



# *Supersonic Particle Deposition Technology for Repair of Magnesium Aircraft Components*

*Project Initiated in March 2006*

*Project Managers:*

*Bruce Sartwell, Naval Research Lab  
Vic Champagne, Army Research Lab*

# *Use of Magnesium Alloys*

- *Magnesium alloys used throughout the aircraft industry for applications such as gearboxes on helicopter transmissions and gas turbine engines*
- *Use of magnesium alloys expected to increase due to favorable properties:*
  - *40% lighter than steel and 20% lighter than aluminum on a like-for-like strength ratio*
  - *Good damping qualities, absorbing noise and vibration*
  - *Low density means easier, faster machining of components*
  - *High thermal conductivity and good EMI shielding*
  - *Ductile, with ideal casting properties; can be molded into large, thin-walled components at near net shape*
- *Current usage and future increased usage impacted by high reactivity and susceptibility to corrosion (especially galvanic corrosion); relatively soft and susceptible to scratching; adhesion problems of coatings*

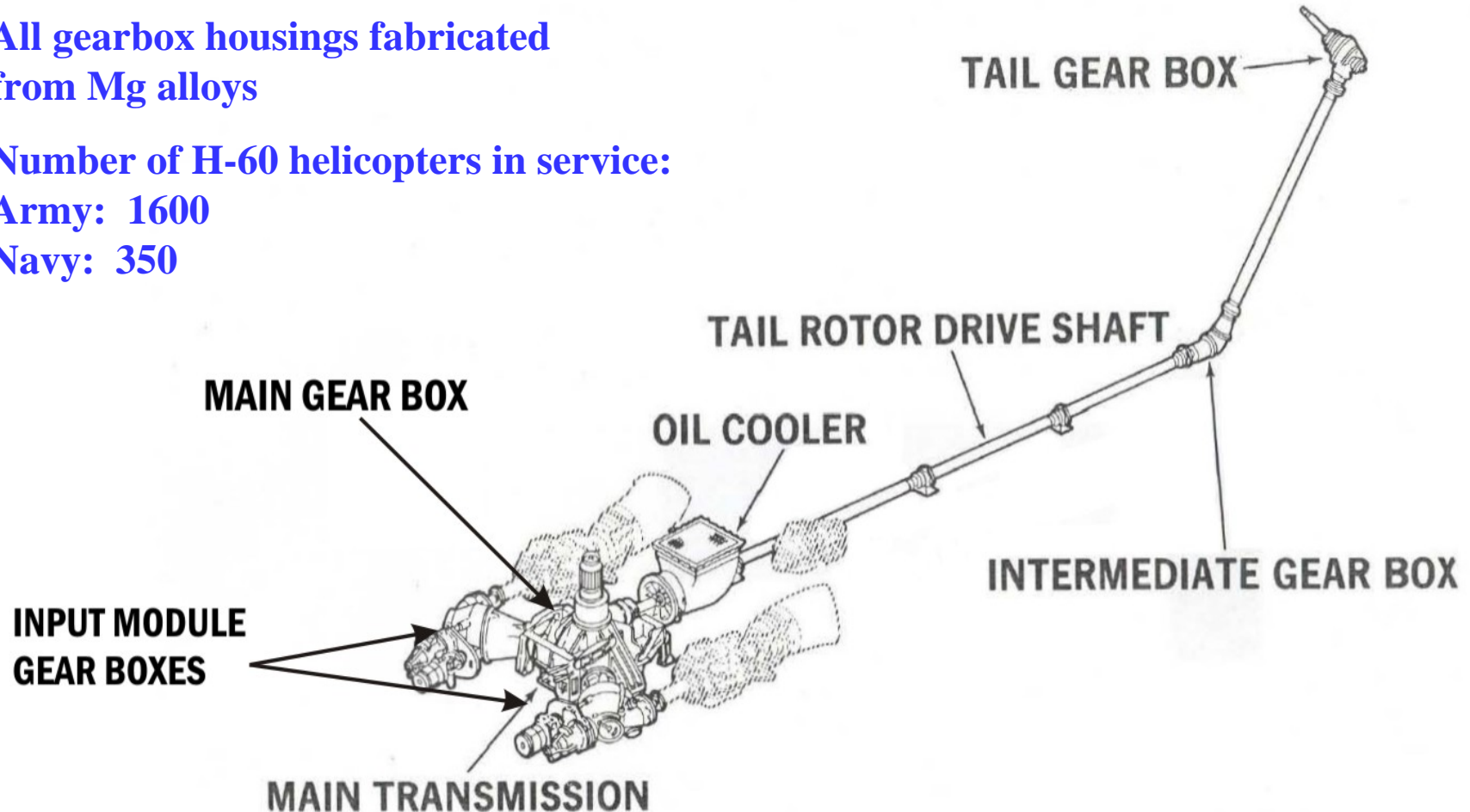
# *H-60 Transmission System Powertrain*

All gearbox housings fabricated from Mg alloys

Number of H-60 helicopters in service:

Army: 1600

Navy: 350



# *Current Methods for Providing Surface Protection to Magnesium Alloy Components*

- *For OEMs such as Sikorsky, surface is hard anodized using the Dow 17 process followed by application of a phenolic resin; for non-mating surfaces, chromate epoxy polyamide primer followed by epoxy paint are applied; for mating surfaces, sealant compounds are used*
