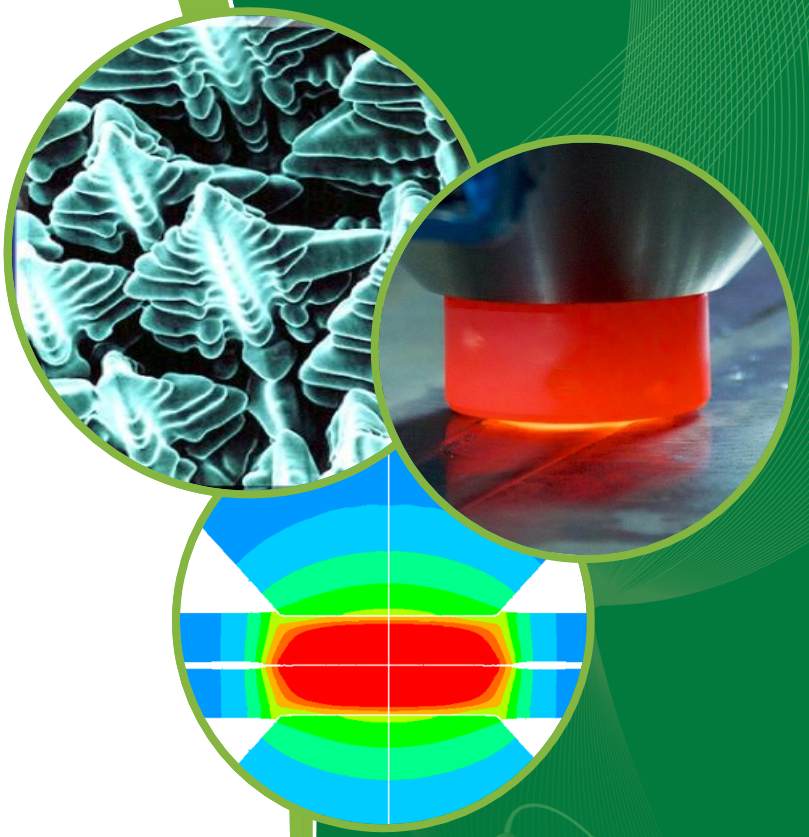
Technology Validation of Innovative Dissimilar Materials Joining Method in Automotive Production Environment



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Oak Ridge National Laboratory

2018 U.S. DOE Vehicle Technologies Office Annual Merit Review

June 20, 2018 **Project ID: MAT135**

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Overview

Timeline

- Project start date: Nov 1, 2017
- Project end date: June 30, 2020
- 10% complete

Budget

- Total project funding
  - DOE share: $633.8K
  - Contractor share: $633.8K
- Funding received in FY 2018
  - DOE Share: $633.8K
  - Contractor share: $633.8K

Barriers

- Barriers addressed
  - Utilize lightweight materials (e.g., CFRP, AHSS, Mg and Al alloys) for light vehicle applications
  - Critical technical challenge for **joining of dissimilar lightweight materials** to form a unified car structure to meet design and performance requirement
  - **Scale-up of dissimilar joining technology** for near-term commercial readiness

Partners

- CRADA Partners: Hyundai America Technical Center, Inc., Eagle Bend Manufacturing, 3M, ORNL
- Project lead - ORNL

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Relevance

- **Objective**
  - To scale up and validate an innovative dissimilar material joining method – friction bit joining (FBJ) that has been successfully developed and demonstrated in the lab (TRL4) – to assemble prototypical auto-body components made of advanced high-strength steels (AHSS) and carbon fiber reinforced plastics (CFRP) in automotive production environment at an automotive Tier 1 assembly plant (TRL 6)
- **Impact**
  - The successful validation on an auto-body assembly line will be an essential cornerstone to accelerate the FBJ technology commercialization
  - The project will enable the broadest insertion of lightweight materials in the transportation industry, lead to significant economic benefits and reduce environmental impacts

