Large Aircraft Depaint Manipulator Initiative

Background:

AFRL identified a technical requirement to evaluate emerging and alternative technologies for their ability to meet customer requirements in the surface processing of large aircraft (C-130, C-141, K/C-135, C-5) at USAF Air Logistic Centers (ALC) during Programmed Depot Maintenance (PDM). This effort was tasked to the Air Force Coatings Technology Integration Office (CTIO) and addressed establishing a simple, low-cost stripping system concept to reduce depot flow time, reduce ALC personnel exposure to the extremely hazardous work environment, and reduce man-hours and lost time due to injuries.

Surface processing of large aircraft requires multiple "on aircraft" processes including washing, depainting, inspection, surface prep, and painting. These processes are labor intensive, subject personnel to undue strain, and require extensive stands, fixtures, man-lifts, or overhead stacker cranes to allow access to the surfaces of the aircraft. Automated manipulators and carrier systems, when used to access large aircraft surfaces, have the potential not only to reduce the physical strain placed on a worker but also to improve the quality and productivity of a process. These improvements, and a reduction in aircraft flow-time during PDM, can be realized by the capability of automated systems to control and carry multiple process tools beyond what a single operator is capable of handling.

Project Sponsor/Customer: AFMC Air Logistic Centers
Period of Performance: Mar 99 – Sep 00

Objectives:

AFRL and the Coatings Technology Integration Office (CTIO) supported the first phase of a multi-phase effort using the following philosophy: The objectives are below:

- Significantly reduce capital investment requirements (low automation hardware costs)
- Reduce dependence on sensing and software (put the operator in the loop rather than autonomous operation)
- Use multiple depaint devices/methods in the same facility with the potential for simultaneous operation to improve throughput; and emphasize

durability/resiliency in the automated system design and operational concept that minimizes scheduled/unscheduled downtime.

Status:

The Integrated Process and Product Development (IPPD) method was selected to guide this project to ensure that the customer requirements would drive the final solution. All three USAF ALCs (OO-ALC, OC-ALC, and WR-ALC) and the Boeing Aerospace Support Center in San Antonio, Texas were visited to collect baseline requirements information. The two technologies originally selected for review by this program were NIST's RoboCrane® cable operated Stewart platform and the Grey Pilgrim LLC's EMMA® serpentine manipulator. Upon further investigation, the EMMA manipulator proved not mature enough in development to meet the desired demonstration schedule. The design team was then tasked to locate and/or develop additional concepts. A "Value Stream Map" was developed for the depaint process at Hill AFB to better understand the processes involved and to develop a strategy that could best reduce flow-time. Multiple "brainstorming sessions" and industry research efforts were conducted. Four final concepts were selected as being potentially viable. These four were then assessed for their ability to meet the customer requirements by using James Gregory Associates' IPPD software to score and compare their potential

The final four concepts consist of two carriers (systems that bring the operator close to the aircraft) and two manipulators (devices that assist the operator in performing his tasks once located near the aircraft). The two carrier concepts are the **RoboCrane**®, a cable suspended carrier, based on a Stewart platform geometry, that yields great maneuverability and control while remaining very rigid; and the **Enhanced Aerial Lift**, a concept that applies intelligent control to the joints of an aerial lift (cherry picker) to allow for intuitive coordinate motion. The two manipulator concepts are the **Tripod Manipulator**, a high payload to weight manipulator based on parallel link technology; and a **Power Assist Wand**, an intuitively controlled telescoping wand which actively reacts to the blast force and is counterbalanced to offset the weight of the blast hose/nozzle. The IPPD software calculated that all four concepts show good desirability and manageable risk, and are therefore worthy of further development. Each of the concepts offers unique benefits and advantages to the respective ALCs. Thus, they should not be considered as interchangeable solutions. Concept descriptions follow:

RoboCrane®

A cable suspended carrier based on a Stewart platform geometry that yields great maneuverability and control while remaining very rigid. This rigidity is achieved through the six parallel members in tension while the innovative replacement of telescoping members with cables allows for a large work volume. The platform has great application for large facilities servicing large aircraft, and is potentially much less expensive and flexible than currently used stackers. The potential benefits include increased ability to access the upper portions of very large aircraft and to carry a very large payload. Potential impact on the depaint process is the possible application of new depaint processes that have heavy equipment requirements. The disadvantage of this technology is its limited ability to reach the underside of the aircraft. Impacts in the Value Stream include decreased material movement times during the prep, depaint and deprep activities. (See Figure 1 below)

