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# Defense System Perspectives on Multifunctional Design for Actuation

*presented to The 2<sup>nd</sup> Multifunctional  
Materials for Defense Workshop*

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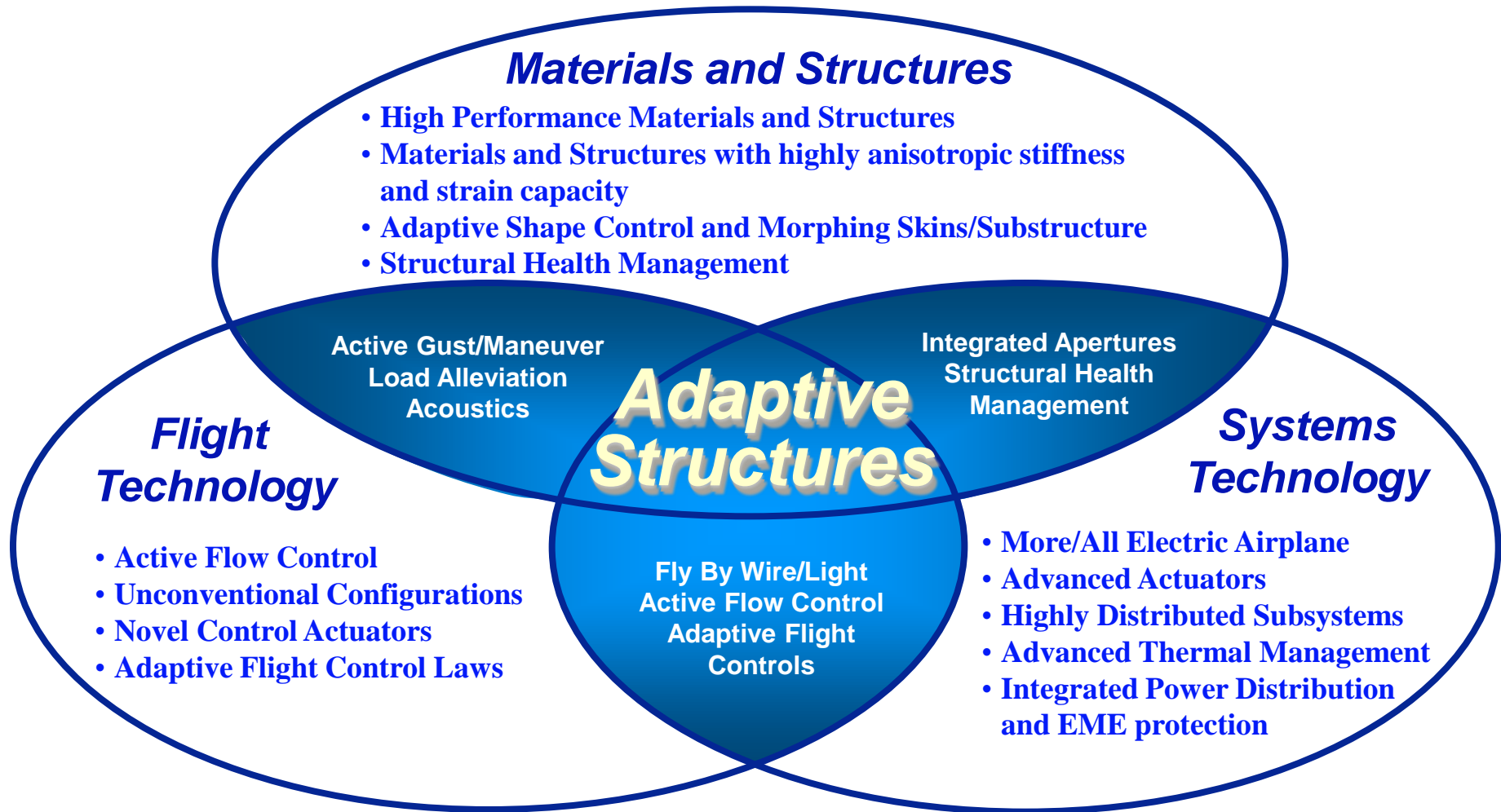
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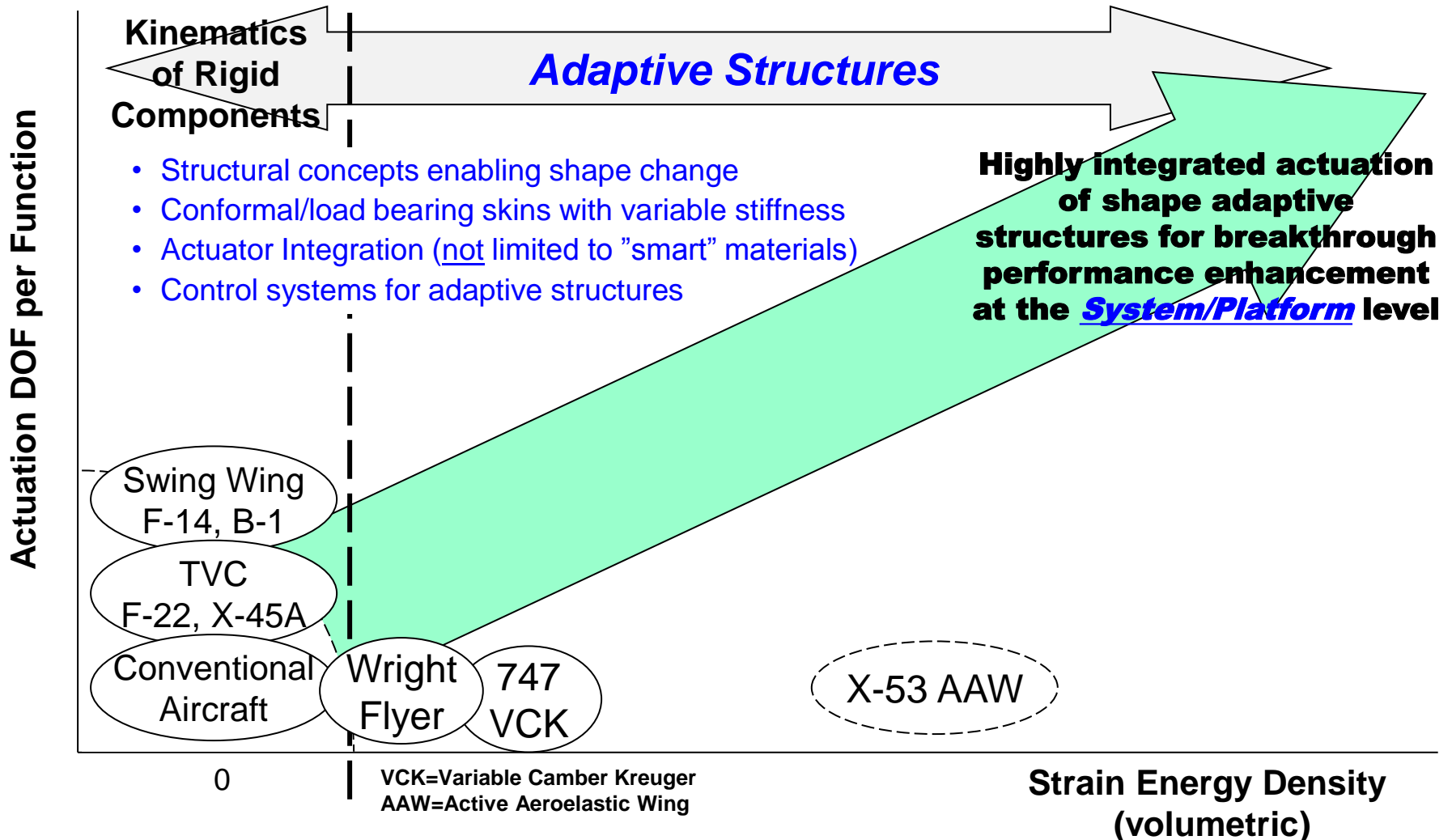
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# Adaptive Structures Need for Multifunctional Systems Design



