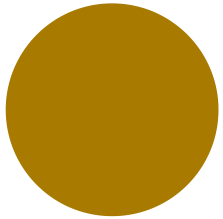


Agenda

- **Research Team**
- **Research Questions**
- **Research Process Overview**
- **Literature Review**
- **Industry Engagement**
- **Key Findings**
- **Future Research Areas**

Introduction

- **ASSURE A53** – Advanced Materials and Processes Survey for AAM and UAS Aircraft
- **Lead Principal Investigator**: Gerardo Olivares, NIAR AVET
- **ASSURE Researchers**
    - **NIAR AVET**: Luis Gomez, Aswini Kona Ravi, Akhil Bhasin
    - **MSU ACI**: Christopher Bounds (Co-PI), Wayne Huberty, Matthew Roberson
- **Other FAA Personnel** – Katie Constant-coup, Hector Rea & L Q G \ $ V K I R U W
- **Industry Partnerships/Other Collaborations** – Raw material suppliers, Original Equipment Manufacturers (OEMs), tier one suppliers, Subject Matter Experts (SMEs).

Research Questions

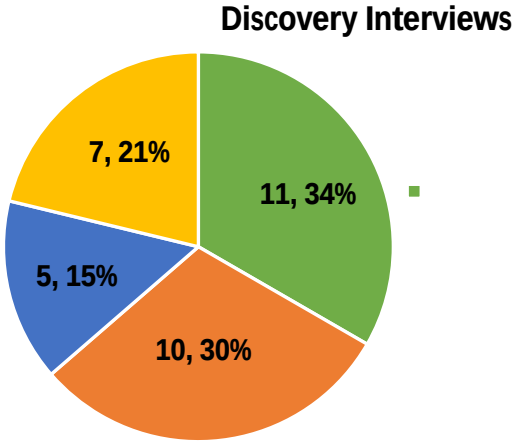
Research Question #1 **Are there any new or unique composite or other advanced materials used in AAM and UAS vehicles that are not in use in traditional aircraft or rotorcraft?**

- Identify all the composite and other advanced material systems.
- Identify all the advanced manufacturing applications.
- Includes all the primary, secondary structural and non-structural applications.

Research Question #2 **Are there any new or unique applications of existing composite materials?**

- To analyze materials intended for traditional aircraft applications to AAM and UAS vehicles.
- Document if the following advanced materials are in use:

Research Process Overview



AAM Literature Review – Research Question #1

A53 – Advanced Materials and Processes Survey for AAM and UAS Aircraft

Literature Review (AAM) – RQ#1

Joby Aviation

- **Carbon fiber thermoset prepregs**
- **Automated Fiber Placement (AFP)**
-


Joint

Literature Review (AAM) – RQ#1

Presented below are some of the high-rate applicable advanced materials and processes suitable to the AAM industry:

- **Faster curing prepregs – Hexcel [ACMA AAM Composite Technology Days (21)]:**
  - Reducing cure time of well-established primary structure prepregs.
  - Improving performance of industrial grade fast curing prepregs.
  - Studies on 8552 system for 10-25% shorter cure times
    - Compression molding – 30 mins with similar mechanical performance as autoclave.
- **Hybrid prepreg – molding compound [ACMA AAM Composite Technology Days (21)]:**
  - Co-molding, co-curing of continuous fiber reinforced prepreg and molding compound.
  - Specifically designed for compression molding processes.
  - Phenolic, snap cure phenolic, vinyl ester resin38 0 Td [(s)-2 (nw26 -2 (om)-6 (pr)-5.9 (es)-2 (s)-2 7.4 (in)-3.2 (s)]TJ -0.)Tj 0 Td (6g

Literature Review (AAM) – RQ#1

Presented below are the research programs focused on the design and development of <u>propellers</u> for the AAM industry:

- **Smart rotors [23]:**
  - Ultra-efficient propeller and rotor blades specific to hybrid and electric aircraft and drones.
  - Development of technologies such as automated preforming with dry fibers.
- **Braided thermoplastic propellers [24]:**
  - Triaxial braiding for complex geometry structures such as propellers.
  - Novel manufacturing process that combines bladder molding with commingled thermoplastic and carbon fiber reinforcements.
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Joint

AAM Industry Survey [Material Suppliers] – RQ#1

Identify all the composite and other advanced material systems, manufacturing processes and their applications.

