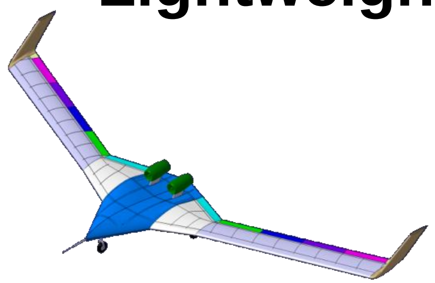
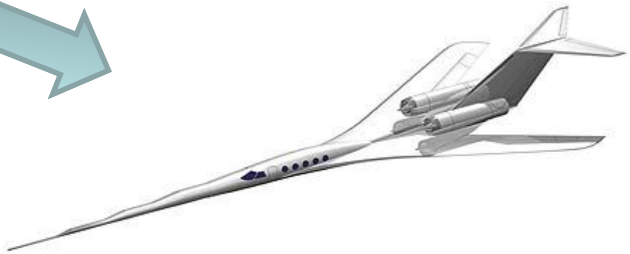
Beyond Rigid Body

Integrated Structural Control of Extremely Lightweight Flexible Aircraft





John T. Bosworth - June 2012

Why?

- Reduced weight is fundamental to aerospace design
- Many years of aerospace development has resulted in extremely efficient lightweight structures
- Advancement now requires a new paradigm
  – Retain strength but allow for reduced stiffness
  – Provide apparent stiffness with integrated active structural control
- Side Benefit: Advancement of full-authority adaptive flight control for realistic full-scale vehicles will not proceed until methods for sensing and accounting for structural limitations are developed

“The Super Hornet, even more than it’s predecessor, has incorporated a number of tradeoffs between flying qualities and keeping structural loads in the box.”

