P-3 SERVICE LIFE ASSESSMENT PROGRAM (SLAP) – A HOLISTIC APPROACH TO INVENTORY SUSTAINMENT FOR LEGACY AIRCRAFT

Nam D. Phan
Head, Support and Rotary Wing Aircraft Strength Branch
United States Navy, Naval Air Systems Command
47123 Buse Road, Patuxent River, MD 20670

ABSTRACT

With the P-3 fleet rapidly approaching the end of its service life, the United States Navy (USN) and its Foreign Military Sale (FMS) partners initiated the Structural Life Assessment Program (SLAP) to address two major airframe degraders – fatigue life and material condition. To sustain this legacy aircraft until 2015 the SLAP team utilized a holistic approach to minimize Total Ownership Cost (TOC) and increase readiness for the P-3. This entails maximizing the intrinsic capabilities of the airframe, enhancing protection to withstand the operating environment, and improving the ability to detect defects. Optimized structural performance of the legacy aircraft can then be achieved by incorporating state-of-the-art and maturing technologies to lower operational, maintenance and support cost.

Keywords: airframe, service life, fatigue, corrosion, coating, sealant, aluminum alloy, NDI.

INTRODUCTION

The P-3 Orion aircraft has provided the USN and its international operators with strategic blue water and littoral undersea warfare capabilities for over 40 years. A Lockheed Electra derivative, the four-engine turboprop P-3A was originally introduced to the fleet in 1962. The aircraft was upgraded two years later with the P-3B, followed by the increased capability of the P-3C in 1968. Currently, the USN operates over 200 P-3C aircraft around the globe. The aircraft has continually proven its versatile capabilities by evolving well beyond traditional missions - blue water Anti-Submarine Warfare (ASW), Search and Rescue, Mining and Anti-Surface Warfare (ASUW) - to include over-land Intelligence, Surveillance and Reconnaissance (ISR) and Precision Strike Targeting (PST) operations (see Figure 1). Today, the P-3C provides the Unified and Fleet Combatant Commanders with a multi-mission, network centric platform at an unprecedented level of operational effectiveness. Unfortunately, the P-3 fleet is rapidly approaching the end of its fatigue life and the material condition of the airframe has significantly impacted fleet readiness.

The Multi-mission Maritime Aircraft (MMA) will eventually replace the aging P-3 fleet as the long-term solution for broad area maritime and littoral armed intelligence surveillance and reconnaissance. However, since the MMA Initial Operational Capability (IOC) is not expected until the FY12 timeframe, the USN will continue to rely on the existing P-3 fleet for the foreseeable future. The USN and its FMS partners - Canadian Forces (CF), Royal Australian Air Force (RAAF) and Royal Netherlands Navy (RNLN) – proactively initiated the P-3C SLAP to re-assess the P-3C fatigue life in 1997. This program also determines structural inspections, modifications, replacements and redesigns necessary to sustain the P-3C fleet to at least the year 2015. Since material condition, obsolescence and supportability/maintainability issues associated with aging airframes significantly affect the TOC, other material and process improvements were also evaluated for potential fleet implementation (see Figure 2). The SLAP Full Scale Fatigue Test (FSFT) confirmed the analytical predictions and provided a test bed for the newly developed materials, designs, and processes (Figure 3).

ANSWERING THE CALL

The P-3 was designed in the early 1960s and 7075-T6 aluminum alloy was utilized extensively in the airframe. Despite its high strength properties, this 7075 temper exhibits extremely poor stress corrosion and exfoliation characteristics. Coupled with a harsh marine operating environment, it has led to significant material degradation affecting TOC and mission availability.

The traditional prevention and control approach had not proven to be effective in addressing the root cause of the corrosion damage found on the P-3 (see Figure 4). Under the P-3 SLAP a holistic methodology was adopted to mitigate this problem. This entails three key pillars – maximize the intrinsic capabilities of the airframe, enhance protection to withstand the operating environment, and improve the ability to detect defects. In addition, certain components will require re-engineering to eliminate existing design deficiencies and improve producibility. Optimal structural performance of the legacy aircraft can then be achieved by incorporating state-of-the-art and maturing technologies to lower operational, maintenance and support cost.

Maximize Intrinsic Capabilities

Several alloys with superior corrosion resistance properties were investigated as possible material substitution for one-to-one parts replacement. 7150-T77511, 7249-T76511, and 7055-T7XXXX have emerged as prime replacement candidates. The full characterization of these new materials by the SLAP team is unprecedented with respect to the number of alloys developed within any given aircraft program.

