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Environmentally Compatible Coating Removal for Weapon Systems

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The U.S. Department of Defense's depot and sustainment activities produces large amounts of hazardous waste each year in the re-furbishment of all types of military equipment. These include but are not limited to tanks, combat ground vehicles, ships, aircraft and their associated armament. Budgets for new materiel acquisition in all the services have dropped substantially since the early 1990s and services are committed to holding on to their existing inventories of equipment. In one example, the Air Force B-52 Bomber will remain in service until the 2030's, extending its life cycle to over 90 years.

Right now the U.S. is postured in a position to maintain its aging inventory of legacy system equipment. There is no doubt that many pieces of equipment will go through many Rework cycles until it is placed in surplus. Coupled to the fact that since the end of the Cold War, the U.S. Military has been subject to stringent air and water pollution control through legislation and executive order. The military services which operate the shipyards, air logistics centers and depots now face the two fold challenge of a vastly increased workload and much stricter environmental guidelines of which to operate. In addition, many Government Owned, Government Operated depots face endless cost cutting challenges from outsourcing in the private sector to remain open.

Many of these maintenance operations involve paint stripping and re-painting of vehicles and aircraft. Other operations involve coating removal of inorganic coatings such as those in engines and other assemblies such as landing gear. For example, it is estimated that 80% of the Air Force hazmats are created by painting and de-painting operations alone. Both the Army and the Navy employ extensive means to their painting and stripping operations. These until recently involve conventional means of paint stripping and coating removal that involve chemical and mechanical means. Chemical means using methylene chloride requires elaborate compliance means such as air emissions controls and filtering systems. Occupational health and safety issues are also considered in that personnel must wear protective equipment and receive the proper Hazmat training. In addition, permits must be obtained and inspections by many state agencies in which the depots operate.

Another important point is that many states, in this case California has air emission standards that are far stricter than Federal ones. This is especially true of the SouthCoast Air Emission Standards around the Los Angeles basin and also further south in San Diego. For example, it not uncommon to for the Marines to move trucks and equipment to a neighboring states to strip and paint these vehicles. Again this takes additional time and will increase costs of operations. Hazmats must be stored, cataloged and disposed of properly. Depots are subject to inspections and must comply with paperwork and all this adds up to increased costs of operation.

The traditional approach to the environment is to focus on complying with the law and to clean up wastes that were generated throughout the years. All of this is fine but it can be somewhat shortsighted in that all things being equal, unless one changes the process, hazardous

materials will continue to be generated. In short, compliance and clean up costs will always remain if not grow due to future legislation. The key is in source reduction by initial elimination or reduction of chemicals. Solutions must also go beyond the environmental compliance issues in that they must make economic sense and have relatively short payback periods.

In military terms, pollution prevention, especially in the area of coating removal is an issue that effect force readiness. Commanders whether at the depot or theater level know that equipment, particularly aging equipment must in top working condition. This means relatively short cycle times and with reliable output. As we shall see in the remainder of this paper, when implementing P2 solutions, this is a major selling point to the Commander.

Many technologies have been implemented in recent years to address pollution prevention concerns. Some have been around for many years but only recently have been used for paint stripping and coating removal. Technologies such as Ultra High Pressure Waterjet (UHPWJ), CO2 Pellet Blasting, Xenon Lamp and Laser Stripping will be addressed in this paper. These processes represent the state of the art in coating removal and some are more in a stage of advancement than others are. The advantages and limitations of each will be discussed along with examples of their applications. Economic considerations will be outlined in a section on Environmental Cost Accounting Methodology. (ECAM). This will be used as objective accounting tool, based on activity based costing to validate the cost savings of these technologies.

UHPWJ has been around for many years and has been employed in the area of precision cutting. Recently, this technology has been applied to surface coating removal. The waterjet is built around an enclosed cell with a programmable robot platform or used manually with a waterjet lance. Water is recycled through the system and through a filtering system, the coating residue is collected into a solid cake. The jet is used at ultrahigh pressures between 30 and 50 ksi for metallic coating removal and the water consumption is about 1 to 3 gallons per minute (gpm). For organic coatings, UHPWJ is used at pressures between 10 and 30 ksi with a 2 to 6 gpm water usage. A rust inhibitor added to the water to prevent corrosion to the stripped part. Variables in using the UHPWJ include the standoff distance, the nozzle rpm and traverse rate.