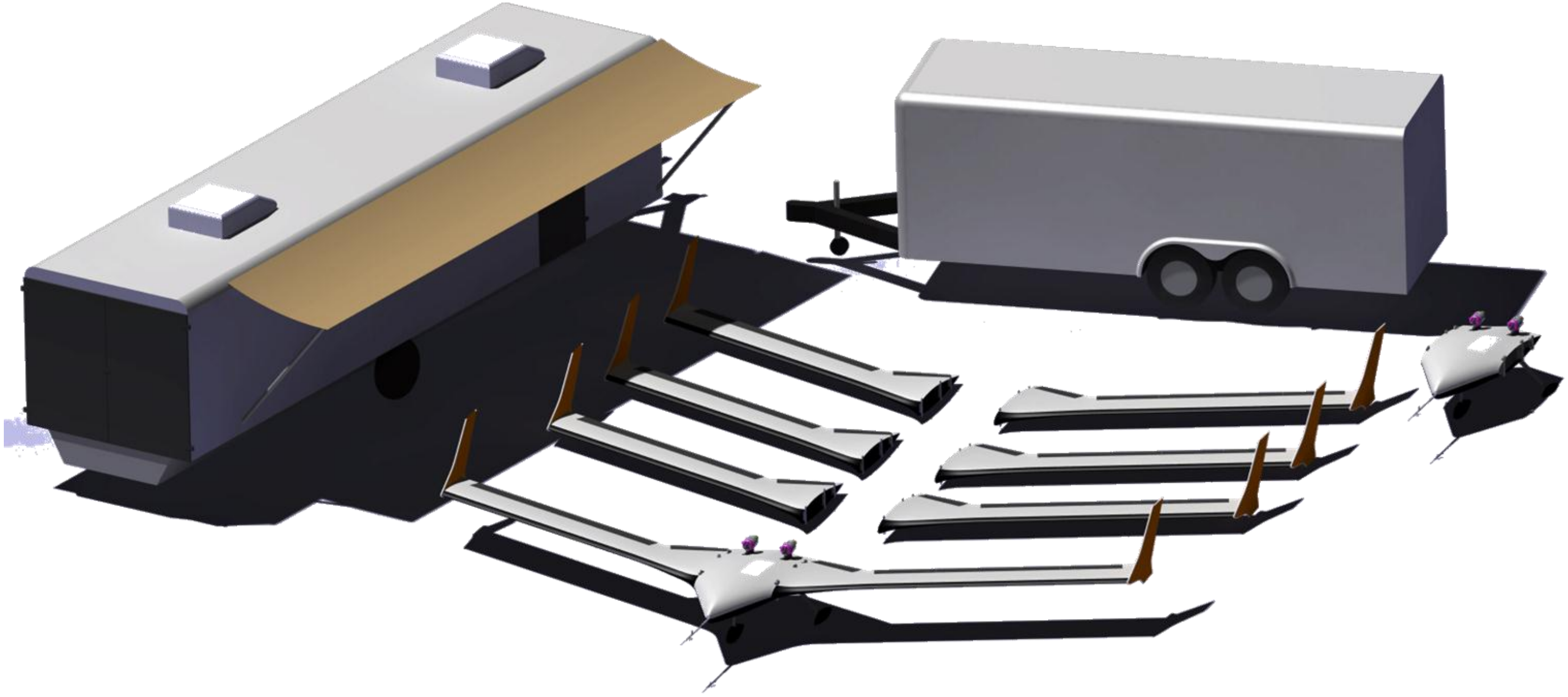
Development Areas

- Modeling
  - Static Structures – large margins, very conservative
  - Dynamics – conservative notch filter designs result in large feedback phase loss
  - MDAO elastically tailored structures
- Sensors
  - Fiber Optic Shape Sensing (FOSS)
  - Fly-by-feel (hot films and beyond)
  - Others …
- Actuation
  - Potentially very high bandwidth requirements
  - Piezoelectric, mems, others …
- Control Algorithms
  - Balance structural shape, structural load, dynamic interaction suppression, with rigid body performance requirements