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Project Milestones

Milestone No	Milestone Description	Date (Month)	Status
1	Complete design and fabrication of new FBJ welding machine	6	In-progress
2	Complete system integration of FBJ with assembly line	9	In-progress
3	Refine FBJ process at coupon level	12	In-progress
4	Validate the Scale-up FBJ technology at EBM and validate mechanical performance produced at EBM facility with ORNL result	15	
5	Complete fabrication of prototype components suggested by OEM and assembly fixtures	18	In-progress
6	Complete assembly of prototype structures	21	
7	Complete project validation and verification by prototype part testing and performance	24	

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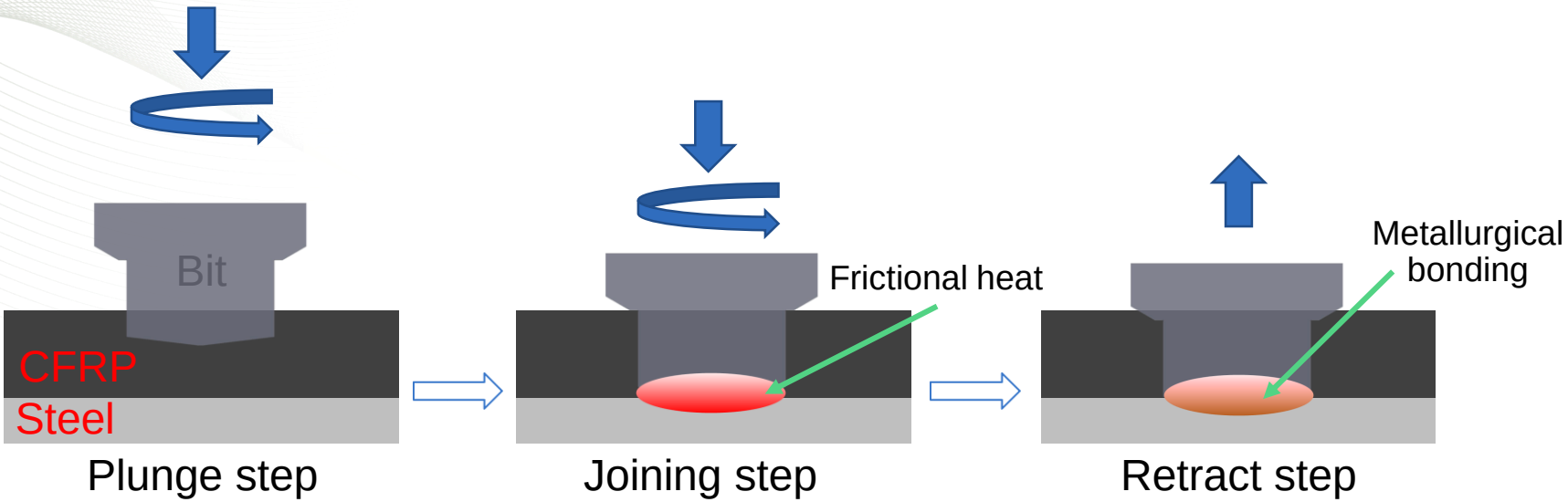
Approach: Solid-State Friction Bit Joining



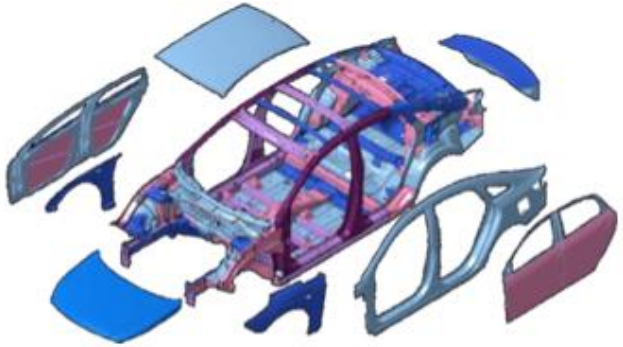
- Use joining bit to facilitate bonding
- Self-cleaning of bonding surfaces
- Increased bonding area (increased strength)
- Multi-stack sheet joining
- Thick sectioned material joining
- Additional mechanical interlocking