# Adaptive Structures Design Space



# DARPA SAMPSON Program - Aircraft Inlet Shape Control

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Multifunctional Structures

## Major Program Accomplishments

- ❑ *First full-scale demo of smart materials to provide large forces and displacements*
- ❑ *First integration of SMA rod actuators within compliant skin structure*



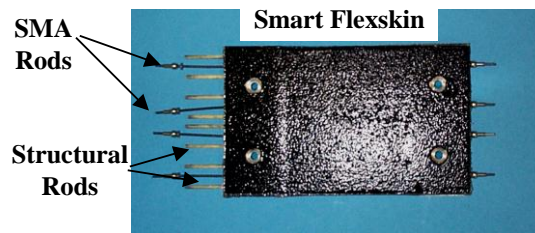
- ❑ Met: *Integrated SMA actuator system into F-15 Inlet cowl*
- ❑ *6000 Lbs Force Demonstrated*
- ❑ *Capable up to 20,000 Lbs*
- ❑ *6 inches Displacement*
- ❑ *Flow speeds up to Mach = 0.8*



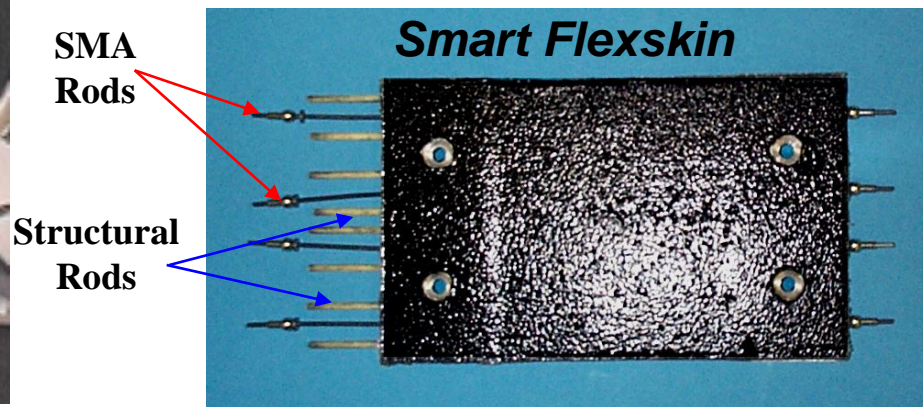
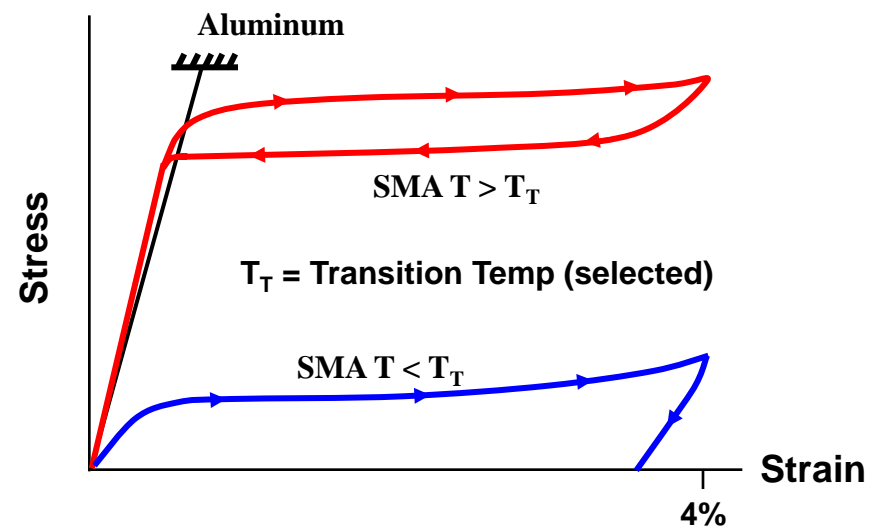
- ❑ Met: *Integrated SMA actuators into smart flexskin to drive leading edge flap*
- ❑ *LE deflection > 20 degrees*
- ❑ *Flow speeds up to Mach = 0.8*



SAMPSON = Smart Aircraft and Marine Projects System Demonstration  
SMA = Shape Memory Alloy



# Leading Edge Flap Integrated Actuation by Shape Memory Alloy (SMA)



# Three Key Technology Developments are Needed

- 1. Compact, highly weight efficient variable geometry primary load paths**
  - Highly anisotropic structural properties
  - Not just materials, novel structural architectures at all scales
- 2. Skins to provide fairings and gap closeouts to support the variable geometry**
- 3. Highly integrated, multi-degree of freedom actuators**
  - High energy/power density and high efficiency
  - Actuators must be controlled and controllable
  - Inherent feedback sensing is highly desirable

# What's Stopping Adaptive Airframes?

- **Solutions based on kinematics of rigid structures are**
  - Usually too heavy (or perceived to be too heavy)
  - Introduce concerns with added complexity, reliability, maintainability
- **A key barrier is the benefits of adaptive airframes accrue at the platform performance level**
  - MDAO can simultaneously optimize aerodynamic and other platform performance along with structural design (for fixed airframe elements)
  - We are limited on our ability to do MDAO with adaptive airframe elements
  - We can create point designs for adaptive airframe solutions, but not within an MDAO environment
  - *Multifunctional Design adds another level of complexity that we must be able to handle*

# And what have I forgotten? Oh yeah...

- **Size, Weight and Power (SWAP)**
- **Safety**
- **Life**
- **Thermal environments**
- **Load environments**
- **Graceful degradation**
- **All those good words ending in “...ility”**
  - **Reliability**
  - **Maintainability**
  - **Certiability**
- **Has it flown?**

- ***Adaptive Structures (applied to large structures) requires technology development in three areas***
  - ***Compact, weight efficient variable geometry load paths***
  - ***Large deformation/load bearing skins/fairings***
  - ***Integrated/Distributed Actuation***
- ***Design of Adaptive Airframes must be performed as part of system level trade studies and optimization***
  - ***The development of tools (particularly objective functions) to do this lags significantly behind the research SOA***
  - ***Multifunctional design is both the savior and the bane of Adaptive Structures***