ALCOA produced 7150-T77511, a proprietary heat-treated temper, for both narrow and wide extrusions. Spectrulite Consortium Inc. and Universal Alloy Corporation optimized the heat-treatment process for the non-proprietary 7249-T76511 wide and narrow products (see Figure 5). Both non-proprietary 7055-T74511 and 7055-T76511, supplied by ALCOA, were evaluated as candidate replacements for narrow 7075-T6511 and 7178-T76 extrusions, respectively (see Figure 6). Aerospace Material Specifications (AMS) for these materials were developed and approved for general use by Society of Automotive Engineers (SAE) Committee D. Over 100 coupons for each alloy were tested to generate A and B basis design allowables, and this data has been submitted for inclusion in the Department of Defense Military Handbook 5 (MIL-HDBK-5). The USN also conducted six-month environmental exposure testing for the new materials aboard aircraft carrier in the Indian Ocean (see Figure 7).

Enhance Protection

The SLAP team evaluated advanced coating and sealant technologies to both improve material performance and reduce life cycle costs. More stringent OSHA requirements dictate the replacement of existing hard coatings, including chrome plating. High-Velocity Oxygen Fuel (HVOF) has been identified as the most suitable process for coating high strength steel components. It is a combustion-driven, high-speed gas jet applied powder metal coating technique.

The P-3 landing gear cylinders and bomb bay actuators were selected for HVOF application (see Figure 8). The certification program includes coupon and full scale testing, as well as in-service trial installations. Laboratory test results confirm properties equivalent to or greater than chrome plating; similar adhesion properties; increased hardness, wear, corrosion & impact resistance; reduced fatigue knockdown and hydrogen embrittlement susceptibility. On the SLAP P-3 FSFT, no anomalies were detected through 59,000 landing cycles, and a complete post-test destructive teardown of the landing gear is underway. To date, the in-fleet landing gear cylinder has accumulated over 2,000 landings and the bomb bay actuators have logged over 600 flight hours without any reported service discrepancies.

Ormecon's Chemie coating product, CORRPASSIV®, is another material and process improvement under evaluation. CORRPASSIV® represents a paradigm shift in protective coating technologies. Acting as an electron acceptor/donor, its polyanilines donate electrons to oxygen and assist in the formation of a metal oxide barrier. Preliminary results indicate that this product could perform better than traditional polymer coatings and perhaps could eliminate the use of chemical conversion coating. Continued investigations on a larger scale are planned.

Improve Detection

Another focus to reduce TOC is the assessment of current and emerging Non Destructive Inspection (NDI) technologies (see Figure 9). These state-of-the-art tools hold great promise for faster detection of smaller damage size with better accuracy. If successful, fleet implementation will result in earlier and less extensive corrective actions required, thereby lowering repair costs and increasing aircraft availability.

The JENTEK Meandering Winding Magnetometer (MWM) can be used to detect crack initiation and to monitor crack growth around fastener holes. It is an array of four sensing elements with a detection sensitivity of 0.03 inches. Mountable on both surfaces and between layers, it was installed at two fatigue-critical locations on the FSFT article (see Figure 10).

Ultra Image International's UT scanning system is capable of detecting over a large area both first and second layer cracks as well as stress corrosion and exfoliation using shear wave C-Scan imaging. It was utilized on the FSFT article outer wings to provide baseline inspections. All inspection results from these techniques are being validated during the test article teardown.

Another promising crack detection technology evaluated is sonic (vibro) thermography. It utilizes infrared cameras to detect the heat generated by rubbing crack faces subjected to high-energy ultrasonic energy. This detection method has been tested at NAS Patuxent River during the inspection of an aircraft engine compressor disk section (see Figure 11).

Redesign

Recurring in-service problems with the upper nacelle longerons, main landing gear truss ribs and landing gear drag struts have contributed to excessive aircraft downtime and high maintenance cost for the P-3 fleet. The current rework/repair/replacement process has not provided a long-term and economically acceptable solution to the fatigue cracking and corrosion damage associated with the existing designs and manufacturing methods. The SLAP team has re-engineered these parts, incorporating design and producibility improvements by taking advantage of the latest technologies.

