Maintenance Steering Group-3 (MSG-3)-based Maintenance and Performance-based Planning and Logistics (PBP&L) Programs

A White Paper

Security, Government & Infrastructure, a division of Intergraph
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1. Introduction

Intergraph’s award of the C-5 Maintenance Steering Group-3 (MSG-3)/Performance-based Planning & Logistics (PBP&L) contracts was a direct result of the goal of the Air Mobility Command C-5 Tiger Team that convened in May of 2000. The C-5 Tiger Team membership included the General Officer Steering Group with representatives from each of the major commands and Warner Robins Air Logistics Center (WR-ALC); depot operations officers; field operations officers; and the Independent Analysis Team (IAT), including Brigadier General Tom Owen, C-5 System Program Director; Stan Garriety, Northwest Airlines Maintenance Programs; Bill Geib, Delta Airlines Maintenance Programs; and several Air Force Reserve maintenance officers.

The C-5 Tiger Team’s charter encompassed the challenges, purpose, goal, and tasks associated with the C-5 aircraft.

Challenges

- What can we do now?
- What can we change?
- What do we need help with to change?

Purpose

- To analyze command practices, processes and policies regarding operations, maintenance, supply, sustainment, and logistics support for the C-5

Goal

- To improve C-5 reliability, availability, and maintainability

Tasks

- Analyze C-5 operational concepts and logistics practices in need of improvement
- Make recommendations for improvement
  - Solutions within Major Command authority
  - Solutions requiring Air Staff/DoD authority

During C-5 Tiger Team discussions, Stan Garriety, a member of the IAT and now a subcontractor to Intergraph, offered information about a commercial best practice maintenance program design tool – the MSG-3 Operator/Manufacturer Scheduled Maintenance Development. This discussion, and the resulting maintenance analysis research, ultimately led to Intergraph’s award of the C-5 MSG-3 contract in September 2002, and the PBP&L contract award in September 2003.
2. **Maintenance Steering Group (MSG) and Reliability-centered Maintenance (RCM) Defined**

MSG/RCM is a decision logic process used to determine what actions need to be accomplished to ensure the availability of physical assets, in their specific operating context, when needed by the operator or user. MSG is commercial aviation’s version of RCM.

2.1 **Background**

Pre-MSG aircraft were delivered with conservative maintenance programs designed exclusively by the original equipment manufacturer (OEM). These programs were resource intensive and expensive, and lacked the end-user input necessary to realize an efficient maintenance program. The airlines wanted to be involved in building scheduled maintenance programs for the aircraft they operated to improve safety, reliability, availability, maintainability, and reduce rising maintenance costs.

2.2 **MSG versus RCM**

There are several reasons why MSG analysis is superior to standard RCM programs on commercial and military aircraft. First, MSG has evolved over 35 years and was designed specifically for aircraft. Second, MSG concepts incorporate a simple and concise inspection convention with standard and enhanced zonal inspections. Third, MSG-based maintenance programs are compatible with hierarchical maintenance concepts, facilitating a shift of structural inspections to later intervals to capitalize on aircraft downtime. In addition, MSG moves systems inspections to lower level inspection intervals, significantly improving aircraft reliability and availability.

2.3 **MSG Process Evolutions**

MSG has experienced several process evolutions throughout the years:

**MSG-1, 1968:** MSG-1, the “Maintenance Evaluation and Program Development Document,” was specifically designed for the Boeing 747-100. After implementing MSG-1, the airlines who operated the 747 realized an immediate reduction in total maintenance costs by an astounding 25 to 35 percent. This caused the airlines to lobby for removal of 747-100 terminology from the document so all new commercial aircraft maintenance programs could be designed using the MSG-1 process.

**MSG-2, 1970:** The airline industry developed and implemented MSG-2, the “Airline/Manufacturer Maintenance Program Planning Document,” as a follow-up to MSG-1. They removed Boeing 747 terminology to allow use on other aircraft. The MSG-2 philosophy was parts-driven, bottom-up, and process-oriented. The first MSG-2 aircraft were the Lockheed L-1011 and the DC-10.

**MSG-3, 1979:** Nine years after the airline industry developed MSG-2, experience and events indicated an update was necessary. The result was MSG-3, the “Operator/Manufacturer Scheduled Maintenance Development Document.” The airlines restructured MSG-3 to be a system-driven, top-down, and task-oriented process. Process-oriented means that on-condition, hard-time, and condition monitoring processes, all RCM terms, were used in MSG-2 to describe inspection tasks. MSG-3 inspection tasks are now written in a specific descriptive format (task-oriented) that is
easier to understand, instead of just citing the task process. The Boeing 757 and 767 were the first MSG-3 decision logic designed aircraft.

2.4 MSG-3 and Aged Aircraft

Refinement through the years has proven that MSG-3’s decision logic works even better on aged aircraft because of the wealth of available knowledge and technical data. Known as empirical data, this information is crucial to building a comprehensive scheduled maintenance program for any asset. Analysts build MSG-3 working groups, leveraging knowledge and experience from field and depot-level maintenance experts, engineers, and flight crew personnel for research and analysis. These working groups determine exactly how each failure consequence affects operating safety and reliability. Once the working groups analyze each structural item or system component, they draft scheduled proactive and preventive maintenance tasks to eliminate or mitigate each failure mode identified during the analysis process. These tasks become the new MSG-3 scheduled maintenance program.

