stage Research and Development to Advance High-Volume Manufacturing Process Technology



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APPROACH

- Four projects
  - Project 1: Interface by Design — ORNL lead
  - Project 2: Mg to Steel by solid-state methods — PNNL Lead
  - Project 3: Enhancement of Adhesives — ORNL Lead
  - Project 4: Mg to CFRP Trials — PNNL Lead

- Materials of focus:
  - Magnesium: AZ31 sheet, AZ91 and AM50 casting
  - CFRP:
    - Continuous fiber and chopped fiber
    - thermoset and thermoplastic
  - Steel: Mild steel, DP590, DP980

APPROACH:
SUMMARY OF MATERIALS AND ACTIVITIES

	Mg-Steel	Mg-CFRP	CFRP-Steel	Interface-by-Design
Coordinator	Darrell Herling	Scott Whalen	Zhili Feng	Xin Sun
Materials	• DP590 • AZ31 & AM50	• AZ31 • AM60 (overcast) • Nylon / chopped CF • Epoxy / woven CF	• DP980 • Nylon / chopped CF • Epoxy / woven CF	N/A
Joining Methods Investigated	• Friction Stir Welding • Ultrasonic Welding	• Friction Stir Interlocking • Bolting and Friction Self-Piercing Rivet • Magnesium Overcasting • Ultrasonic Welding	• Adhesive	• Friction Stir Welding • Ultrasonic Welding • Adhesive Bonding
Outputs	• Interfacial characterization – Chemistry – Physical • Characterization of diffusion mechanism(s) and kinetics • APS experimental design	• Feasibility report on each method: – Potential for joining – Bond strength – Technical/physical limitations – R&D needs • Down-select recommendations	• Interfacial performance limits: – Strength – Fatigue • Corrosion/compatibility • Effective surface modification methods • Bulk adhesive properties	• Insights to surface geometry (CFRP-steel) • Insights to interfacial chemistry (intermetallic formation) • Insights into diffusion enhancement mechanism

TECHNICAL ACCOMPLISHMENTS
ORNL SUMMARY MILESTONES FY18

- All Tasks: Determine specific material systems (Alloys, surface coatings, composite architectures, polymer systems) for the studies in each task. Procure the material samples and cut the initial rounds of coupons to the required specimen dimensions. (Q1) - Complete
- CFC to Mg Task: Demonstrate the ability to ultrasonically weld magnesium to carbon fiber composites. (Q2) - Complete
- AHSS to CFC Task: Demonstrate an improvement of at least 20% in adhesive bond strength between AHSS and CFC due to laser structuring of the two adherents. (Q3) – On track
- CFC to Mg Task: Complete hole generation in composite materials using a mixture of different hole generation methods and hole sizes. Perform tensile tests in specimens and compare to specimens which have not had holes produced. (Q4) – On track