Nacelle Longerons. The existing 39-part spot welded nacelle upper longeron is difficult to fabricate and experiences cracking at the fore-aft segments' splice. The new design utilizes Computer Numerical Control (CNC) machining of 17-4 PH corrosion-resistant steel billet to reduce the total parts count to six (see Figure 12). This concept not only improves producibility but also eliminates the fatigue problem.

Main Landing Gear Truss Ribs. The machined forging WS167 Main Landing Gear (MLG) Truss Rib is inherently susceptible to stress corrosion damage as well as cracking in the bore of the jack point due to the use of 7075-T6 material. Limited rework tolerances led to frequent parts replacement. The new CNC-machined rib employs the more corrosion resistant 7050-T7451 with increased rework limits. This design will also shorten manufacturing time from six months to six weeks. Vought Aircraft has successfully tested the rib to ultimate loads using the same MLG FSFT fixture.

Landing Gear Drag Struts. The closed 4340 steel tube design of the drag strut promotes corrosion damage due to its tendency to trap moisture. It also hinders internal inspection and the ability to rework. Furthermore, complex manufacturing techniques coupled with a dearth of vendors have made parts hard to come by. The new strut utilizes CNC-machined AERMET 100 steel with an open section design (see Figure 13). This concept will significantly enhance producibility and facilitates inspection and rework.

CONCLUSION

Using state-of-the-art technologies, current engineering tools, and improved materials and processes, the SLAP team has successfully addressed the primary P-3C aircraft degraders. In addition, structural performance of the legacy aircraft has been optimized to achieve lower operational, maintenance, and support costs, leading to a significantly reduced airframe TOC. The necessary inspections, modifications, replacements, and redesigns are now in place to sustain the P-3C fleet and meet USN inventory requirements through at least the year 2015.

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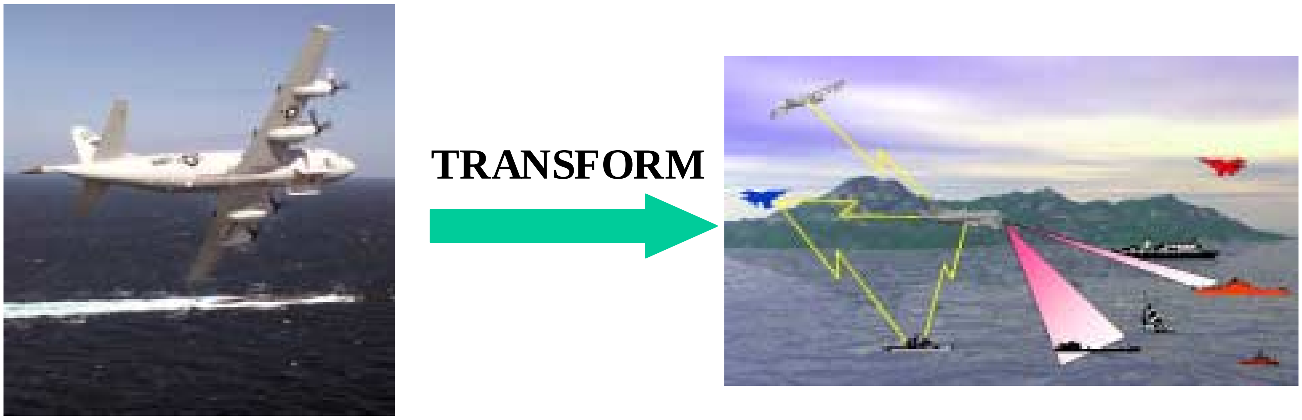

