**Problem Statement**

- Objective: Investigate morphing panels for improved aerodynamic performance at high vehicle speeds (150+ mph)
- Methodology:
  - Identify vehicle body shapes for aerodynamic drag reduction and examine smart material technologies to create appropriate shape changes
  - Propose shape morphing body concepts to reduce overall aerodynamic drag
  - Develop models and laboratory demonstrations to test the selected approaches and provide a basis for future development

**Background**

- There is growing interest in the use of morphing materials in both land and air vehicle applications to enhance aerodynamic performance
- Morphing vehicle structures must be lightweight and durable over a wide range of operating conditions
- Morphing panels can be used to improve aerodynamic performance by reducing drag and generating downforce at high speeds
- A variety of smart materials, composites, and devices can be used to create morphing structures for different applications

**UAM Active Hinge with SMA Ribbons**

- UAM active hinge concept using SMA ribbons
  - SMAs embedded in Al matrix are trained in a 180 degree folded shape for shape memory effect by heating shape set temperature of around 500 °C for 25 min and quenching in cold water
  - By applying electrical current through the two Al plates, SMAs actuate to fold the plate when heated above the transformation temperature
- 2.25"x4.5" active hinge panels with nine embedded SMA ribbons

The panels are activated by ~23 A drawn from the battery. If the SMA wires are electrically isolated and connected in series, activation current will be reduced to less than 1 A.

**Actuator Technologies and Morphing Panel Concepts**

- Actuator technologies
  - Short-term: Torsional SMAs
    - Objective: Develop welding methods for joining NiTi alloys to common structural materials and enhance thermal dynamic response
  - Mid-term: Electro-hydraulic actuators driven by smart materials
    - Objective: Develop lightweight and small scale electro-hydraulic actuators driven by smart materials such as magnetostrictive or piezoelectric materials in order to actuate UAM panels
  - Long-term: Shape memory polymer composites
    - Objective: Develop morphing shape memory polymer (SMP) composites with shape fixity and shape recovery
- Morphing panel concepts
  - UAM panels and hinges
    - Objective: Develop morphing panels and hinges by joining dissimilar materials, smart materials, polymers, or electronics
  - UAM origami structure
    - Objective: Develop morphing structure by joining multiple UAM panels with integral smart hinges

**Active Hinge with SMA Torque Tube**

- Shape memory alloy torque tube hinge concept
  - Both ends of 6" SMA tube are welded to 2.5" 304 stainless steel (with Ni filler) by orbital TIG welding
  - Applied 222 in-lb torque (Critical finish torque of TIG weld: 201 in-lb)
- Thermal dynamic response can be enhanced by using a cartridge heater with larger diameter and filling the tube with a highly conductive material

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