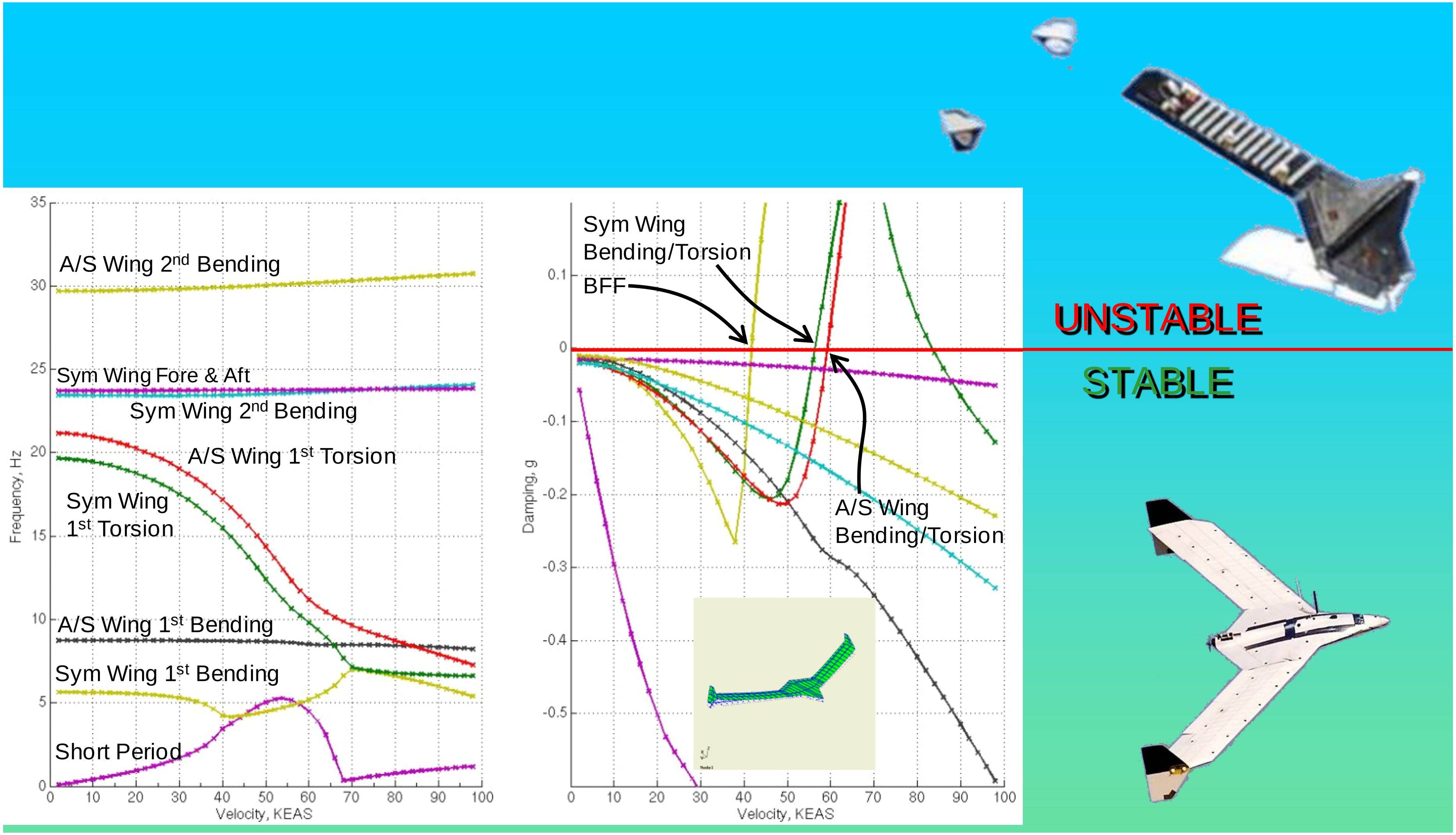
X-56A Multi-Utility Technology Testbed

Multi-utility Aeroelastic Demonstration

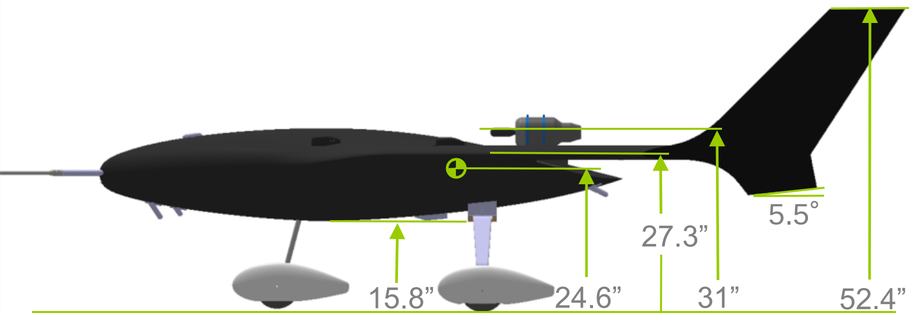
- Complete Research System
  - 2 Center Bodies
  - 1 Stiff Wing Set
  - 3 Flexible Wing Sets
  - 1 Ground Control Station
    - With Simulation and SIL Capabilities



