ARMD Transformative Aeronautics Concepts Program

CONVERGENT AERONAUTICS SOLUTIONS PROJECT

Spanwise Adaptive Wing

Matthew Moholt
NASA AFRC

Dr. Othmane Benafan
NASA GRC

September 19-20, 2017
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

F-111 Mission Adaptable Wing

Historical Perspective

Morphing Aircraft

Folding wing aircraft

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

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**SMA Actuator**

Model # CAS2016

- Size ~450 in³
- Weight ~58.5 lbs
- Temperatures~ tunable based on alloy used
- Torque ~ 100,000 in-lbs
- Angle ~ 90 deg

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

<table>
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<tr>
<th>Configuration</th>
<th>Sweep Angle (°)</th>
<th>Wing tip Span (in)</th>
<th>C.G. shift (50% of root chord)</th>
<th>Wing tip Yaw Control (0°, 75°, 10°)</th>
<th>Structural Assessment</th>
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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