- Suitable for joining of soft and hard materials
  - Al / steel
  - Mg / steel
  - ***Polymer composite / steel***
- Can weld through adhesive interlayer for weldbonding
  - Corrosion protection at the joint

Approach/Strategy

- FBJ machine will be scaled-up in terms of both machine functionality and process readiness to handle different part geometries and other production requirements
- Then, FBJ machine will be integrated into a prototype body assembly fabrication cell with dedicated tooling and fixtures, and a part moving and handling system
- FBJ will be scaled-up with scale-up coupons with multiple joint configuration using the prototype welding cell
- Prototype parts developed by the project team will be assembled in the assembly fabrication cell and will be tested for project validation

New FBJ machine



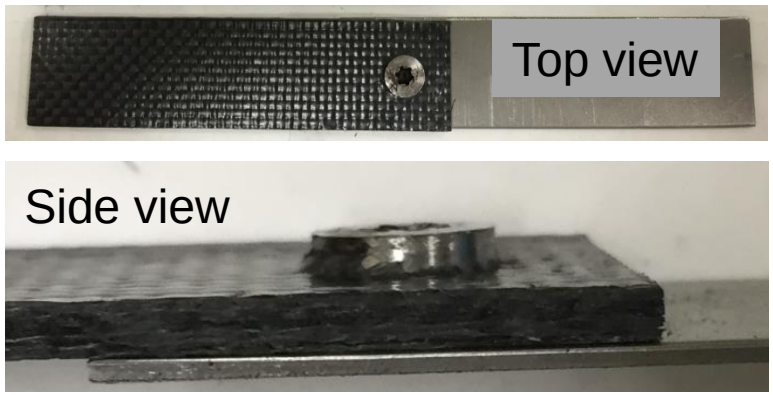
http://www.greencarcongress.com/2015/05/20150526-sonata.html

Development of demonstration parts (CFRP-AHSS)

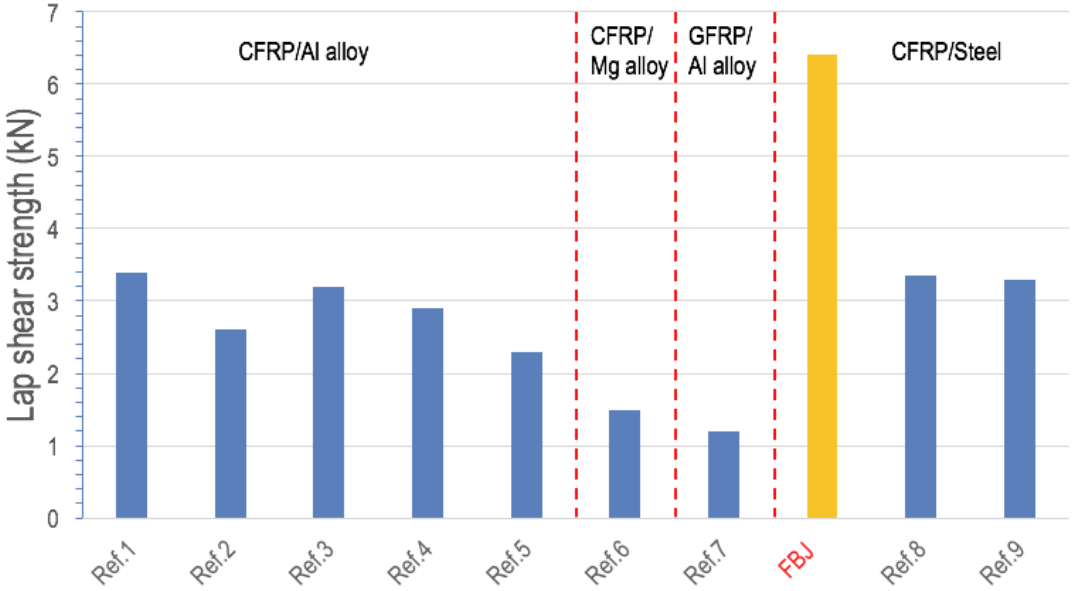
Assembly of demonstration parts at prototype assembly cell