Rigid / Flex Coupling

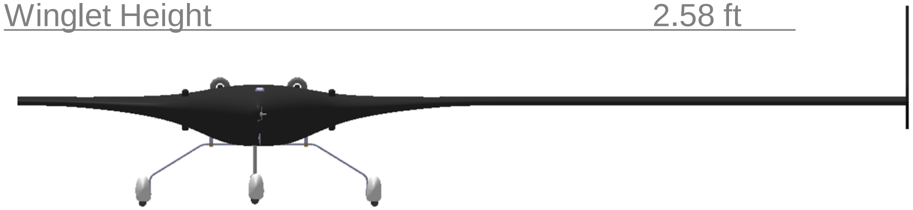


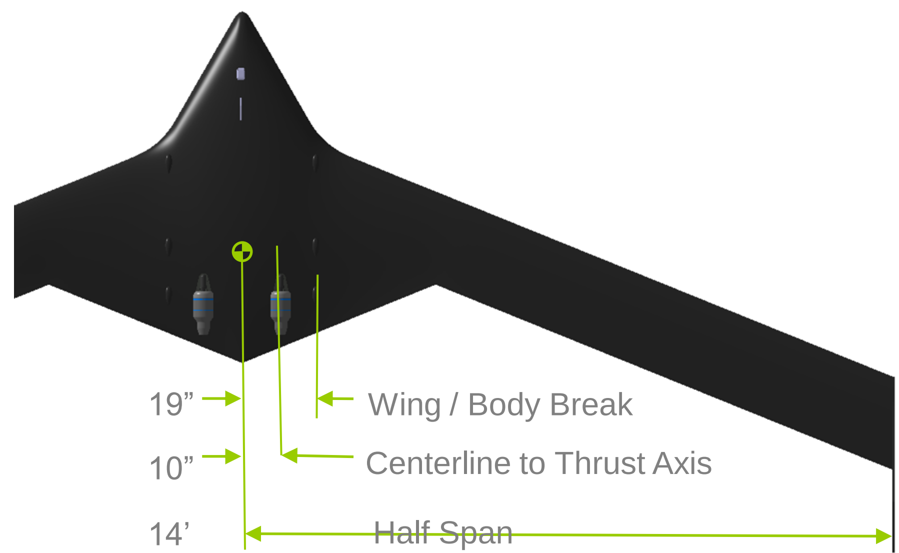
MAD/MUTT X-56A



TOGW	480
lb	
Reference Area	56.0 ft^2
W/S	8.6 lb/ft^2
T/W	0.225
Span	28.0 ft
Aspect Ratio	14.0
Fuselage Length	7.56 ft
Fuselage Depth	1.33 ft
Total Height	4.37 ft
Fuselage Width	3.17 ft
Wetted Area	170.70 ft^2
Fuselage	41.27 ft^2
Wing	113.43 ft^2
Winglet	16.00 ft^2
Wing Leading Edge Sweep	22.00°
Wing Trailing Edge Sweep	22.00°
Fuselage Leading Edge Sweep	60.00°
Fuselage Trailing Edge Sweep	-22.00°

M.A.C.	2.00 ft
Root Chord	4.33 ft
Thickness Ratio	16.5%
Tip Chord	2.00 ft
Thickness Ratio	10.0%
Body Flap Reference Area (Ea)	1.10 ft2
Control Surface Reference Area (Ea)	1.15 ft2
Winglet Reference Area (Ea)	3. 90 ft^2
Winglet Height	2.58 ft





Current Status

Under construction at GFMI in Fountain View CA

First flight planned for August of 2012

After AFRL/Lockheed flights becomes NASA asset

References

Nicolai, L., Hunten, K., Zink, S., and Flick, P., Zink, S., “System Benefits of Active Flutter Suppression for a SensorCraft-Type Vehicle,” AIAA-2010-9349.

Beranek, J., Nicolai, L., Buaonanno, M., Burnett, E., Atkinson, C., Holm-Hansen, B., and Flick, P., “Conceptual Design of a Multi-utility Aeroelastic Demonstrator,” AIAA-2010-9350.

Holm-Hansen, B., Atkinson, C., Beranek, J., Burnett, E., Nicolai, L., and Youssef, H., “Envelope Expansion of a Flexible Flying Wing by Active Flutter Suppression,”

Conclusions

- Integrated structural control will enable breakthroughs
  - New class of extremely lightweight vehicles
  - Advance feasibility of full authority adaptive flight control

- The X-56A MUTT vehicle provides an excellent tool to explore this technology

- NASA has been given a great opportunity for future research