FIGURE 1 - P-3C Mission Transformation

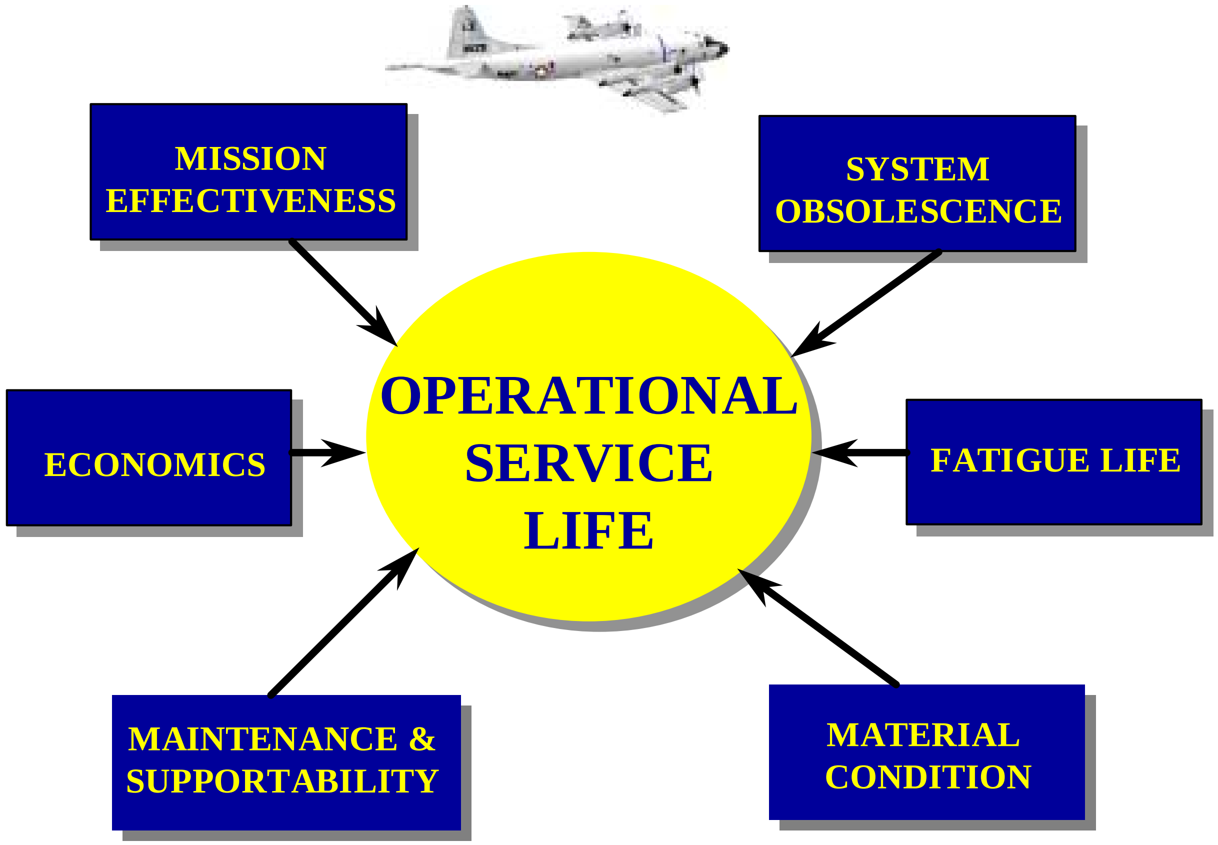

FIGURE 2 – Operational Service Life

FIGURE 3 – P-3C Full Scale Fatigue Test Article

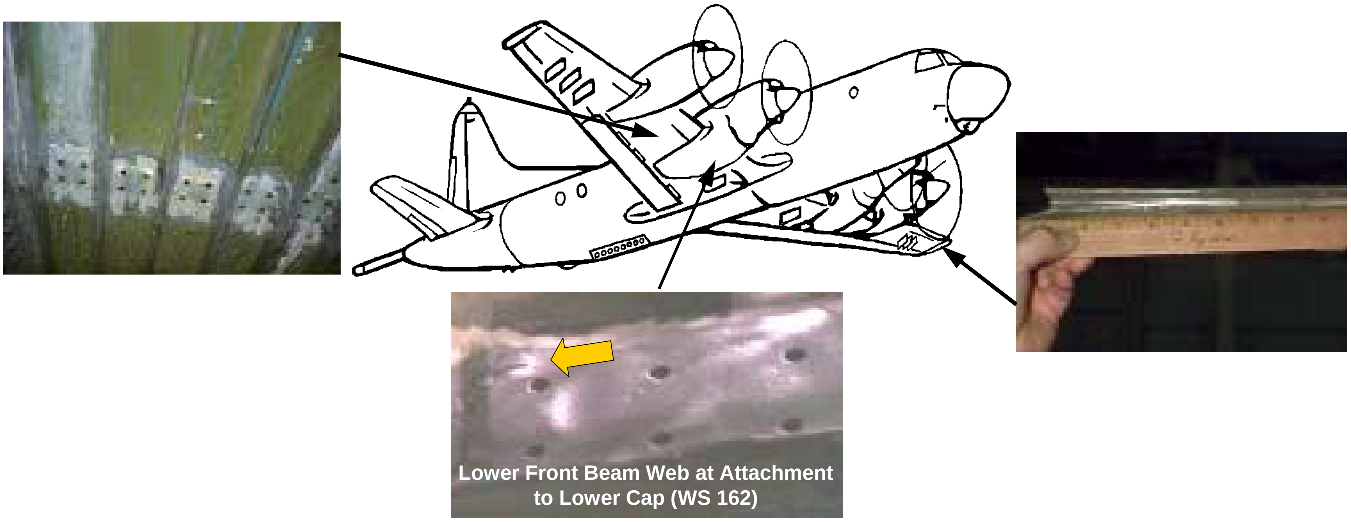