Accomplishment: FBJ of CFRP/AHSS (coupon level)

- Achieved superior lap shear joint strength compared with other joining technologies from open literature



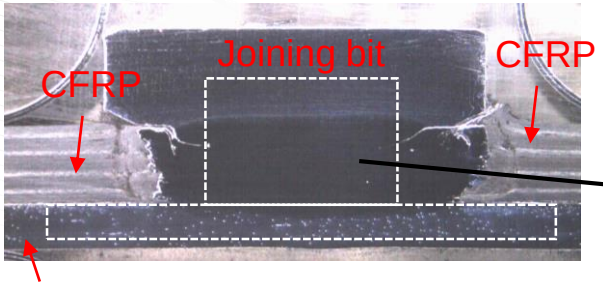
Top and side view of FBJ joint (CFRP-AHSS)

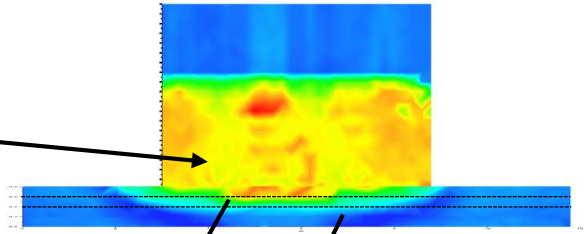


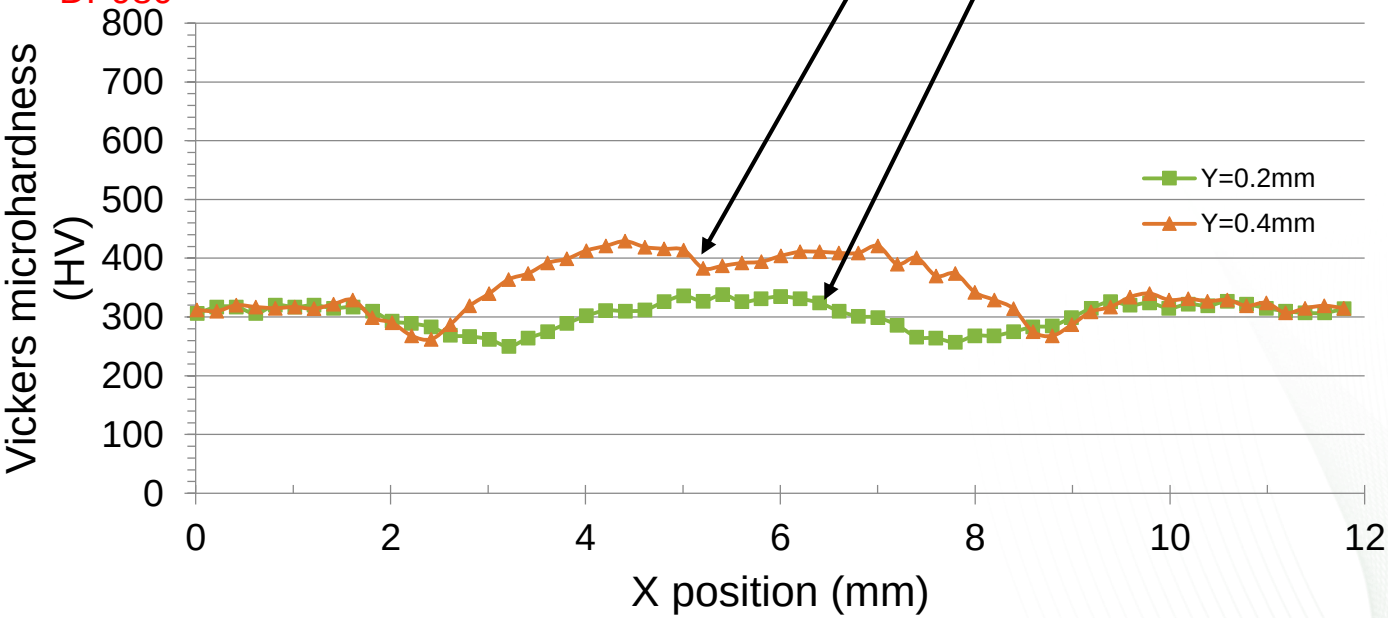
Comparison of lap shear failure load with open literature

