

A Large-Scale Robotic System for Depainting Advanced Fighter Aircraft

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ABSTRACT

The general benefits of automation are well documented. Order of magnitude improvements are achievable in processing speeds, production rates, and efficiency. Other benefits include improved process consistency (inversely, reduced process variation), reduced waste and energy consumption, and risk reduction to operators. These benefits are especially true for the automation of the aerospace paint removal (or “depaint”) processes.

Southwest Research Institute® (SwRI®) developed and implemented two systems in the early 1990's for depainting full-body fighter aircraft at Robins Air Force Base (AFB) at Warner Robins, Georgia, and Hill AFB at Ogden, Utah. These systems have been in production use, almost continuously for approximately 20 years, for the depainting of the F-15 Eagle (Figure 2) and the F-16 Falcon fighter aircraft, respectively. Based on these previous systems, the Advanced Fighter Aircraft Depaint System (AFADS) has been designed, built, and installed as part of a large maintenance facility for advanced fighter aircraft.

The AFADS includes a number of technology enhancements, such as increasing the robot reach by an additional 10 feet to give it the capability of depainting any of the fighter aircraft in the USAF fleet. The AFADS is comprised of two identical robots (one positioned on either side of the aircraft), an aircraft positioning system, an operator control room, three levels of operator control, and an interface with the dry media depaint process. The media to be used in the process is MIL-P-85891A Type VII cornstarch-based media.

Though the AFADS system represents a significant advancement in robotic depaint technology, SwRI sees other opportunities to further advance the state of the art of aircraft

depaint, particularly with regards to laser processes, automation control, path programming, and the application of mobile robotic platforms. SwRI, with their collaborators, is currently developing a new laser paint removal process that was recently demonstrated on the AFADS robotic platform.

INTRODUCTION

The general benefits of automation are well documented. Order of magnitude improvements are achievable in processing speeds, production rates, and efficiency. Other benefits include improved process consistency (inversely, reduced process variation), reduced waste and energy consumption, and risk reduction to operators. These benefits are especially true for the automation of the aerospace paint removal (or “depaint”) processes, such as chemical stripping, mechanical removal methods (sanding, scraping, etc.), high or medium-pressure water blast, laser ablation, and dry media blast. These processes are all very labor intensive, and can risk damaging sensitive substrates, pose health and safety risks to the operator, or both. Automation has the potential for mitigating the risk to the substrate by providing more consistent and potentially controllable process application, and for mitigating the risk to the operator by essentially removing them from the hazardous environment.

There have been a number of automation systems developed for the depaint process - some for off-airframe components (Figure 1), and a few for full aircraft. The systems that have been successful for production operations use a variety of depaint processes, such as dry media blast (various media types), laser ablation, and a hybrid process known as Flashjet. The automation of other processes, such as medium-pressure water and dry ice blast have been attempted, but have not been successful in the full-aircraft production environment.

Southwest Research Institute (SwRI) developed and implemented two systems in the early 1990's for depainting full-body fighter aircraft at Robins AFB at Warner Robins, Georgia, and Hill AFB at Ogden, Utah. These systems have been in production use, almost continuously for approximately 20 years, for the depainting of the F-15 Eagle (Figure 2) and the F-16 Falcon fighter aircraft, respectively. Though these systems are well past their design life, and require upgrades, they have been very successful and provide a good basis for future designs.

Based on these previous systems, the Advanced Fighter Aircraft Depaint System (AFADS) has been designed, built, and installed as part of a large maintenance facility for advanced fighter aircraft.

BACKGROUND

ROBOTIC PLATFORMS

There are several generic types of robotic platforms that can be used to automate the aircraft depaint process. These are described in the following sections.

Gantry Robots

Gantry robots require a frame structure, which provides support and up to three degrees of freedom to an under-hung, multi-axis manipulator. Because this robot type accesses the work area from above, it can access the top and sides of a work volume, but cannot easily access the underside. For depainting, it is best suited to off-airframe components that can either be mounted vertically, or can be flipped when in the horizontal position. The gantry is not well suited to full aircraft due to the difficulty in reaching the underside of the wings and fuselage, and also due to the prohibitively large size and weight that would be required for the structure.