FIGURE 4 – Typical Corrosion Damage on the P-3 Aircraft

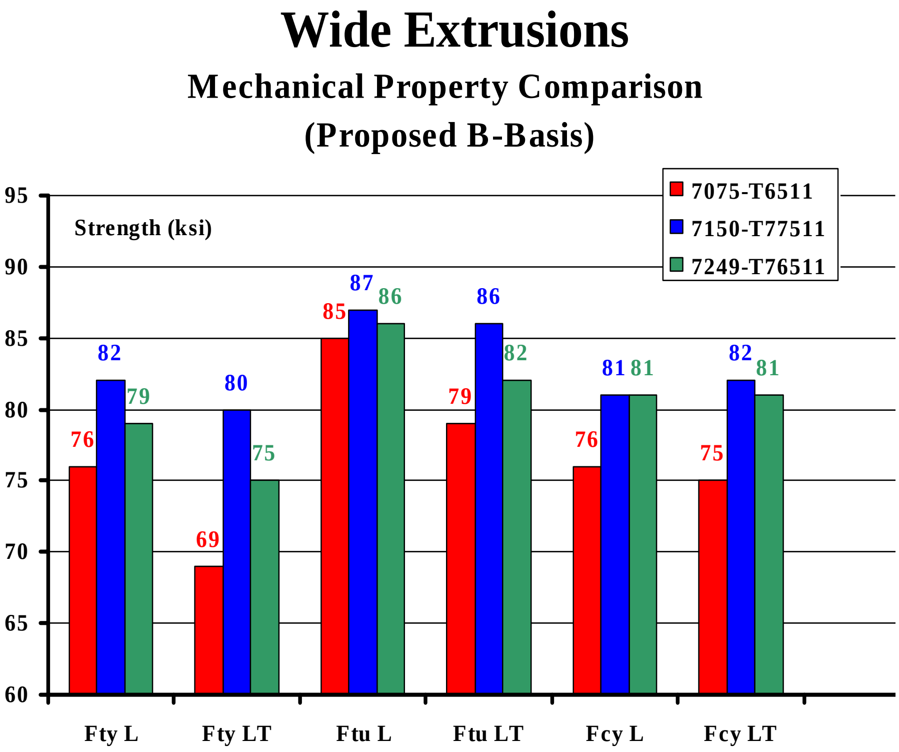

FIGURE 5 – Wide Extrusion Mechanical Property Comparison

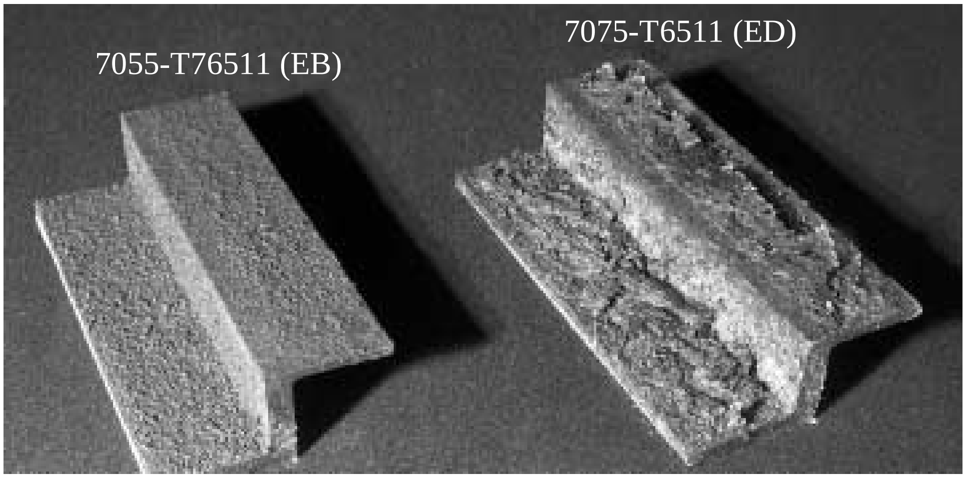

FIGURE 6 - Exfoliation Corrosion Test (ASTM G34)

