Present day controllers occupy volumes of less than a cubic foot and represent a 5000 percent reduction over the early systems. This size reduction can be projected into the next decade. Controllers will rely heavily on new packaging techniques to further reduce controller sizes. The envisioned controller unit will undergo further halving in size when compared to present day optimum designs. The impact of this electronics revolution is to free aircraft designers from using hydraulic actuation systems, and allowing them to employ the variety and flexibility of the electric actuation concept.

SUMMARY

Within the promise of the All-Electric Airplane, is the need for electric motors and drives. For smart actuation systems, the use of high voltage dc supplies make possible motor size reductions. This advantage is muted if the motor electronic places unbearable size, weight, and thermal burdens on the aircraft design. The power electronics revolution has provided promise in the area of reasonable drive circuits for use in an aircraft environment. The technologies gaining the most attention are the high drive, low loss switches. In this category, the IGT can service applications in the 500V and 25-amp range. This is a niche in which gate turn-off thyristors and power MOSFETs do not adequately fill. To make use of a smart actuation system, low level logic functions will be required of the actuator. The interface between the low- and high-voltage circuitry is a challenge to the electronics industry. The HVIC is well suited to serve as this interface. The device opens the door to truly smart power. The most difficult issue facing the electromagentic actuation system approach is the need for a physically efficient design. To this end, the use of hybrid packaging techniques to combine both HVIC and IGT technologies is providing the needed approach to achieve a competitive controller package.

REFERENCES


ROBOTIC SYSTEMS FOR AIRCRAFT SERVICING/Maintenance

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ABSTRACT

This paper explores concepts which apply emerging ground support technology (GST) to the rapid turnaround of tactical aircraft. This technology has the potential to reduce manpower requirements for ground servicing, increase sortie generation rates and expose fewer ground personnel to the lethal agents anticipated during biochemical warfare. The near term approach examines automated systems for refueling and rearming tactical aircraft assuming the returning aircraft suffer no disabling malfunctions or battle damage. In the far term, it is proposed that additional maintenance and servicing functions be performed by GST systems. Consideration is given to linking diagnostic computers on tactical aircraft with future robotic systems for direct repair and maintenance. It is concluded that GST systems, including robotics, provide the opportunity for revolutionary changes in aircraft servicing and maintenance and provide a viable option for generating sorties during and immediately following biochemical attack.

INTRODUCTION

The development of aircraft technologies has far outpaced corresponding technologies for handling the aircraft once it has recovered on its airfield. New concepts in GST are intended to close this gap. In combat, a tactical aircraft can only contribute to the battle when airborne and prepared for
air-to-air or air-to-ground engagements. Additionally, aircraft on the ground awaiting service or maintenance are highly vulnerable to attack. The problem of aircraft turnaround has been compounded by the requirement for servicing and launching sorties in a biochemical environment. The Soviet threat in biochemical weapons has been growing at an alarming rate. Unclassified sources give the Soviets a forty to one advantage over the United States in operational capability in this area. During or following a biochemical attack, ground crews are expected to perform complex servicing tasks in an extremely hostile environment. Protection is provided by standard chemical defense ensembles; however, this protective clothing impedes dexterity, visibility and communications, Figure 1.

3. GST concepts must be developed for providing rapid diagnosis of a malfunction and quick repair or replacement of the defective system. This includes repair of subsystems suffering combat damage.

There have been many efforts to examine the limiting factors in sortie operation but little technology to improve capability. Most of the improvements have been evolutionary and have not kept pace with parallel developments in other combat related technologies.

**DISCUSSION**

Robotic technology provides the opportunity to reduce, or in some cases eliminate, the exposure of ground support personnel to the hostile biochemical environment. Robotic systems in this paper include both mobile or fixed base teleoperated systems, depending on the requirements of the application. The level of human interface is partially a function of the danger associated with the operation to be performed. For example, a robotic system designed for explosive ordinance disposal could be an unmanned, autonomous vehicle controlled remotely or through self-contained sensors employing artificial intelligence, while a robotic refueling system could employ a human operator interactively controlling a teleoperated arm with remote sensors for feedback. The degree to which robotic systems can assume flight line functions now performed manually can only be assessed through extensive analyses of the many factors involved. These factors include both near and far term focuses.