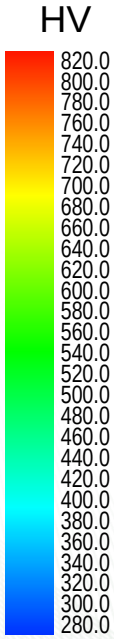
Accomplishment: Vickers microhardness map at FBJ joint

- Strong metallurgical bonding between joining bit and steel substrate is achieved









Macrograph of cross section view and Vickers microhardness map

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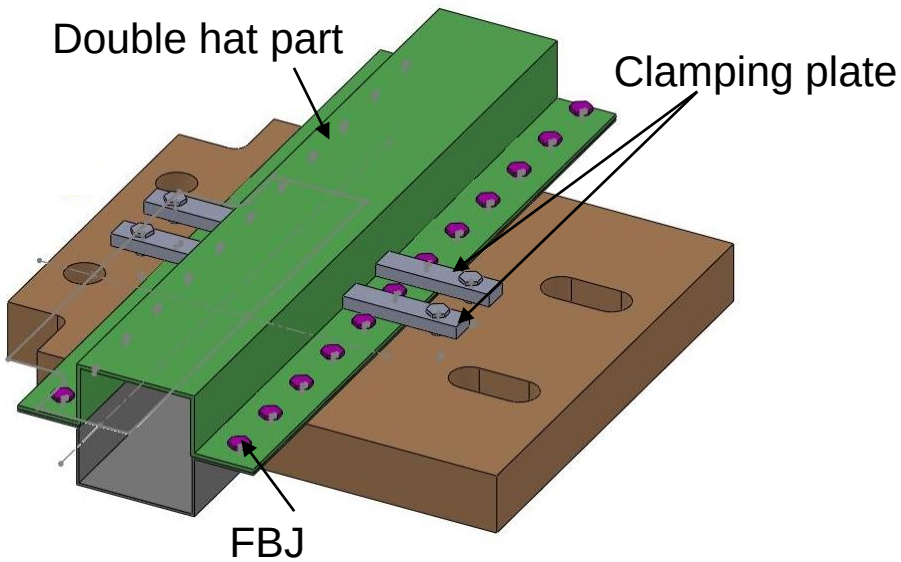
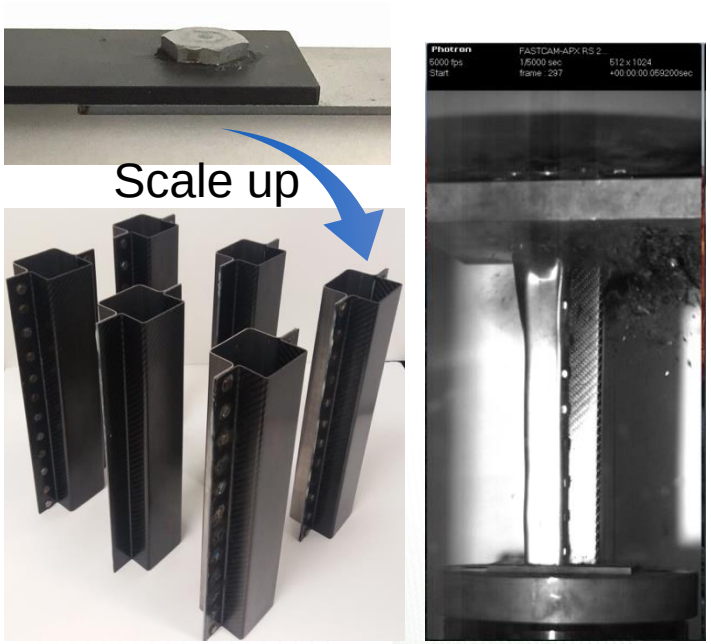
Accomplishment: scale up of FBJ from small coupon to sub-component