FIGURE 7 - Environmental Exposure Testing

FIGURE 8 – HVOF Application on the P-3 Main Landing Gear Cylinder and Bomb Bay Actuators

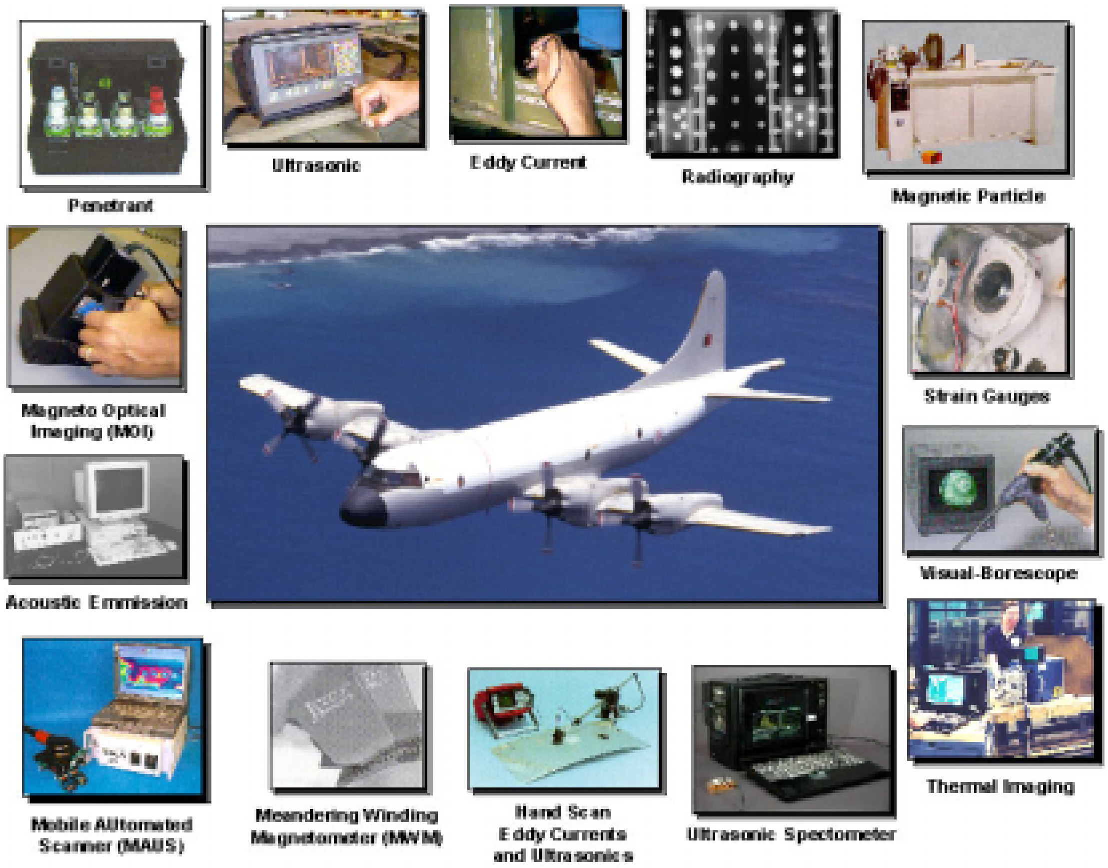

FIGURE 9 – NDI Toolbox

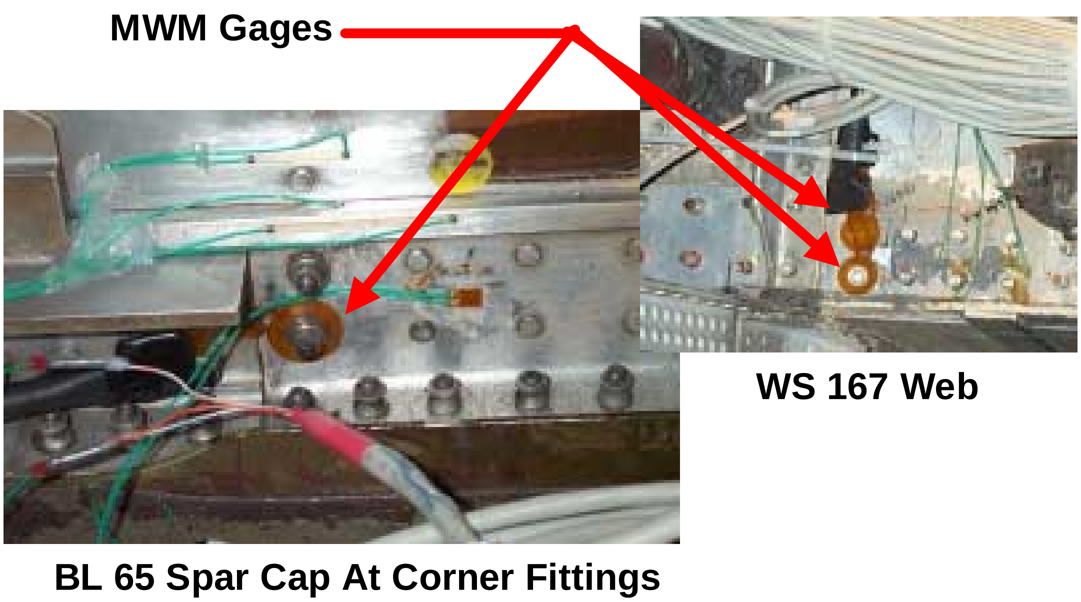

FIGURE 10 – MWM Installation Locations on P-3C SLAP Full-Scale Fatigue Test Article