TECHNICAL ACCOMPLISHMENTS PNNL SUMMARY MILESTONES FY18

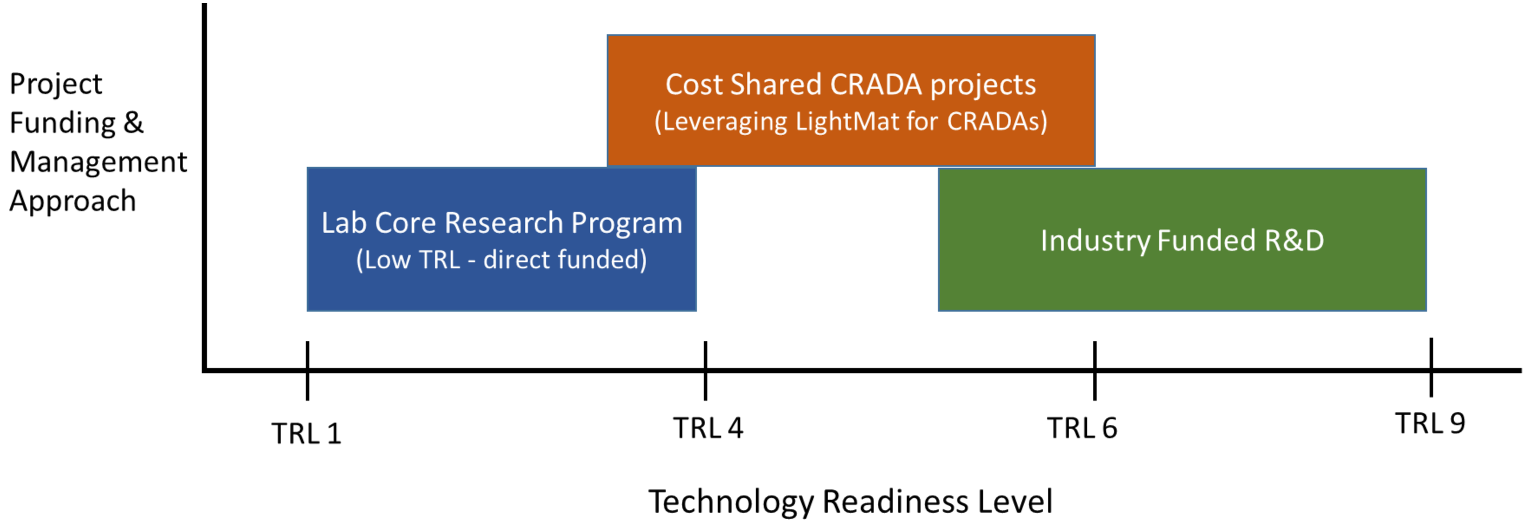
- Interface by Design Task: Identify experiments to be carried out to provide calibration of modeling parameters and measurements to model validation. (Q1)- Complete
- Mg Alloy to CFRP Task: Establish criteria for down selecting joining methods and set level of success for evaluating performance. (Q2) – Complete
- CFRP to AHSS Task: Demonstrate completion of surface characterization of thermoplastic CFRP and DP980 steel to determine the surface chemistry and surface morphology. (Q3) – On track
- Mg Alloy to AHSS Task: Complete characterization of type and extent of intermetallic formation between AZ31 and DP590 and down select to one or two joining methods for continued development. (Q4) – On track

COLLABORATION AND COORDINATION

- Core program national labs
  - Pacific Northwest National Laboratory
  - Oak Ridge National Laboratory
  - Argonne National Laboratory (planning APS characterization task)

- Industry suppliers
  - BASF – Thermoplastic plaques provided
  - U.S. Steel – Steel sheet provided
  - POSCO – Magnesium sheet provided

COLLABORATION AND COORDINATION



- Joining Core Program focusing on early-stage research (TRL 1-4) at National Laboratories to develop fundamental understanding and novel solutions
- Pursue application-specific problems in separate Industry derived projects via LightMAT assistance or other R&D mechanisms (TRL 3-6),
- Leading to successful Industry funded implementation (TRL 5-9)

RESPONSES TO PREVIOUS YEARS REVIEWERS' COMMENTS

- Projects are new starts in FY18 – no previous year comments

- JCP projects reviewed at this year's 2018 AMR
  - MAT136: *High-Performance Computing (HPC) and High-Throughput Characterizations towards Interfaces-by-Design for Dissimilar Materials Joining*
    - –Xin Sun, ORNL
  - MAT137: *Adhesive Bonding of Carbon-Reinforced Plastic to Advanced High-Strength Steel*
    - –Amit Naskar, ORNL
  - MAT138: *Solid-State Joining of Magnesium Sheet to High-Strength Steel*
    - –Piyush Upadhyay, PNNL
  - MAT139: *Joining Magnesium Alloys to Carbon-Fiber Reinforced Polymers*
    - –Darrell Herling, PNNL

SUMMARY

- ❖ JCP is a collaborative research program initiated jointly between ORNL and PNNL, leveraging existing expertise and past efforts in joining technology development and lightweight materials R&D capabilities.
- ❖ Collaborative, early-stage research conducted through this program will address multi-material joining and associated compatibility challenges.
- ❖ Rapid progress is being made toward objectives for each of the four initial projects.