ARMD Transformative Aeronautics Concepts Program

CONVERGENT AERONAUTICS SOLUTIONS PROJECT

Spanwise Adaptive Wing

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Enabling Reconfigurable Aircraft Through The **Spanwise Adaptive Wing (SAW)** Concept

- Increasing aircraft efficiency by reducing the rudder through the incorporation of SAW
- Articulating the outboard portions of the wing via Shape Memory actuation
- Lateral-directional stability and control augmentation
- Supersonic - Increased compression lift and reduced wave drag
  - Enabler for supersonic flying wing design
SAW Development Path

Flight test

Ground test

CAS Objective: to develop all of the sub-systems for full scale infusion

- Technology and tool development and validation
- Scale-up validation
- A plan for the next a larger demonstration in a more relevant environment
Reconfigurable Aircraft

Morphing Aircraft

Folding wing aircraft

Historical Perspective

F-111 Mission Adaptable Wing

Adaptive Compliant Trailing Edge

Flexsys Flex Foil™

XB-70 Valkyrie
Ground Folding
A New Way to Actuate

• Shape Memory Alloy (SMA)
  – NiTiHf
    ➢ Alloys that have a “memory.” These materials have the ability to remember and recover their original shapes with load or temperature.
    ➢ SMAs exhibit a solid-to-solid, reversible phase transformation
    ➢ Can be **ALL-Electric** driven
Current State-of-the-Art **Rotary Actuators**

**Assessment of Current Technology - With ARMD Thrusts in Mind**

Current Technologies (hydraulic, pneumatic, or magnetic motors) do not provide a step-change towards “Big Leaps” in efficiency & environmental performance

- Heavy, and bulky – other options include gear boxes – large systems
- With SMA technology: **20%** the weight & **15%** the size of comparable hydraulic system

<table>
<thead>
<tr>
<th>SMA Actuator</th>
<th>Model # CAS2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>~450 in³</td>
</tr>
<tr>
<td>Weight</td>
<td>~58.5 lbs</td>
</tr>
<tr>
<td>Temperatures</td>
<td>tunable based on alloy used</td>
</tr>
<tr>
<td>Torque</td>
<td>~ 100,000 in-lbs</td>
</tr>
<tr>
<td>Angle</td>
<td>~ 90 deg</td>
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</tbody>
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Non-traditional – Revolutionary – Transformative
Flight testing out of the box ideas

PTERA

Prototype-Technology Evaluation and Research Aircraft

• Roughly based on an 11%-scale 737
• Baseline configuration has an 11.3ft span, 12ft length, and 4.3ft height
• ~200lb gross takeoff weight (40lb payload)
• Powered by two JetCat P200 turbojet engines (50 lbs thrust each)
• Flown 13 times (SysID, performance evals)
Flight Test Experiment

Trade space evaluation

Aero analysis

Hinge Loads

Actuator Loads

Actuator Design

Baseline Values

Design Space Explored

Wing and Joint Design

For the PTERA demonstration SAW produces nearly 40% of total rudder authority. Can this be used to reduce rudder size?
Flight Test

• Two flight campaigns on Edwards Air Force Base dry lakebed
• First flight late October/Early November 2017
WORKING TOWARD FULL SCALE
NiTiHf Alloy Processed in Large Scale

• **60lbs of NiTi-20Hf material were melted**
  – Melting process scalable from 1 lbs to >100 lbs
  – Repeatable properties (for lab verification, actuator back ups, and future flights.

• **Extrusion to rod and tubing**
  – From 4” to 0.5” in diameter and from 1.2” to 0.5” in diameter reduction

• **Tubes drilled and splined**
  – Final form of actuator before training and instrumentation.
Ground Test: Large tube testing underway

- 1” tube
- 10” long

- 20,000 in-lbf test rig
- Fully instrumented for SMA large tube testing
3 Mechanisms for Ground Test

- Use 0.5” and 1” tubes
- Target for 90 degrees of rotation
- 5000 in-lbf torque
- Explore locking features
F-18 Demonstration?

Figure 1: View of the analyzed SAW F-18 geometry (-70 deg wing deflection)

Figure 2: Percentage changes in lift coefficient for different wing deflections, from Cart3D
Fin