



Advancing Manufacturing of Sustainable Multi-Material Composite Structures for Space Applications Via Ultrasonic Welding

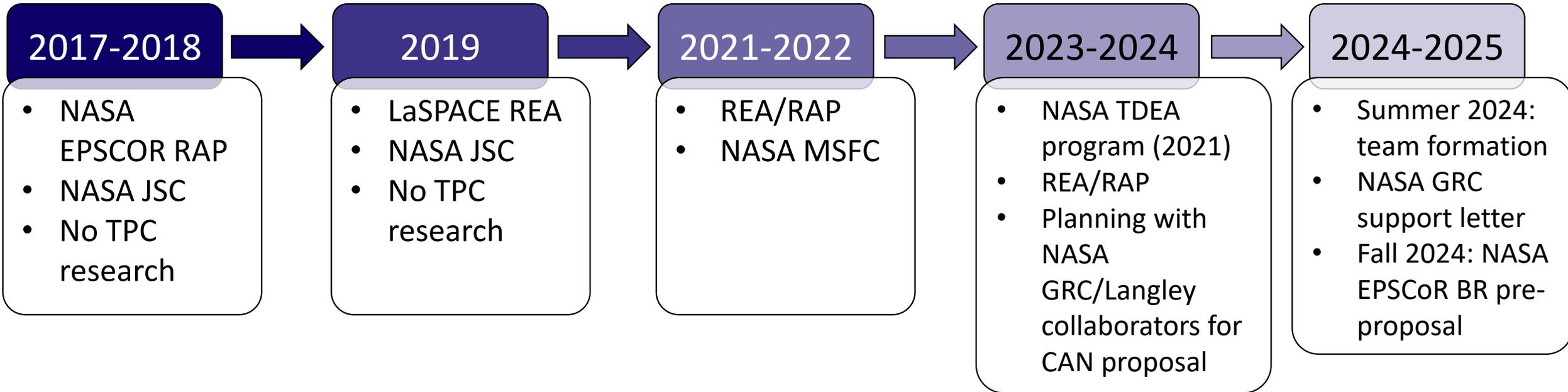
NASA EPSCoR Basic Research (2025-2028)