- Scale-up of FBJ process from lab coupon to sub-component level
- Achieved superior mechanical joint performance for FBJ of CFRP and AHSS structure



Scale up of FBJ process to sub-component level



Fabrication of sub-component and impact test

Accomplishment: Finalized specification of new FBJ machine for body assembly cell

Content	Requirement
Machine type	C type or stationary type
Welding force	27 kN
Rotation speed	4000 ~ 6000 rpm
Z axis	250 mm
C-frame throat	550 mm
Gantry system	
X-axis	650 mm
Y-axis	800 mm
Z-axis	250 mm

- Considerations of assembly plan for joining of demonstration parts
  - Stationary FBJ + moving demonstration parts by robot
  - Stationary FBJ + moving demonstration parts by gantry system
  - Moving FBJ by robot + stationary demonstration parts

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Accomplishment: Identifying demonstration parts (CFRP-AHSS)

- Different options of demonstration parts composed of CFRP and AHSS from project team (HATCI)
  1. Rear package tray
  2. Seat cross member at central floor
  3. Roof top
- Demonstration parts will be finalized after reviewing with entire project team by considering project time and cost

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Responses to Previous Year Reviewer's Comments

- This project is a new start

Collaboration and Coordination

- Monthly conference calls and biannual face-to-face all hands meeting
- *CRADA* partners with significant cost share
  - Hyundai America Technical Center Inc: OEM automotive manufacturer
    - Provide functional performance targets and assessment support for automotive structural applications
    - Determine material systems, and candidate parts/structures.
    - Perform relevant corrosion experiment
  - Eagle Bend Manufacturing: Tier 1 assembly plant
    - Integrate assembly welding system and demonstrate joining of prototype parts
  - 3M: Adhesive company
    - Provide structural adhesive and technical guidance to investigate mechanical joint performance, corrosion protection and thermal distortion management

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Remaining Challenges and Barriers

- There is a gap between laboratory scale and automotive production environment for FBJ process; for example, single joint in small coupon vs. multiple joints in scale-up coupon, requiring further refinement of FBJ process
- There are unknowns such as corrosion resistance and distortion for scale-up coupons
- Commercialization plan needs to be finalized

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Proposed Future Research

- Refinement of design and build a near production ready FBJ machine
- Integration of FBJ machine into a prototype assembly fabrication cell at our project team facility with fixtures and part moving and handling system
- Refinement of FBJ technology for the selected target material combination
- Scale-up FBJ with multiple joint using prototype welding cell
- Assembly of demonstration parts developed by project team in the prototype FBJ assembly cell
- Test of assembled demonstration parts for project demonstration and validation

Any proposed future work is subject to change based on funding levels

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Summary

- **Relevance:** To scale up and validate an innovative dissimilar material joining method (FBJ) to assemble prototype auto-body components made of AHSS and CFRP in automotive production environment at an automotive Tier 1 assembly plant
- **Approach:** Scale up the FBJ machine and build a welding cell for joining of demonstration parts (AHSS and CFRP)
- **Collaborations:** Hyundai America Technical Center, Inc., Eagle Bend Manufacturing, 3M
- **Technical Accomplishments:**
  - Achieved excellent mechanical joint performance for small coupon and sub-component level
  - Identified required specification for new welding machine
  - Identified demonstration parts
- **Future Work:**
  - Refinement and build new FBJ machine
  - Integration of new FBJ machine into prototype assemble line with fixtures and part handling system
  - Refinement and scale-up of FBJ process using prototype welding cell
  - Joining of demonstration parts in prototype welding and testing it for project validation