- Legacy, certified, aerospace-grade composite material systems - primary & secondary structural applications.
  - Qualified materials in public material databases.
  - Most companies want to be first to market.
- Change in material selection when the market evolves and matures into high production rates.
  - Most aircraft OEMs are opting for thermosets to begin with and plan on switching to high production rate materials and processes.
- High-rate applicable materials – snap cure thermosets, thermoplastics.
- Manufacturing processes: Autoclave cure, out-of-autoclave processes, resin infusion processes, snap cure processes, automated fiber placement, automated tape laying, compression molding, injection molding, stamp forming, thermoset press cure, rapid clave.

AAM Industry Survey [Tier One Suppliers] – RQ#1

Identify all the composite and other advanced material systems, manufacturing processes and their applications.

- Many aspects discussed in the previous two sections with the interview results from material suppliers and OEMs were repeated by the tier-one suppliers.
- Most companies are currently using standard thermoset prepreg materials.
  - This is expected to shift to thermoplastics, fast curing thermosets.
- Continuous fiber thermoplastics would be of interest due to their high performance and toughness.
  - Combination of processes – continuous fiber with over molding of short fiber composites.

AAM Industry Survey [Subject Matter Experts] – RQ#1

Identify all the composite and other advanced material systems, manufacturing processes and their applications.

- The interviews with the SMEs contained some of the key points discussed in the previous sections, such as high-production rate-related issues and the need for more qualified high-rate applicable materials such as thermoplastics, snap cure thermosets.
- The materials and processes might not be very unique or different from the traditional aerospace industry, but industrialization might be one of the key differences.
  - Legacy process systems are labor dependent. Push for automation with minimal touch labor and faster, efficient processes.
  - In-process checks to monitor product quality along the manufacturing stages.


Joint

UAS Industry Survey – Research Question #1

A53 – Advanced Materials and Processes Survey for AAM and UAS Aircraft

AAM Literature Review – Research Question #2

A53 – Advanced Materials and Processes Survey for AAM and UAS Aircraft

Research Question #2

Literature Review [AAM] – RQ#2

Literature Review [AAM] – RQ#2

Presented below are the bonding applications suitable to the AAM industry:

- **FusePly™ [34][35]:** epoxy-based film that is designed to co-cure with a prepreg and create a chemically active surface.
  - Combination of co-cure bonding and secondary bonding methodologies.
  - End product - Bonded structures joined by chemical bonds.
- **AeroPaste® [34]:** structural paste adhesives.
  - Room to high temperature


Joint

Industry Survey [AAM/sUAS - OEMs] – RQ#2

Novel

Research Question #2

Are there any material characteristics that are uniquely critical for UAS and AAM vehicles that are not included in material databases for traditional aviation applications?

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Key Findings – AAM

Advanced Air Mobility Industry

- Advanced material systems in use and planned to be in use –
  - Thermoset material systems (Solvay® MTM45-1, Cycom® 5320-1).
  - Snap cure resins.
  - Thermoplastic material systems.
- Fabrication processes in use and planned to be in use in AAM –
  - Hand layup, autoclave cure, AFP, ATL.
  - RTM, VARTM.
  - AM.
  - CCM, stamp forming, overmolding.
- Applications of existing traditional aviation material systems for short-term programs. The material selection and manufacturing techniques may change once production rates increase.
- Joining methods: limited fasteners, secondary bonding for thermosets, and welding for thermoplastics.
- Repair & inspection criteria: similar to traditional aviation; inspection frequency could be higher.

Key Findings – UAS

Small Unmanned Aircraft Systems (under 55 lbs 14 CFR 107)

- Advanced material systems in use and planned t.9(c)-2.7 (d0.6 (c)-5.2)-0.6 (pl)-1. /Cao8pQ9.3 2 ( )8.5 (i)-1

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