LaSPACE Meeting, November 8, 2025



Background and Timeline

NASA EPSCoR BR RFP



TPC: Thermoplastic composite

JSC: Johnson Space Center

MSFC: Marshall Space Flight Center

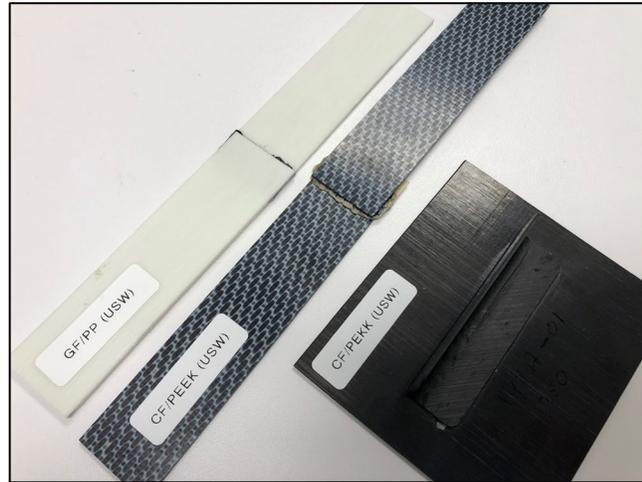
GRC: Glenn Research Center

Background and Motivation

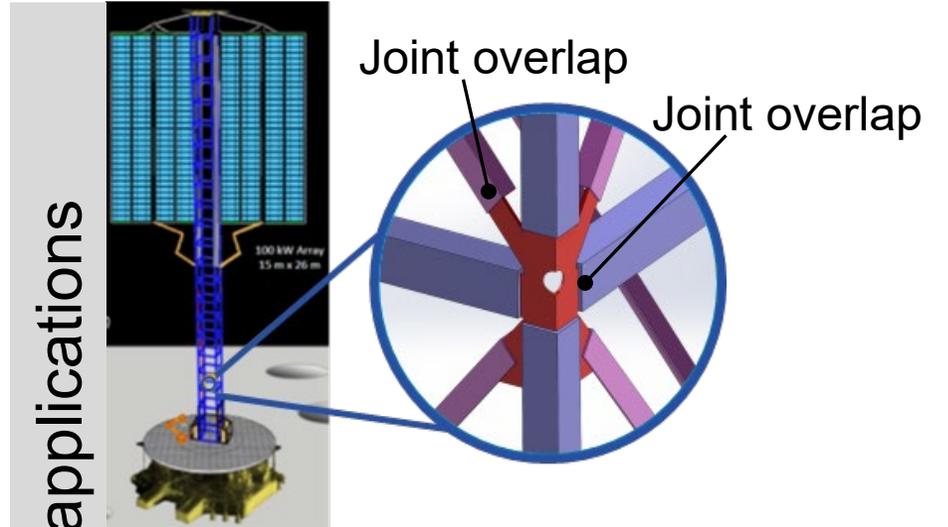
Spot welding and continuous welding applications for TPCs



Clean Sky Eco-Design TPC airframe demonstrator (2014 - present)

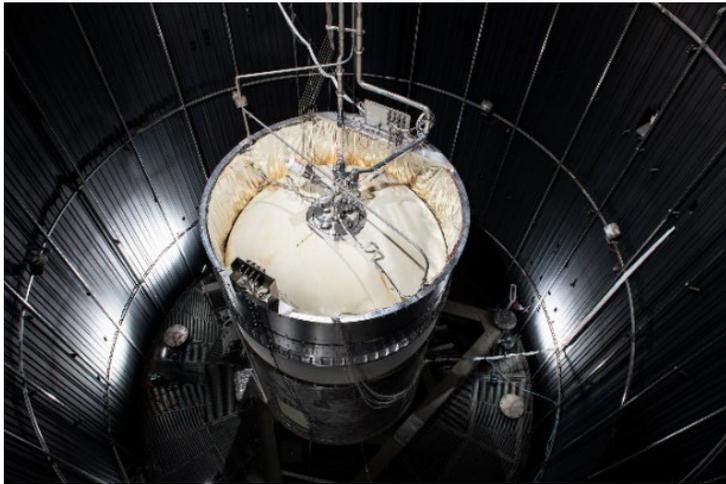
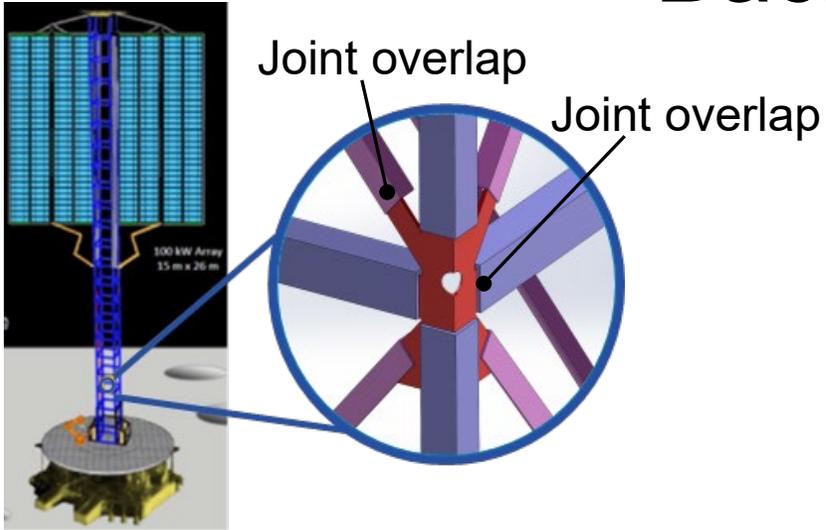