- *For repair depots, surface corrosion protection provided by AMS-M-3171 (formerly MIL-M-3171) followed by phenolic resin and primer/paint for non-mating surfaces and sealant for mating surfaces*
- *Dow 17 and AMS-M-3171 processes both involve use of sodium dichromate containing hexavalent chromium; operations will be severely affected if new OSHA Cr(VI) PEL is implemented*

# *Magnesium Alloy Components on Joint Strike Fighter*

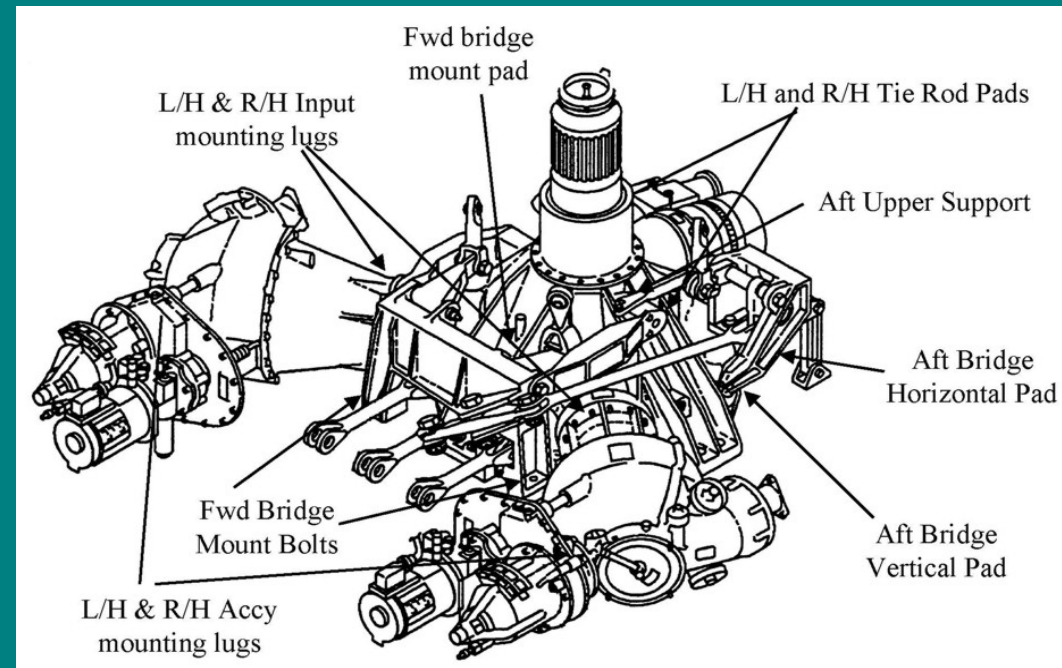
- *Four Mg components in power system*
  - *Generator housing in Power and Thermal Management System*
  - *Lube pump housing, oil tank, and engine start generator housing in Electrical Power System*
- *Dow 17 would normally be used on these components but chromates are on JSF Restricted Materials List; therefore, JSF intends to investigate alternative surface protection processes*



**Power and Thermal Management  
System magnesium alloy  
generator housing**

# Performance Problems With Current Surface Treatment Methods

- **Even with chromated surface treatments, Mg components suffer severe degradation in service**
- **Most corrosion occurs at mating pads, supports, and mounting lugs where dissimilar metal is in contact with Mg; damage is most likely to occur in those locations as well**