The result is that parts are stripped in a fraction of the time compared to the existing methods of chemical bath stripping. Also, a fraction of hazmats, (10%) is produced with the waterjet versus the conventional methods. UHPWJ technology is currently applied in production scenarios both at the Army's Corpus Christi Army Depot (CCAD) and the Navy's Naval Air Depot - Jacksonville (NADEP-JAX). In the case of the former, CCAD is the Army's chief depot for rotary wing aircraft. Not only are the Army's aircraft serviced there, but some Navy and Air Force helicopters also. The facility does service foreign military aircraft of allied and friendly nations.

The T700 gas turbine engine is refurbished at CCAD and it is used in the UH-1 platform. Certain parts of this engine have flame sprayed coatings which must be removed. Until the UHPWJ was implemented, parts were submerged in chemical baths for as much as 8 to 12 hours. In addition, the parts had to be abrasive blasted every hour. With the programmable waterjet, parts are stripped in 45 minutes. The resulting time saving represents significant gains in productivity and costs savings. Pay back is less than a year.

In Jacksonville, the Navy services a variety of its aircraft from carrier jets to the Orion P-3 used in offshore maritime patrol. Like CCAD, NADEP-JAX has an extensive Engine re-work facility and has similar production challenges. Here the UHPWJ workcell is used on wide variety of jet engine parts that require coating removal. Parts are stripped in a fraction of the time and

part rejection has dramatically dropped from a 30% to nearly zero and eliminated a bottleneck in operations.

Other applications of UHPWJ include ship hulls for removing paint when ships are in dry dock. Again, the technology must be adapted to that application but the cost savings and productivity gains can be just as attractive. As far as future applications go, waterjet technology is being considered for use in wheeled and tracked combat vehicles. The Army is interested in applied this technology at the field level to rapidly strip epoxy primers and polyurethane paints from combat vehicles. So far, under the direction of the National Defense Center for Environmental Excellence (NDCEE) the preliminary trials have been quite successful.

The next technology application is CO₂ pellet blast media using a high rpm (12000) turbine wheel to accelerate the cylindrical pellets (approx. 3mm diameter and 12mm length) before they strike the surface. Unlike convention dry blast media such as sand or plastic pellets, the media sublimates and only the residual paint remains. One has to remember that when dry blasting, the media such as plastic becomes classified as hazardous waste. Like the UHPWJ, the volume of hazmats created is greatly reduced and also like the waterjet, a programmable work cell is used. The CO₂ gas is ventilated and filtered out of the workcell.

NDCEE has tested this technology at its Johnstown, PA facility on steel coupons and engine container cans supplied by NADEP-JAX. The preliminary results have been most promising and the next step is to transition the technology to full production. The strip rate varies between 36 and 56 ft² per hour and is a line-of-sight system. That means the areas in corners and tight spaces that cannot be 'seen' need to be stripped by conventional means. Although small in area, it does take additional time.

Xenon Flashlamp/CO₂ technology was developed by the McDonnell Douglas Aircraft in Mesa, Arizona to service the Army's Apache helicopters and at Kingsville, TX for the Navy's T45 jet trainer. Now part of Boeing, this technology named *Flashjet* has been used on various rotary and fixed wing aircraft as part of technology transition plan. Being ablated by a high temperature xenon lamp strips paint and then a low-pressure stream of CO₂ pellets hit the surface to remove any remainder of coating. The entire residue is then captured by a large vacuum and is stored as waste. The advantages are indeed many, mostly the time saved in rapid paint removal and the exponential reduction of hazardous materials generated by conventional chemical means. Aluminum and composite aircraft skins tend to be somewhat delicate and highly aggressive paint removal can damage the substrate.