Single lap joints and welded clip made from TPCs

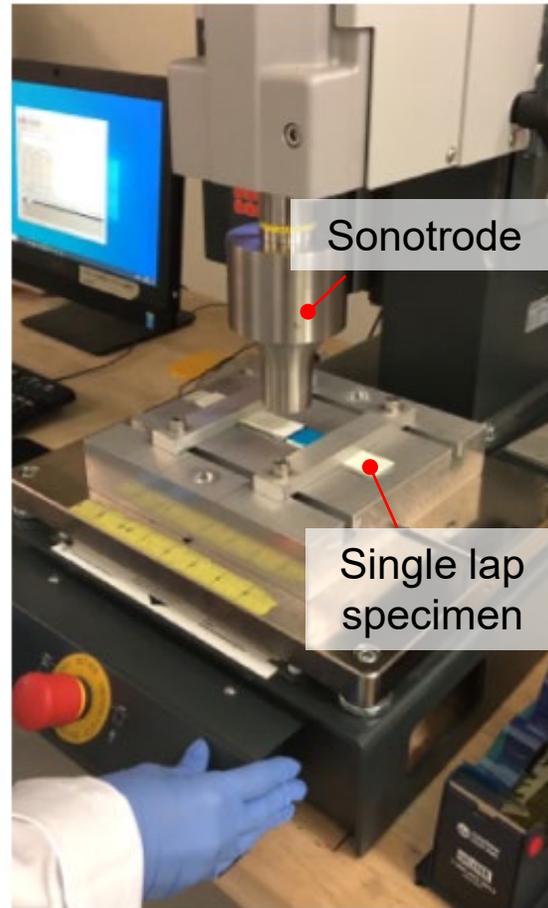


Applications for composite materials joints: e.g., lunar tower, cryogenic tank (NASA)

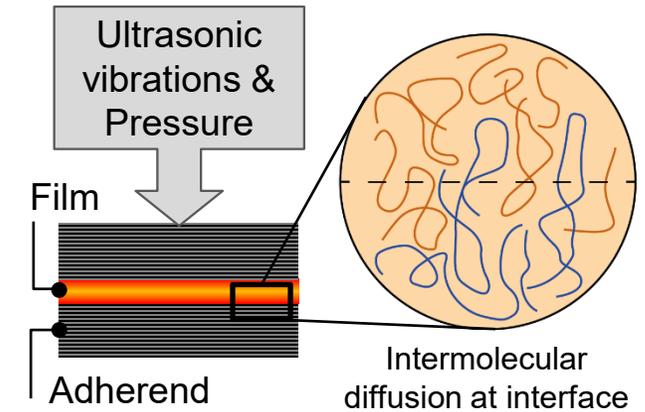
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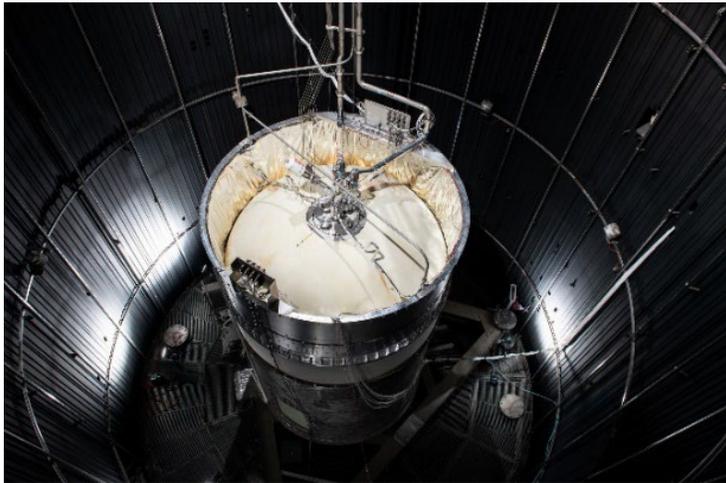
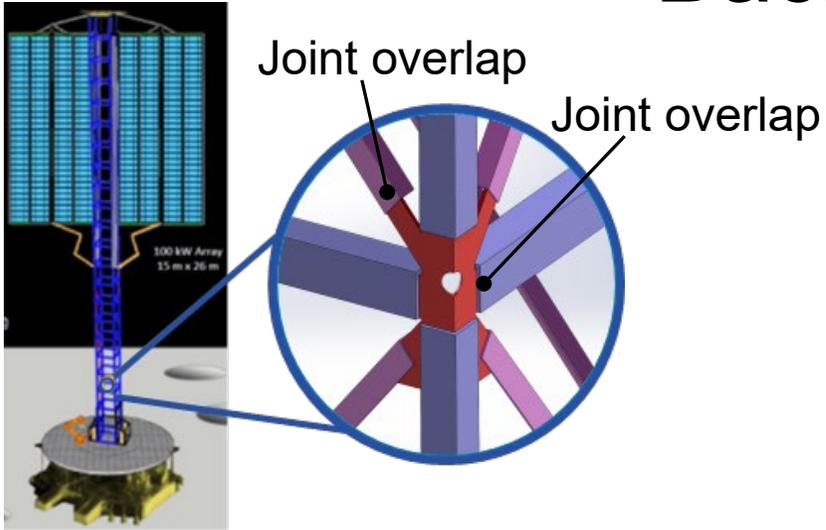
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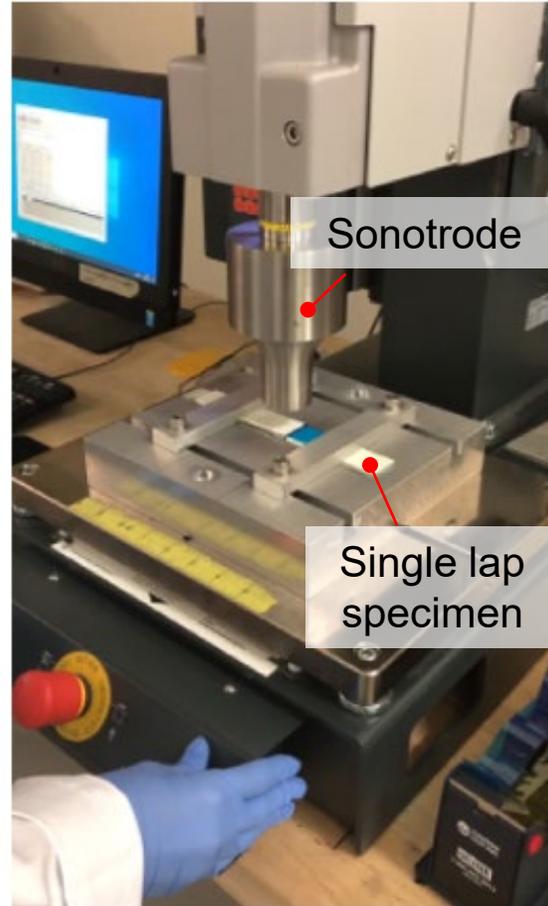
Ultrasonic welding for
thermoplastic composites
and vitrimers