H-60 Main Transmission Housing showing areas most susceptible to corrosion

Corrosion on H-53 Tail Gearbox Housing



# *Project Description*

- ***Objective:*** *Demonstrate and qualify SPD aluminum alloy coatings as a cost-effective, ESOH-acceptable technology to provide surface protection and a repair/rebuild methodology for Mg alloy components on Army and Navy helicopters and advanced fixed-wing aircraft such as the Joint Strike Fighter*
- ***Technology Description:*** *SPD, also called cold spray, involves the introduction of a heated high-pressure gas such as He or N<sub>2</sub> together with 1- to 50- $\mu$ m-diameter particles of a metal or alloy into a gun containing a nozzle designed such that the gas exits at supersonic velocities ranging from 400 to 1000 meters-per-second, considerably higher than those achieved by any thermal spray process*

*Because temperature of gas generally ranges from 200° to 400° C, no melting of particles takes place, plus there is no oxidation or decomposition of deposited particles*

# *Project Execution*

## ***Project divided into six separate tasks as follows:***

- ***Task 1: Acquisition of SPD system and installation into Fleet Readiness Center – East (Cherry Point); training of personnel; performing demonstration depositions (Note: CGT System purchased through ASB Industries; delivery expected in April 2007)***
- ***Task 2: Selection of optimum Al alloy/composite coatings; initial coatings to be investigated include:***
  - *Commercially pure Al*
  - *Al-12Si*
  - *5000 series Al alloy*

*Optimum coating determined through microstructure, adhesion, and limited electrochemical/B117 corrosion testing*
- ***Task 3: Demonstration Plan, including development and execution of Materials Joint Test Protocol (JTP)***

# *Project Execution*

- **Task 3 (continued): *Following types of tests anticipated to be required for JTP***
  - *Electrochemical corrosion testing including anodic polarization and galvanic corrosion*
  - *ASTM B117 neutral salt fog and G85, Annex 4, SO<sub>2</sub> salt fog tests on intact and scribed Al-coated Mg panels*
  - *Crevice corrosion tests using Sikorsky protocol*
  - *Field corrosion testing of coated panels on test racks on Navy aircraft carrier*
  - *Fretting fatigue tests using UTRC equipment*
  - *Impact and scratch-resistance testing*
- **Task 4: *Technology transition and insertion***
  - *Establish procedures for coating deposition on candidate components*
  - *Establish surface prep and post-deposition finishing procedures*

# *Project Execution*

## ■ Task 5: *Cost and environmental evaluations*

- *Cost/benefit analysis for application of SPD AI on all relevant components at NADEP-CP*
- *Implementation assessment by Rowan Technology Group for full insertion of SPD technology at NADEP-CP and CCAD*

## ■ Task 6: *Program Management*

- *Preparation and submission of Demonstration Plan (incl. JTP)*
- *Preparation and submission of Final Report*

# *Expected DOD Benefit*

- *Proposed project differs from, for example, project to replace EHC plating with HVOF coatings in that the performance of EHC was considered acceptable but there were ESOH issues*
- *In proposed project, performance of current multi-step process is unacceptable, leading to rejection of many Mg housings at a very high cost*
- *Benefits of proposed project are derived from:*
  - *Contributing to elimination of Dow 17 and AMS-M-3171 processes involving Cr(Vi), a high priority due to pending PEL*
  - *Providing additional corrosion protection to critical areas on Mg housings, resulting in longer life, leading to fewer rejections during overhaul*
  - *Ability to reclaim previously rejected housings*
  - *Potential of using portable SPD units to provide repairs in field, thereby reducing requirements for replacement and return of damaged components to depot*

# *Project Sponsors*

*ESTCP*

*Army*

*Joint Strike Fighter Program*

*Navy ManTech Program*

*Total of ~ \$3.5 million committed over three years*

*Army funding will generally support ARL's coating development work, portion of execution of Materials JTP, demonstration of coating application on Army components, and CCAD/AMCOM involvement in project*

*JSF funding will support DSTO (with sub to ARL) in coatings development and materials testing for F-35 gearbox housings*

*Navy ManTech funding will generally support Applied Research Lab at Penn State (ARL-PS) for coatings development, training of NADEP-CP personnel, and demonstrations of coating application on Navy components*