**Near Term: Aircraft Turnaround.** The near term covers the period up to 1990. Robotic systems required for aircraft turnaround could be developed during this period by applying emerging robotic technology. The turnaround process mainly comprises aircraft refueling and weapons uploading.

1. **Aircraft Refueling.** The air refueling receptacle could be used for ground refueling by employing a teleoperated arm with an end effector consisting of a refueling probe. Several configurations for such a concept can be envisioned. Figure 2 presents a configuration where an overhead track is used to provide a translational degree of freedom to the shoulder hinge of a teleoperated boom. The boom can be controlled about the shoulder hinge in pitch and yaw. In addition, the refueling probe is mounted on a telescoping section of the boom.

![Figure 1. Wing Tank Installation During CB Exercise](image)

![Figure 2. Robotic Refueling Using the Air Refueling Receptacle](image)

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In operation, the robotic system would be positioned such that the angle between the boom and longitudinal axis of aircraft was about 35 degrees, consistent with normal air-to-air refueling geometric requirements. The position of the boom would be adjusted until the cross hairs on the closed loop TV camera were aligned with the air refueling receptacle and then the telescoping probe inserted into the receptacle. Since the air refueling receptacle is located over the main feed tanks, the fuel flow is normally higher during air-to-air refueling (29% higher for the F-16) than during ground refueling. Consequently, this concept not only removes the ground personnel from the lethal environment, but also allows the refueling function to be accomplished faster. This basic refueling concept would be compatible with any tactical aircraft equipped for air-to-air refueling.

A second concept for ground refueling using the air refueling receptacle is presented in Figure 3.

![Figure 3. Mobile Concept for Ground Refueling](image)

This concept employs a two element teleoperated arm, mounted on an advanced refueling vehicle, to insert the refueling nozzle into the air refueling receptacle. A closed loop TV camera is mounted on the probe boom to provide position feedback. The operator is located in the chemically benign cab of the vehicle. The mobile refueling concept is equally applicable at main or deployed operating bases, thus providing an additional degree of flexibility in employment.

2. Rearming. Future tactical aircraft development has been moving towards the elimination of high drag external stores for sustained supersonic flight. Conformal weapons carriage appears to be an attractive alternative. Conformal carriage presents the opportunity for preloading the weapons in modules and then using robotic hoist systems for mounting the modules onto the aircraft. An alternate approach to weapons loading could employ an active landing gear where the cylinder pressure is controllable. In this concept, the aircraft is positioned over the weapon module, the cylinder pressure reduced lowering the aircraft onto the module, the interface is locked, and finally the cylinder pressure is increased lifting the module off its transporter. This type of system would provide the aircraft with a more autonomous loading system and be useful in operating from deployed bases.

3. Integrated Rapid Turnaround Facility. Figure 4 presents a conceptual layout of a taxi-through Rapid Turnaround Facility exploiting robotic systems and employing modular conformal weapons and an overhead teleoperated refueling probe.

In operation, an aircraft would taxi into the facility following centerline markings and shut down at a predesignated point. The aircraft would be checked for battle damage using closed loop TV cameras, feeding visual information to the control operator in the biochemically benign room shown beyond the far wall. The control operator would incline the refueling probe to the refueling position. The overhead carriage would then be positioned with the TV camera cross hairs centered on the air refueling receptacle and the telescoping probe inserted into the receptacle for refueling. The preloaded weapons modules would be remotely moved into position under the aircraft and aligned with interface locks on the underside of the aircraft. A hydraulic lift could be used to raise the modules for lock-on to the underside of the fuselage. This total process could be accomplished in less than five minutes which is much faster than manual turnaround using today’s technology.

Far Term: Additional Robotic Functions. The far term extends out to the year 2010 and considers additional maintenance functions in addition to turnaround servicing. These functions include the replacement of modular mechanical/avionics subsystems and rapid battle damage repair. The far term will probably include the requirements for artificial intelligence/expert systems in order to provide an unspecified capability for autonomous operations.