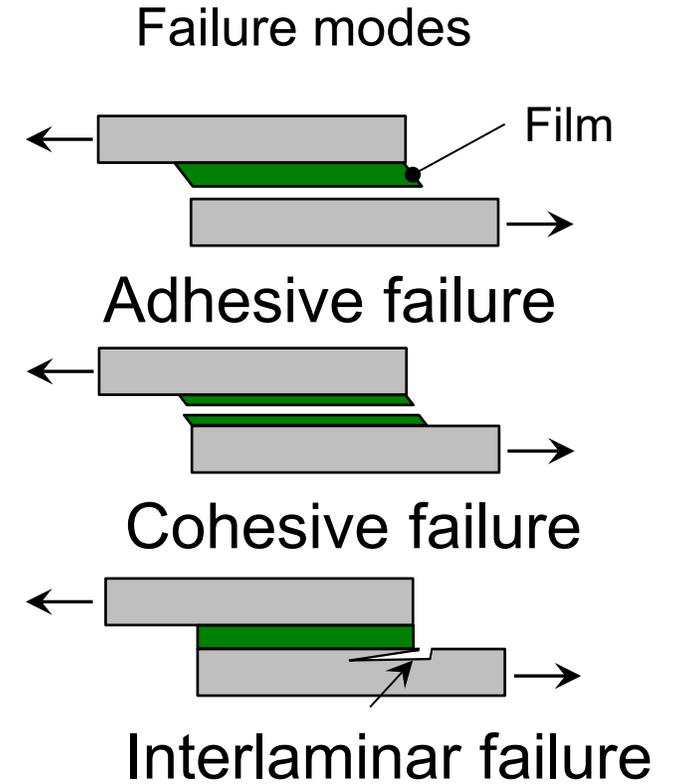
Background and Motivation



Applications for composite materials joints:
e.g., lunar tower, cryogenic tank (NASA)



Ultrasonic welding for
thermoplastic composites
(TPCs) and vitrimers



USW and dissimilar materials:

- Fast assembly
- Repair/disassembly
- Tailoring fracture behavior/strength with film material

