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Paper Title: Status of ERA Airframe Technology Demonstrators

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I. Introduction

NASA has created the Environmentally Responsible Aviation (ERA) Project to explore and document the feasibility, benefits and technical risk of advanced vehicle configurations and enabling technologies that will reduce the impact of aviation on the environment. A critical aspect of this pursuit is the development of a lighter, more robust airframe that will enable the introduction of unconventional aircraft configurations that have higher lift-to-drag ratios, reduced drag, and lower community noise.

The Airframe Technology subproject contains two elements. Under the Damage Arresting Composite Demonstration an advanced material system is being explored which will lead to lighter airframes that are more structural efficient than the composites used in aircraft today. Under the Adaptive Compliant Trailing Edge Flight Experiment a new concept of a flexible wing trailing edge is being evaluated which will reduce weight and improve aerodynamic performance. This presentation will describe the development these two airframe technologies.

II. Damage Arresting Composites

The composite airframes being built today for large commercial transport aircraft do not live up to their original promise of weight reduction compared to aluminum aircraft. However, to achieve aerodynamically efficient, high aspect-ratio wings and advanced aircraft configurations such as a hybrid wing body, which has a flattened pressurized fuselage rather than a traditional circular one, composites are necessary. Today's state-of-the art composites do not easily arrest damage so extra doublers and other materials are added to make them safe to fly in a damaged condition. Low strain levels must be used in the design process, no buckling can be allowed at loads less than design ultimate load, and repairs to damaged edges due to delamination are common. In addition, they depend on either a bond alone or a bond with added fasteners to assemble the structure. This leads to weak through-the-thickness joints or added holes which serve as crack-starters. Additionally, parts are limited in size do to autoclave size limits and there are epoxy resin limitations on how long the material can be out of the freezer before curing. To begin addressing these fundamental challenges, researchers at NASA and the Boeing Co. have worked to refine a new structural concept called the Pultruded Rod Stitched Efficient Unitized Structure (PRSEUS). A sketch of the elements of PRSEUS is shown in Figure 1. Critical features include stitch lines at each thickness change location which provide damage arrestment and improved pull-off strength, the stiff pultruded rod that provides an uninterrupted load path in one direction, the frame which has only a small slot for the stringer to pass through to provide bending strength and the lack of fasteners throughout which creates a unitized structure with reduced part count, reduced cost, and superior structural capability. Although PRSEUS is an enabling technology for the HWB airframe, its superior structural performance can also be utilized to reduce airframe weight for nearer term airplane applications with higher aspect ratio wings and circular fuselage cabins. Details of the PRSEUS concept are described in Ref 1.

III. Adaptive Compliant Trailing-Edge

ERA has partnered with the Air Force Research Laboratory (AFRL) who is sponsoring the development of adaptive compliant wing technology through the Small Business Innovation Research (SBIR) program with FlexSys, Inc. (Ann Arbor, Michigan, Ref 2). The ERA / AFRL partnership has resulted in the establishment of the Adaptive Compliant Trailing Edge (ACTE) experiment. Several studies have shown the aerodynamic benefits of an adaptive airfoil; however a large-scale flight demonstration is needed to establish confidence in an adaptive, compliant structure. The AFRL Phase 3 SBIR efforts with FlexSys propose to mature the ACTE technology with a compliant flap design for integration and flight research on the NASA Armstrong G-III aircraft, shown in Figure 2.

The approach for the ACTE integration onto the NASA Armstrong G-III aircraft is to replace both existing Fowler Flaps with ACTE flaps, as shown in Figure 3. The ACTE geometry is approximately 19-ft in span per flap. The ACTE system on each wing is comprised of inboard and outboard transition surfaces (each having a span of approximately 2 ft), a main flap surface (having a span of approximately 14 ft) and inboard and outboard chordwise close-out panels (a total span of approximately 1 ft). These components will result in an ACTE system capable of -2° to +30° deflections for flight (no in-flight actuation).

The goal of the ACTE flight test is to advance the Technology Readiness Level (TRL) of compliant trailing edge structures for aircraft applications to the point that it can be integrated in the next generation of aircraft as a multifunctional control surface. This capability would be used to further NASA and AFRL goals to develop compliant structure technologies, which enable:

- Cruise drag reduction
- Noise reduction during landing
- Takeoff gross weight (TOGW) reduction and increases payload through reduction of wing weight due to reduced wing root bending moment
- Structural load alleviation
- Increased control surface effectiveness

In addition to raising the TRL, the ACTE experiment will also acquire in-flight structural and aerodynamic data that will be used to verify analysis and design techniques for the adaptive structures.