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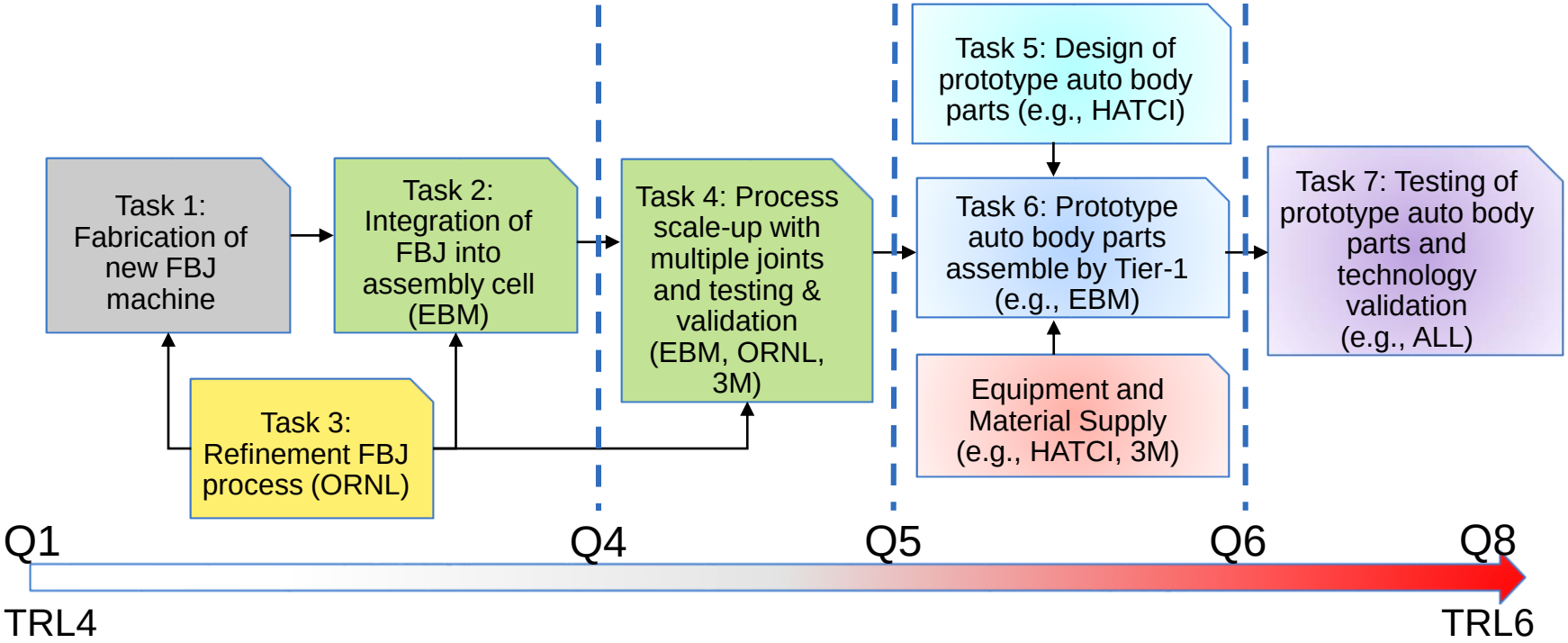
Technical Back-Up Slides

Approach


Task 1: Fabrication of new FBJ machine
Task 2: Integration of FBJ into assembly cell (EBM)
Task 3: Refinement FBJ process (ORNL)
Task 4: Process scale-up with multiple joints and testing & validation (EBM, ORNL, 3M)
Task 5: Design of prototype auto body parts (e.g., HATCI)
Task 6: Prototype auto body parts assemble by Tier-1 (e.g., EBM)
Equipment and Material Supply (e.g., HATCI, 3M)
Task 7: Testing of prototype auto body parts and technology validation (e.g., ALL)
Q1
Q4
Q5
Q6
Q8
TRL4
TRL6