1. Modularity. The assembly of discrete subsystems into modules presents the opportunity for simplifying aircraft maintenance procedures. Avionics technology has been moving in this direction. The conformal carriage of weapons could easily lead to the packaging of air-to-air and air-to-ground munitions into conformal modules. Modular wing tips and empennage surfaces could be envisioned which could be easily replaced in the event of battle damage. The modules would be configured for easy replacement using robotic manipulators or teleoperated systems. Fuselage access panels, compatible with multifunction end effectors, would provide access to modular avionics systems.

2. Computer Interfaces. The status of the modular subsystems could be monitored using embedded microprocessors. This information would be fed to the central airborne computer for monitoring subsystem performance/status and the diagnosis of malfunction information. Appropriate summary displays of this information would be available to the aircrew and also could be downloaded into the robotic maintenance computer as shown in Figure 5. Included in this information could be scheduled maintenance for individual subsystem modules.

In operation, the aircraft subsystem malfunction data and scheduled maintenance data would provide input commands to the robotic system through the central airborne computer.
These data would be integrated with frag commands covering weapons loadout and fuel requirements. Mission requirements for special fusing and other configuration variables also would be inputs to the robotic computer system. Based on the predefined robotic logic, the robotic system would then execute the appropriate actions to repair and service the fighter aircraft in preparation for the next mission.

3. Robotic/Airframe Compatibility. The acceptance of robotic servicing and maintenance would have a direct impact on the design of future aircraft. Modular subsystems would greatly simplify the integration of the robotic systems into the maintenance and servicing process. Weapons and avionics are two areas particularly adaptable to modular concepts. From a practical standpoint, the logical location of the heavy weapons modules would be the underside of the fuselage. Figure 6 presents a Northrop concept of a future fighter using robotic systems for maintenance and servicing.

Figure 5. Computer Interfaces for Robotic Maintenance

Figure 6. Robotic Systems for Future Aircraft Maintenance and Service

The expended modules could be refurbished in a sterile environment where high technology electronic diagnostic equipment could be used even during periods of biochemical attack. Refueling, even in the far term, could probably best be implemented using the robotic probe in conjunction with the air refueling receptacle. However, consideration could be given to applying robotic systems to loading preserviced fuel modules at deployed operating bases. High density fuels of the future could make this a viable option.

ISSUES

A number of issues and concerns, particularly in the near term, have to be addressed when proposing a radical departure from today’s manual approach to aircraft turnaround. Reliability and maintainability of the robotic systems in a combat situation is a vital concern to the AFLC and AFSC communities. Protection will have to be provided against the effects of chemicals on the electronics and mechanical subsystems. The robotic systems must be available and working when needed in a combat environment.

Simplicity and costs are also driving factors. For a robotic system to be credible, it will have to be affordable. Multifunction robots are one approach to containing costs.

Another issue is the compatibility of robotic systems with wartime strategies. For example, if the air war was to be fought from deployed operating bases then mobility should be an important factor in robotic design.

Interoperability in the NATO environment is another important consideration. USAF aircraft must be capable of being turned around at non-USAF NATO bases. The refueling concept shown in Figure 2 is an example of robotic concept compatible with USAF and non-USAF bases. Robotic refueling could be accomplished at USAF bases while standard manual single point refueling would be employed at non-USAF bases.

CONCLUSION

The concepts discussed in this paper are intended to provide a point of departure for future exploratory development efforts in the application of robotics, including artificial intelligence/expert systems, to aircraft servicing and maintenance. Careful judgment will have to be applied in establishing what functions “make sense” for future robotic systems in these roles.

Future robotics efforts in the Air Force must be closely coordinated with the operating commands, logistics and maintenance, chemical defense and life support organizations to keep the effort responsive to eventual user needs.

Robotics provide the opportunity for revolutionary changes in how we turn aircraft around in peace and wartime, with associated payoffs of quicker turnarounds with fewer ground maintenance personnel.