Team Introduction

Science-I

Manage science activities



G. Palardy, LSU
Institution Lead
Tasks 1.2, 3.1, 3.2,
4.1, 4.2

Co-Is and responsibilities



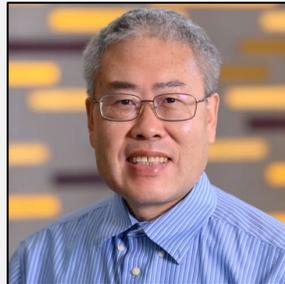
A. Peters, LaTech
Institution Lead
Tasks 1.1, 2.2



C. Wick, LaTech
Institution Co-Lead
Tasks 1.1, 2.2



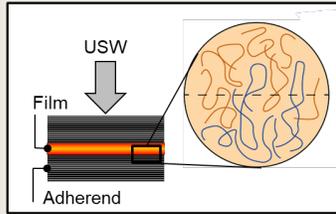
C. Yan, SUBR
Institution Lead
Task 2.1



G. Li, LSU
Institution Co-Lead
Tasks 2.3, 3.1, 3.2,
4.1, 4.2

Research Objectives

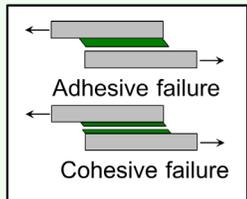
Objective 1: Dissimilar materials welding for TP



1.1 Computational simulations

1.2 Bonding strength and USW

Objective 3: Weld repair and reassembly

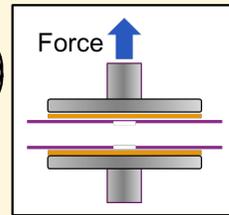
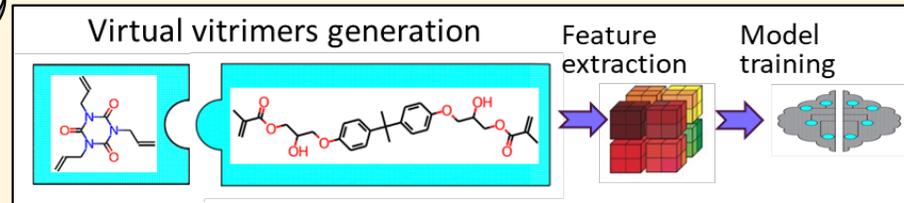


3.1 Reassembly procedures

3.2 In-situ repair strategies

Objective 2: Vitrimer design and welding

2.1 ML-assisted vitrimer design for USW



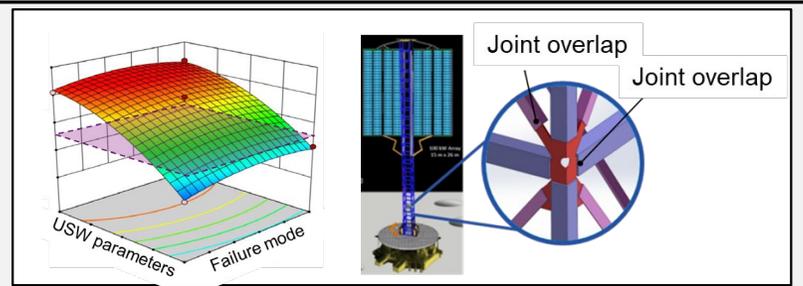
2.2 Vitrimer screening for compatibility

2.3 Bonding and USW validation

Objective 4: Material selection and demonstration

4.1 Material-processing-performance maps

4.2 Application to space structure (e.g., lunar truss)



Collaborative proposals, publications, education, and outreach

Planned Schedule

| Tasks | Y1 | | | | Y2 | | | | Y3 | | | |
|--------------------------------------|----|----|----|----|----|----|----|----|----|-----|-----|-----|
| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 |
| 1.1 Bonding/welding simulations | | | M1 | | | | | M2 | | | | |
| 1.2 Bonding/welding characterization | | | | | M3 | | | | M4 | | | |
| 2.1 Vitrimer formulations ML design | | | | M1 | | M3 | | M1 | | | | |
| 2.2 Material screening simulations | | | | | | M2 | | | | M2 | | |
| 2.3 Vitrimer welding experiments | | | | | | | | M4 | | | | M5 |
| 3.1 Reassembly procedures | | | | M1 | | | | | M2 | | | |
| 3.2 In-situ repair experiments | | | | | | | | | | M3 | | |
| 4.1 Material/processing/performance | | | | | | | | | M1 | | | |
| 4.2 Demonstration on space structure | | | | | | | | | | M2 | | M3 |

- ✓ M1.1 – Characterize concentration gradient and diffusion rates for various materials and process parameters (temperature, pressure);
- ✓ M2.1 – Discover vitrimer formulations meeting USW requirements;
- ✓ M3.1 – Obtain stress-strain curves and LSS for disassembled welds.