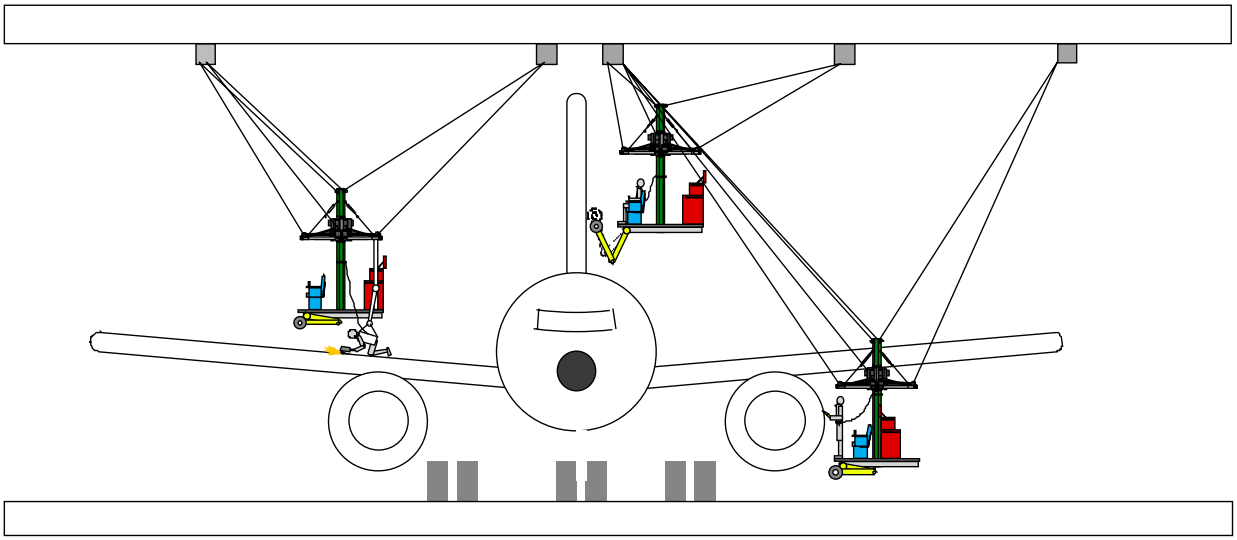

Figure 1. RoboCrane®

Enhanced Aerial Lift

This concept applies intelligent control to the joints of an aerial lift (cherry picker) to allow for coordinate motion. The operator can make natural, direct movements of the basket through a single input device versus multiple individual joint controls. Hardening and basket ergonomic improvements are also a facet of this concept. The potential benefits include reduced training, reduced movement time, reduced ground movements, and reduction in inadvertent collisions with the subject aircraft. Impact on the depaint process is in the potential in reducing overall production flow-time. The disadvantage of this system is the cost of the required modifications to existing aerial lifts to permit smooth operation. Impacts in the Value Stream include decreased material movement times during the prep, depaint and deprep activities. (See Figure 2 below)

Figure 2. Enhanced Aerial Lift

Tripod Manipulator

A high payload to weight manipulator based on parallel link technology. This very rigid yet light structure has great advantages over commercially available serial manipulator or “robots” for this depaint application. The prismatic links are formed into a tripod configuration. By coordinating the extension of these three links, three degrees of freedom in space are achieved. The operator would control the position of the single or

multiple blast nozzles remotely via a joystick. Since remote control is inherent in the design, this approach allows removing the operator from the blast environment. The potential benefits include the ability to gang nozzles, remove the operator from the blast environment, and remove the loads the operator must burden. Potential impacts on the depaint process are the ergonomic and environmental improvements resulting in reduced injury down time and the potential reduction in production flow-time. The disadvantage of the system is the complexity and expense of the additional equipment. Impact in the Value Stream occurs in the decreased material movement during the depaint activities. (See Figure 3)

Figure 3. Tripod Manipulator

Power Assist Wand

An intuitively controlled, telescoping wand that actively reacts to the blast force and is counterbalanced to offset the weight of the blast hose/nozzle. This ergonomic assist tool overcomes the difficulties of compensating for a variable reaction force of the blasting/spraying by constraining the force to always act through a universal joint or gimbal which is rigidly mounted to the support structure. A motorized telescoping member then allows the operator to compensate for the proper standoff distance to the substrate. The operator provides input through an instrumented handle to control a motor to either extend or retract the telescoping member to maintain the desired position of the mounted spray/blast nozzle. The gimbal allows yaw and pitch to be manually adjusted by the operator. A counter weight at the opposite end of the device is used to compensate for the weight of the spraying equipment. The invention transfers the weight to the support structure. The potential benefits include the ability to gang nozzles and remove the loads the operator must burden. Impacts on the depaint process are the ergonomic improvements resulting in reduced injury down time and the potential reduction in production flow-time. The disadvantage of the system is the requirement of additional equipment. Impact in the Value Stream occurs in the decreased material movement during the depaint activities. (See Figure 4)

Figure 4. Power Assist Wand

The project concluded there are several commercial and DoD-developed depaint tools/systems available today but many of them fall short in satisfying the customer's requirements. The depaint customer, therefore, needs additional aids to improve an ergonomically difficult and labor intensive task. This program focused on listening to the depaint customer and subsequently identifying concepts to meet the their requirements. The project team recommends all four presented concepts be further developed for a depainting demonstration. This recommendation to proceed with all four concepts is due to the unique needs of each of the ALCs. The four concepts provide solutions to

location specific problems and could dramatically expand the “tool box” of the depaint customer. It is also recommended simulations be developed to assist in developing strategies to increase trigger time and decrease flow-time using these new technologies. Finally, these concepts offer a new opportunity to explore other nozzles, multi-nozzles, blast pressures, and stand-off distances that would not otherwise be practical in a completely manual process.

Final Report: Titled: ”Automated Surface Processing of Large Aircraft – Phase 0”
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