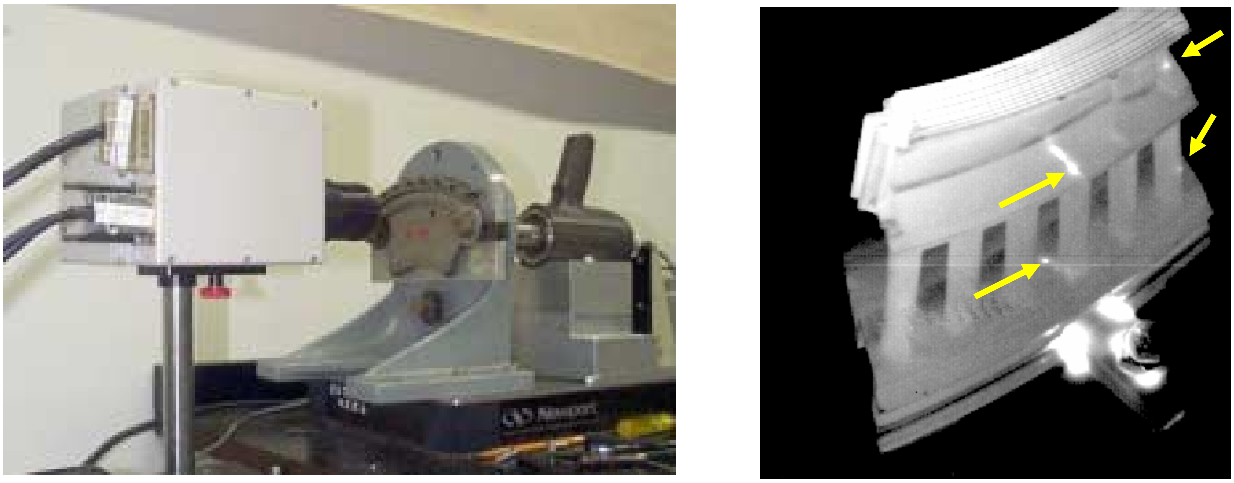

FIGURE 11 – Inspection of Compressor Disk using Sonic Thermography

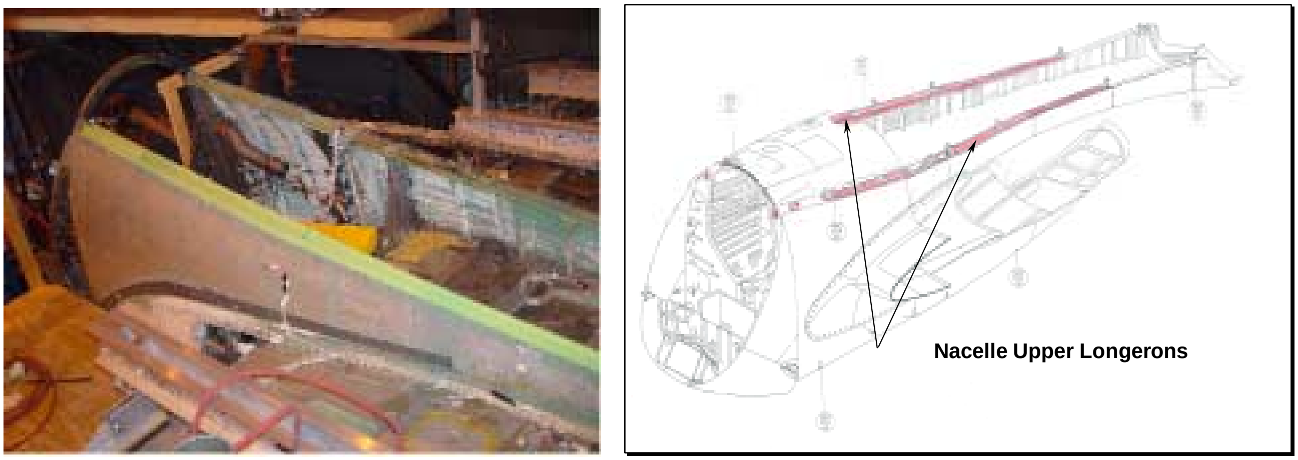