This technology is also line of sight and requires some conventional stripping in small areas that the Flashjet lamp cannot reach. The results are still very impressive. An entire aircraft can be stripped in a fraction of the time not to mention the drums of residual methylene chloride. Platforms are being develop to scale up the Xenon lamp to strip larger aircraft such as P-3 Orion. The NDCEE is expected to explore the application of this technology to combat vehicles.

Laser technology is another solution for environmentally compatible paint stripping and coating removal. Recent developments in feedback control and beam stability have improved the process. Unlike a narrow beam used for cutting, this beam is much wider and disperses energy out. The result is clean and quick paint stripping process. Lasers are especially useful on thin skin composites and aluminum and have the ability to selectively strip layers of paint at a time. In other words, if it was just desired to remove the topcoat without removing or damaging the primer coat, this could be achieved. Powdercoat, an extremely hard baked on coating which is

difficult to remove by conventional means, can be stripped using the laser technology. Lasers can be adapted to portable units (hand held) and automated for high production workcells.

Environmentally friendly technologies must go beyond the obvious environmental benefits. Factors such as increased productivity and lower costs are key to them being implemented. To validate the cost savings of these new technologies, the NDCEE in conjunction with Coopers and Lybrand, developed a Environmental Cost Accounting Methodology (ECAM). This methodology is used for the technical professional as a desktop guide to identify those costs associated with implementing some of these environmentally safer technologies. Non-accountants can use the ECAM to define and compare environmental costs. Based on activity based costing ECAM is desired to identify those environmental costs that are hidden in traditional overhead costs.

Environmental costs associated with maintaining a weapon system have been estimated to be anywhere from 10 to 30 percent. The ECAM has been applied to several of these technologies and the results are indeed impressive. To use the UHPWJ as an example consider the following:

Traditional View

Labor
Utilities
Materials
Equipment

Activity Based View

Permitting
Training
Compliance with regulatory requirements
Plan environmental strategies
Operate/maintain environmental equipment
Treat on site wastes
Handle/Dispose of Hazmats
Perform environmental Remediation

To use the ECAM to identify environmental costs to process activities by comparing the old chemical process with the UHPWJ:

Old Process

Handle Hazmats
Treat wastewater
Analyze Hazmats
and Maintain Personal
Protective Equipment
Maintain Environmental permits
Maintain MSDS

UHPWJ

Dispose/recycle metal cake
Provide safety training
Maintain Material Safety Data Purchase
Sheets (MSDS)

The ECAM is a guide is extremely useful in measuring costs which is crucial to the implementation of this state-of-the-art technology. As one would expect the initial capital costs of the UHPWJ can be quite daunting. Engineers must be able to accurately predict short payback periods to justify the initial costs. Under traditional accounting methods, these costs might not be so easily identified. The ECAM allows for these costs to be identified and then can be used in accounting program or software. For more information the NDCEE ECAM is available on the World Wide Web at <http://www.ndcee.ctc.com/inframe.htm>

Challenges that lie ahead for these technologies besides the initial capital investment are to educate the sustainment community about these cleaner and greener technologies. The equipment discussed in this paper is quite complicated and technology reluctance can be a roadblock to implementation. To be fair, some of the technologies are farther along than others

and is readily adapted to a variety of applications. In this case, the UHPWJ is already in several production applications while CO₂ Turbine Wheel requires some additional work before it is placed in production.

Furthermore, no one technology will solve every coating removal problem. Every application depends of the type of substrate, its configuration and of course, the costs. As mentioned previously, funds at the depot level are scarce and P2 projects are closely scrutinized.

To re-emphasize the point made earlier, the reality is that P2 must take a large role in environmental decision making. Commanders and their civilian managers must look beyond the compliance and clean issues of the present. Using advanced technologies serious cost reductions can be realized. When this occurs along with increased readiness, real environmental change can occur.