IV. Concluding Remarks

The Airframe Technology subproject within ERA is devoted to developing structural technologies that will improve aircraft performance and reduce weight leading to reduced fuel burn fewer emissions. In the Damage Arresting Composites element, the PRSEUS panel architecture was conceived to address the structural inefficiency and cost short-comings inherent in conventional layered material systems. By replacing fasteners with stitching, a highly engineered structural solution is possible that moves beyond traditional composite design practices with better load paths and the ability to stop damage progression. In the Adaptive Compliant Trailing-Edge element a full-scale adaptive structure will be flight tested on a G-III aircraft to increase the TRL of the technology, validate design tools, and provide the foundation for utilizing multifunctional control surfaces for next generation aircraft design. The proposed presentation will describe the developments in these areas through the ERA project.

References

1. Velicki, A., “Damage Arresting Composites for Shaped Vehicles, Phase I Final Report,” NASA CR-2009-215932, NASA Langley Research Center, Hampton, VA, September 2009.

2. Kota, S., Hetrick, J., Osborn, R., Paul, D., Pendleton, E., Flick, P. and Tilmann, C., "Design and Application of Compliant Mechanisms for Morphing Aircraft Structures," Paper 5054-03, SPIE Smart Structures and Materials Conference on Industrial and Commercial Applications of Smart Structures Technologies, San Diego CA, 2-6 March 2003.

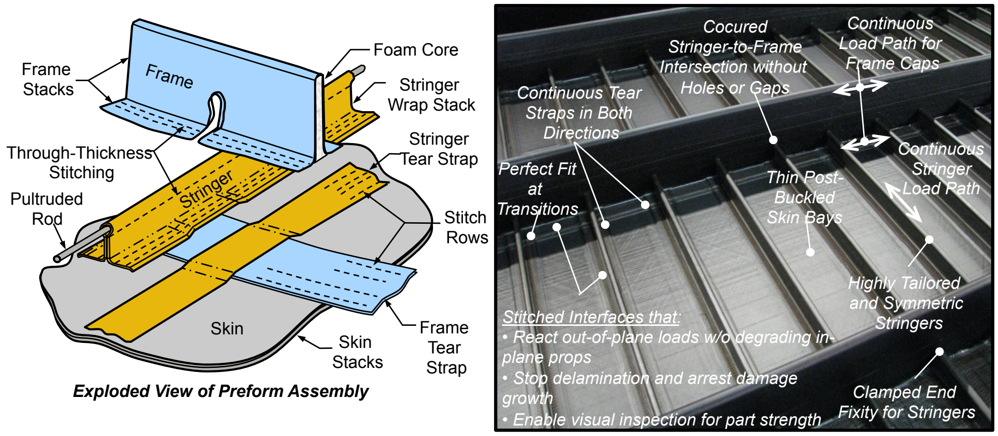
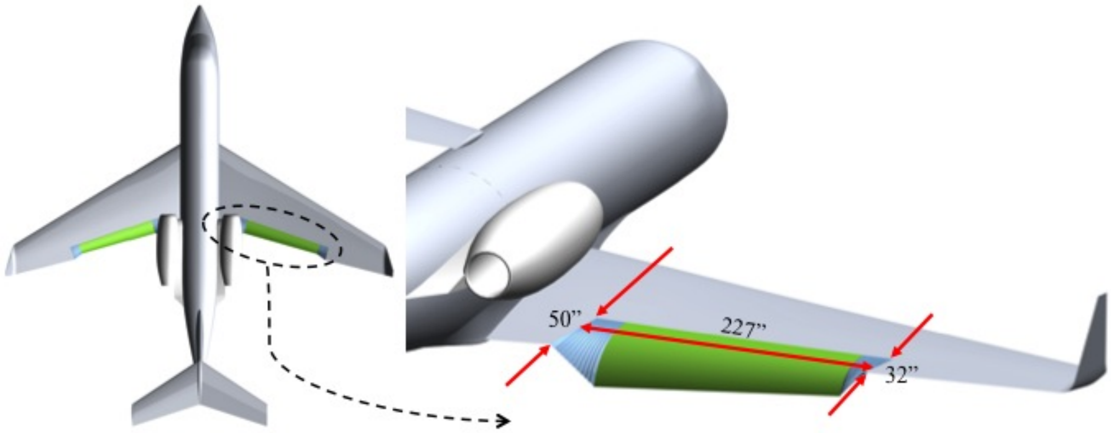


Figure 1. PRSEUS unitized structural concept.

Figure 2: The Armstrong Flight Research Center G-III aircraft.



Note: Inboard and outboard transition surfaces (blue) and a main flap (green) are shown.

Figure 3: The ACTE installation on the G-III aircraft.