Figure 1. Gantry Robot Developed by SwRI for Off-Airframe Component Paint Stripping

Free-Standing Robots

Free-standing or ground-based robots are similar to the gantry robots, in terms of degrees of freedom and work envelop, but do not require the overhead structure and framework. On the other hand, they do require floor mounted supports or tracks, which can limit floor maneuverability. Previous reach studies by SwRI have shown this robot type to be the best suited for fighter sized aircraft. These robots could also be used for large aircraft with more units to service the work volume. The cost of this approach would have to be evaluated for the particular application.



Figure 2. Free-Standing Robots Developed by SwRI for F-15 Paint Stripping

Mobile Robots

A relatively new type of robot is the mobile manipulator, which is based on an autonomous vehicle (Figure 3). The vehicle itself would provide two full degrees of freedom in the X-Y plane around the aircraft, with a third (Z) degree provided by a telescoping or scissor-lift platform. The platform would support a conventional manipulator with the additional 5 to 6 additional degrees of freedom required. The benefit of this concept is that the unconstrained motion of the vehicle would allow access to a larger work envelop. There would also be no floor mounted structure to impair movement around the aircraft. For depaint operations, one or more of these could conceivably move around the aircraft, either autonomously, or under human control. A technical challenge to this approach would be the design of sufficient Z-stroke (vertical) to access the top sections of the aircraft, and to provide stability to the vehicle that would be required by the long arm-reach that would still be required. Other challenges, which will not be described here, relate to reliability and safety considerations specific to the production environment.



Figure 3. Concept for a Mobile Robotic Platform for Large Aircraft Depaint

SYSTEM DESCRIPTION

The AFADS design is based on the free-standing platform, and on SwRI's previous systems located at Hill and Robins AFBs. A number of technology enhancements were incorporated, and the robot reach was extended by an additional 10 feet to give it the capability of depainting any of the fighter aircraft in the USAF fleet. AFADS is comprised of two identical robots (one positioned on either side of the aircraft), an aircraft positioning system, an operator control room, three levels of operator control, and an interface with the coating removal process. The media to be used in the process is MIL-P-85891A Type VII cornstarch-based media. The following sections provide a thorough description of the system.

OVERVIEW



Figure 4. AFADS Overall Layout

The AFADS system incorporates two identical robots as shown in [Figure 4](#). Each robot carries an on-board media blast pot that is refilled automatically by a pneumatic bulk conveying system. The robot controller, manufactured by Kuka Robotics, is housed in a large electrical enclosure that also rides with the robot.

[Table 1](#) provides the general specification for each robot.

Table 1. General Specifications

Height (ft)	27
Reach (ft)	30
Travel Length (ft)	70
Payload (lb)	100
Degrees of Freedom	9
Repeatability (in)	1/8
Gross Weight (lb)	>30,000
Rating	IP-67
Hazard Classification	Class II, Div 2

SwRI determined that nine degrees of freedom are required for full accessibility of the robots around a typical fighter aircraft. The first two degrees of freedom (Axes 1 and 2) are used for gross positioning of the robot's vertical column; with the remaining seven axes providing coordinated motion of the end-effector around the aircraft. This allows approximately 95% of the fighter's surface area to be stripped. Following is a more detailed description of the robot, by axis.

Traveler (Axis 1 Translation)

The primary structure of the robot is referred to as the Traveler ([Figure 5](#)). It is equipped with four steel wheels which ride on a track system which runs the length of the hangar. This movement, referred to as Axis 1, provides gross positioning of the robot along the long axis of the aircraft fuselage. In addition to providing support for the upper and lower beams (described below), the traveler also houses the media blast pot and the control systems for the robot. Axis 1 is driven by a servomotor/gear-driven pinion that engages a long gear rack that is welded to one of the floor tracks.