FIGURE 12 – One-piece Nacelle Upper Longerons

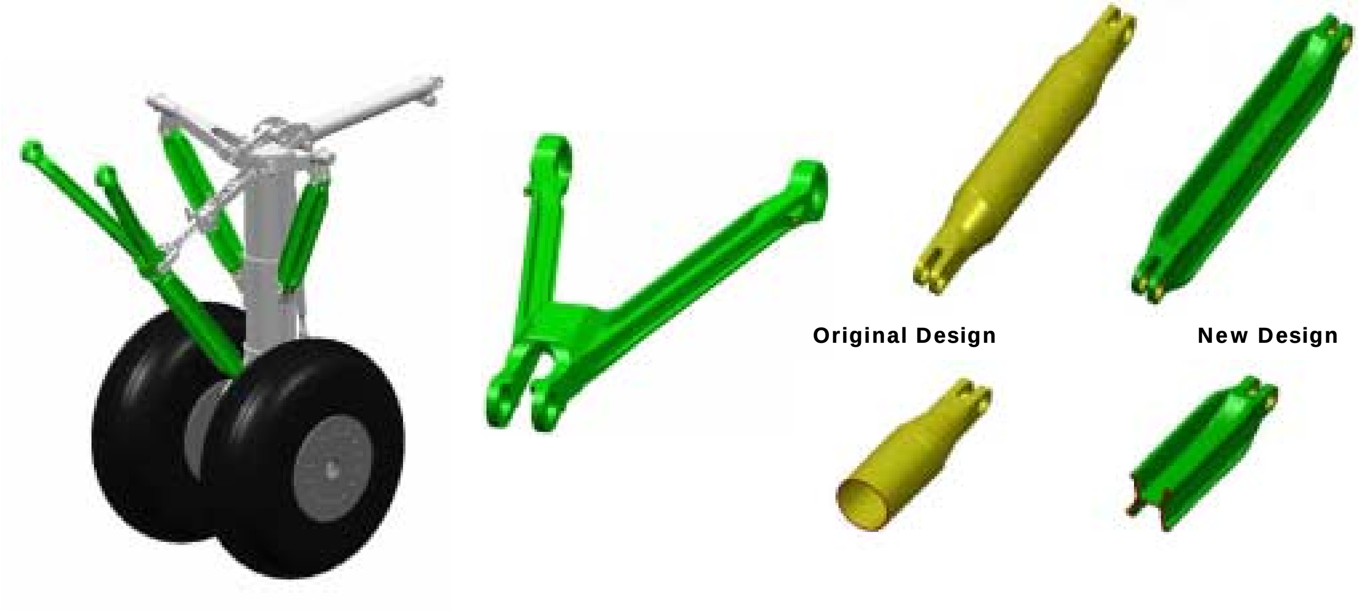

FIGURE 13 – Landing Gear Side Brace and Drag Strut Redesign