Year-1 Research Tasks

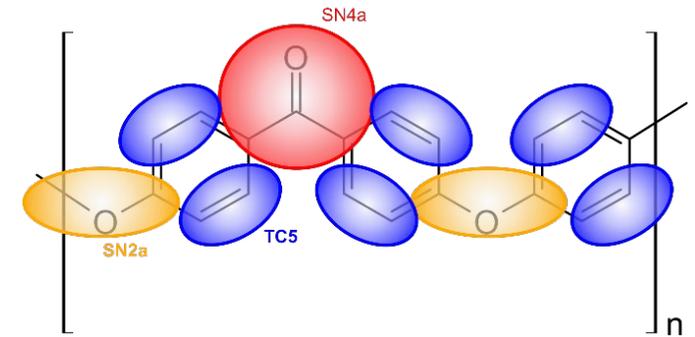
1. Dissimilar materials welding with TPs

1.1 Study intermolecular diffusion, healing, and bonding mechanisms in dissimilar materials via computational simulations (Peters, Wick)

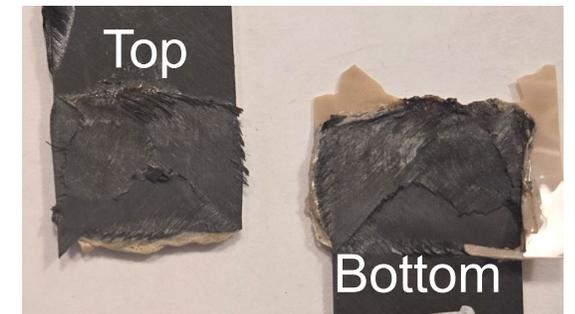
1.2 Experimental assessment of bonding quality via rheological and mechanical tests (Palardy)

Materials considered:

- CF/PEEK (polyether ether ketone) adherends with different thermoplastic films
- Adherends/film combinations:
 - PEEK to PEEK
 - PEEK to PEI (polyether imide)
 - PEEK to PPS (polyphenylene sulfide)
 - PEEK to LM-PAEK (low-melt polyaryl ether ketone)



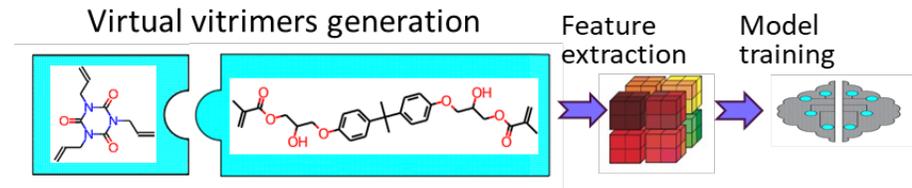
Potential coarse-grained model for PEEK based on the MARTINI 3 model.



Fracture surface for CF/PEEK to PEEK lap joints.

Year-1 Research Tasks

1. Dissimilar materials welding with TPs
2. Vitrimer design and welding
 - 2.1 Design vitrimer formulations tailored to the ultrasonic welding process and bonding compatibility with dissimilar materials (Yan)
 - 2.2 Screen vitrimer formulations for bonding compatibility (Peters, Wick)
 - 2.3 Experimentally validate vitrimer formulations for bonding and USW compatibility (Li, Palardy)



Start with available vitrimers to:

- Run USW trials with vitrimers (identify issues, range of process parameters):
 - Vitrimer to vitrimer composites
 - CF/PEEK to vitrimer
- Establish reference/baseline joining procedures

Education and Outreach

- Demonstrations and presentations to share project's advancements at all three campuses (e.g., ENGage LSU, SUBR STEM days).
- Capstone Design project at LSU to further involve undergraduate students (e.g., design of welding or testing fixture for larger components, such as stiffener configurations)
- LSU SAMPE student chapter to involve students from all 3 campuses (organizes tours at NASA research centers and composites-related companies, opportunities to attend SAMPE conference, etc)
 - SAMPE: Society for the Advancement of Material and Process Engineering

Acknowledgments

