

# **Automated Scarf Routing System for Repair of Composite Structures**

## **Concept Paper For The Commercial Technologies for Maintenance Activities Program**

### **Statement of Problem**

With composite materials becoming more prevalent in present and future aircraft structures, the need for quick and structurally sound composite skin repair is growing accordingly. Currently the repair of damaged composite aircraft structure requires time-consuming methods that are reliant on manual processes. This is particularly true in the repair of high performance composite structures, such as those used on the F-22, F/A-18E/F and Joint Strike Fighter (JSF) aircraft, where repairs are typically required to retain the aircraft's outer moldline. These repairs are referred to as flush or near-flush repairs and often require the damaged region of the aircraft to be scarf machined prior to installing a repair patch. The current state-of-the-art in accomplishing scarf machining is through the use of manual routing tools manipulated by aerospace technicians or aircraft maintenance personnel. This machining step accounts for a large portion of the time required to complete the repair and typically can involve several days of arduous hand labor. A meaningful reduction in the maintenance burden of composite aircraft repairs requires that the time spent scarf machining the damaged structure be reduced to periods of a few hours.

### **Proposed Solution**

Lockheed Martin Aeronautics Company, in cooperation with NADEP Cherry Point and the Air Force Aging Aircraft Program Office, propose to complete development of the STARC Automated Scarf Routing system recently established by PushCorp Inc. under a Navy sponsored small business innovative research program (SBIR). In its current form the STARC router (see Figure 1) has demonstrated the unique ability to accurately scarf machine mildly contoured composite structures using a fully computer controlled Stewart Platform manipulator. This first generation STARC router system successfully eliminates the current repair operations that involve a combination of low technology hand-held rotary grinding tools and highly skilled hourly personnel. In the CTMA program, the DoD and industry propose to adapt the STARC system to address machining of the most critical and frequently repaired portions of advanced fighter aircraft including the F-22 and JSF. The composite structures of concern are the leading and trailing edges of the aircraft. The combination of their high susceptibility to in-flight damage and hanger rash along with their critical performance requirements identifies edge structures as major drivers for aircraft sustainment costs. Severe radii and complex contours associated with edge tips,

roots and flaps present geometric challenges that the current Stewart Platform manipulator is unable to address.



Figure 1. First Generation STARC Stewart Platform Manipulator

In response to the limitations of the first generation STARC router the program team proposes to design, fabricate and test a new robotic manipulator configured for machining fighter aircraft leading and trailing edge structure. The program will also modify the appropriate STARC software modules to control the leading edge manipulator. These modules will perform the required kinematic calculations to position the manipulator throughout the scarf machining operation. The new manipulator design will be designed such that it can be attached to the aircraft via vacuum cups, straps or at hard attachment points. In addition, the manipulator will be able to work in a freestanding mode separate from the aircraft. Further improvements in the current STARC software modules will permit the system to scarf machine pre-cured composite patches, off-the-aircraft which accurately match the machined parent structure located on-the-aircraft.

PushCorp Inc., who developed the first generation STARC router system, will lead the efforts to upgrade the system for use on aircraft leading edges. Included in PushCorp's efforts will be the development of an integral system for collecting and disposing the dust particles generated during the machining operation. Industry and DoD participants will establish the specific requirements of the new manipulator, will quantify the router's cost and performance improvements, and will demonstrate its capabilities on representative structures. Testing of the performance improvements should include shear, compression and damage tolerance testing as well as electrical testing as directed by specific aircraft requirements. Requirements to be dictated by the industry and DoD participants include: 1) size and weight of the manipulator, 2) power requirements, and 3) robustness or durability for field use. Industry and DoD participants will also provide support to PushCorp in regards to router characteristics, controller graphic interface characteristics, and manipulator to aircraft attachment methods.

### **Deliverables**

At the conclusion of the proposed program the Air Force and Navy depot repair organizations participating in the program will be delivered working prototypes of the leading edge manipulator and control system. These prototypes would be used to market the benefits of the automated routing system amongst the military's many structural maintenance facilities. The demonstrated benefits of the prototype routers are expected to lead to incorporation of the such

systems into standard repair manuals used to govern field and depot repair operations. Industry team members will be provided unique rights to procure additional STARC router systems for their internal use.

In addition to delivering the prototype router systems, the program will compile all unclassified test results within a final report. Included in this report will be results of cost benefit analyses comparing automated routing with manual routing for repairs conducted on realistic aircraft components.

### **Benefits**

Automated routing systems offer the means to substantially reduce the maintenance hour per flight hour costs to perform repairs on aircraft structural composites. More rapid repair procedures will also lead to increased aircraft availability and greater sortie rates. In addition to these obvious benefits, a robust STARC automated routing system offers a number of secondary advantages over baseline manual machining:

- Hands-free machining operations and dust control systems increase operator safety.
- Eliminates the dependence on highly skilled (artisan) machinists.
- Reproducibility and quality of the machined joint is improved. Robotically controlled routers eliminate the variability resulting from hand held routers whose applied loads have been shown to vary from 0 to 5 lbs.
- The ability to provide a software simulation of the machining operation improves quality and trace ability of the repair process.
- Patches of higher cure temperature materials, such as bismaleimides, can be formed, postcured and *machined* off-the-aircraft to prevent the need to expose sensitive aircraft components to long, high temperature process cycles.
- The STARC's ability to profile surface contours via an integrated laser mapping system can lead to flat pattern cutting programs for rapid patch fabrication.
- The versatile STARC manipulators can also be used to automate the nondestructive inspection and painting segments of the repair process.

**Anticipated Participants**

Lockheed Martin Aeronautics Company (LM Aero) proposes a CMTA program with participation from multiple DoD and industry members. At present, preliminary discussions within LM Aero, with the Naval Aviation Systems organization (Navair), and with PushCorp Inc. have generated a high degree of interest amongst those parties. Representatives from the Air Force Aging Aircraft program office and the F-22 SPO are also recommended participants. Additional industry participation is desired to increase cost share levels to those suitable to complete the program within 2 years. As such 2 to 3 additional industry partners are to be sought. Although not members of the National Center for Manufacturing Sciences consortium, Bell Helicopter Textron and Boeing are known to also have a high degree of interest in further development of automated routing systems.

**Estimated Cost and Duration**

LM Aero proposes a 2-year \$750K program to develop and demonstrate prototype aircraft leading edge manipulators.