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Program Outline

- **Statement of Problem**
- **Approach**
- **Technologies and Production Applications**
- **Economic/Cost Validation**
- **Challenges**
- **Summary**



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Problem Statement

- Department of Defense Depot Activities generate large quantities of hazardous materials (HAZMATs) in the painting/depainting of combat vehicles, ships and aircraft
- 80% of Air Force HAZMATs waste created by paint/depainting operations
- Conventional methods costly and time consuming
- HAZMATs expensive to store, monitor and dispose of



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Approach

- Use of cleaner, “greener” technologies for coating removal
- Must go beyond environmental concerns - need for faster, better, cheaper
- Address safety and occupational health issues
- Address issues of airborne particulate, National Emission Standards for Hazardous Air Pollutants (NESHAP) requirements
- Bottomline: Emphasize pollution prevention (P2) by allocating resources to reduce of HAZMAT generation



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Technology Solutions

- **Ultrahigh Pressure Waterjet**
- **Media Blasting - CO₂ pellet**
- **Xenon Lamp**
- **Laser Stripping**



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UltraHigh Pressure Waterjet

- **Uses water spray at 30k to 50k psi to remove flamed sprayed coatings and paint from surfaces**
- **Used in conjunction with programmable robot workcell**
- **Closed system which recycles water and collects residue through filtering system**



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UltraHigh Pressure Waterjet

- Used in engine parts coating removal
- Program to use in paint removal for combat vehicles
- Removes coating in a fraction of the time
- A fraction of HAZMAT generated Vs. conventional chemical means



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UHPWJ Production Applications

- **Corpus Christi Army Depot**
 - T700 turbine engine parts
 - parts stripped in 45 minutes Vs. 8 to 12 hours by conventional chemical stripping
 - Pay back period approximately a year
- **Naval Air Depot - Jacksonville**
 - used on jet engine parts to remove coatings
 - 9month payback, 0% part reject(30% before)



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UHPWJ Future Applications

- **Project to strip paint off combat wheeled and tracked vehicles**
- **Remove top coat and epoxy base coat primer**
- **Goal is to have safer, faster and more effective paint stripping**
- **Mobile unit being designed and assembled for field use**



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Media Blast CO₂ Pellet

- **CO₂ Pellets are used as abrasive media for paint and organic coatings**
- **Pellets shot at surface from high velocity turbine wheel (12000 rpm)**
- **Used in conjunction with programmable robotic arm**
- **Media evaporate and leave paint residue only**
- **Tested in stripping paint from engine container cans and test coupons using a variety of coatings**



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Xenon Lamp

Combines high temperature Xenon lamp with CO₂ pellet blast media.

- **Extreme temperature differences shatter coatings, vacuum captures residue**
- **Time savings - Can strip large aircraft in fraction of the time**
- **Cost savings in labor (masking) and storage/disposal of HAZMATs**



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Laser Stripping

- **Has been investigated in the past to remove inorganic and organic coatings**
- **Recent technology improvements in feedback control and power and beam stability**
- **Potential for great applications especially on more delicate substrates like composites**
- **Has great applications to remove very hard coatings such as powdercoat**



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Environmental Cost Accounting Methodology (ECAM)

- **Developed by the National Defense Center for Environmental Excellence in conjunction with Coopers & Lybrand**
- **Based on Activity based costing**
- **ECAM collects total environmental costs, especially those hidden in traditional overhead costs**
- **Tool for non-accountants to define and compare environmental costs**
- **Applied to coating removal projects**
- **Web site: <http://www.ndcee.ctc.com/inframe.htm>**



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Challenges

- **Clean coating removal technologies contain initial high capital costs**
- **Some technology reluctance, both depots and configuration managers**
- **Funding for full implementation**
- **Educate community to emphasize P2 and away from strictly compliance and clean-up**



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Current Status

- UHPWJ in use at CCAD and NADEP-JAX
- UHPWJ workcell being developed for paint removal on vehicles
- CO₂ is being explored for a variety of surfaces
- Xenon lamp being developed for aircraft and vehicles
- Laser stripping workcell in use at CCAD



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Summary

- Many approaches to problem of stripping which depend on:
 - Substrate
 - Configuration
 - Cost
- Some technologies more mature than others
- Specific application and requirement dictate which method



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