2.5 Hierarchical Maintenance Concepts

MSG-3-based maintenance programs are readily adaptable to hierarchical maintenance concepts, the process of rolling up all lower-level core inspection requirements into the next higher inspection interval. For example, once an aircraft reaches the heavy depot-level inspection interval, all previous core tasks are included in the inspection work cards for a total scope inspection program. This reduces overall inspection flow days (field- and depot-level); improves aircraft reliability, availability, maintainability; and ultimately reduces the amount of time each aircraft spends in depot functional check flight status. No matter how you compute the numbers, the bottom line is a more mission-capable aircraft on the ramp.

2.6 Commercial Aviation Success

In 1968, under the new MSG-1 maintenance program for the Boeing 747-100, United Airlines expended only 66,000 man-hours on major structural inspections before reaching a basic interval of 20,000 hours for the first heavy inspection for this aircraft. Using traditional maintenance procedures, the smaller and less complex DC-8 required more than 4,000,000 man-hours on major structural inspections to reach the same 20,000 hour structural inspection interval. Cost reductions of this magnitude are of obvious importance to any organization responsible for maintaining large fleets of complex equipment.

<table>
<thead>
<tr>
<th>Interval Check</th>
<th>Pre-MSG-3 (Traditional Program)</th>
<th>Post-MSG-3 Analysis</th>
<th>Man-hour Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Months</td>
<td>Flow Days</td>
<td>Man Hours</td>
</tr>
<tr>
<td>18</td>
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<tr>
<td>108</td>
<td>50</td>
<td>37,500</td>
<td>40</td>
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</tbody>
</table>

*Figure 1: Northwest Airlines MSG-3 analysis of the DC-9. Reliability increased to a phenomenal 98.5 percent.*
More importantly, organizations can achieve these large cost reductions without a decrease in reliability. A thorough understanding of the failure process in complex equipment has actually improved reliability by pinpointing the focus on potential failures and facilitating the precise design of proactive and preventive maintenance tasks.

The objective of the MSG decision logic process is to develop a scheduled maintenance program that ensures maximum safety and reliability for the equipment at the lowest possible cost. The economic benefit of MSG maintenance programs is underscored by comparing the Douglas DC-8 against the DC-10. The DC-8 traditional program had 339 scheduled overhaul items. In stark contrast, the MSG DC-10 had only seven scheduled overhaul items. One item no longer subject to overhaul limits in MSG maintenance programs is aircraft engines. Elimination of scheduled overhauls not only led to major reductions in labor and material costs, but also reduced spare engine inventories required to cover back shop maintenance by 50 percent. Engines for large aircraft cost millions of dollars each. This fact alone guarantees major savings over time.
3. **Intergraph MSG-3 Analysis Process**

The Intergraph MSG-3 analysis process is led by a team of skilled analysts and engineers trained in MSG-3 processes. Intergraph has augmented the MSG-3 decision logic tool with the latest version of RCM2 methodologies. RCM2 is especially useful during systems analysis preparation, providing our analysts with step-by-step instructions for building Failure Modes and Effects Analysis (FMEA). Intergraph uses FMEAs to systematically capture all the functions and failure information prior to analysis. The initial analysis focuses on researching all empirical data, to include technical experts, failure data, engineering reports, technical data, and all other information pertinent to end-item maintenance.

Throughout the entire MSG-3 analysis process, Intergraph analysts consider the inherent reliability and safety impact of every failure mode. We ultimately eliminate or mitigate failures by building proactive and preventive scheduled inspection tasks with applicable and effective intervals. As a result, Intergraph helps organizations achieve these goals with minimum total costs, including maintenance and failure costs over time.

### 3.1 Maintenance Effectiveness

MSG-3 analysis is a rigorous, structured process that by-design determines optimal scheduled inspection tasks and intervals. It employs a lean set of building-block inspections consisting of (1) zonal, (2) general visual, (3) detailed visual, and (4) non-destructive. Each successively higher inspection incorporates lower-level tasks. For example, a depot-level, non-destructive inspection for a structural item will satisfy all lower-level visual inspections. The end result is a totally integrated maintenance program.

### 3.2 Standard and Enhanced Zonal Analyses

Standard zonal inspections are general visual inspections applied to each zone, defined by access and vantage point of the inspector. Zonal inspections are not designed to target a specific failure mode, but rather to enhance safety by providing a level of security that ensures visually evident failures will be addressed before they become serious. The commercial airline industry reported that 80 percent of all structural defects are found during zonal inspections. Zonal inspections support the entire maintenance program and keep the operators safe until they reach the “time to find, time to fix” inspection interval.

Intergraph inventories and documents the contents of every zone on the aircraft and routes this data through the MSG-3 zonal analysis decision logic. If an aircraft zone contains only structure, then standard zonal inspections apply. If a zone contains wiring, Intergraph uses the enhanced logic tree and answers a series of logic questions such as, “Are there combustibles in close proximity to wiring? Is there fuel or hydraulic lines in the zone?” If the answer to these questions is yes, then we design detailed and general visual inspection tasks to target these areas to ensure safety. Enhanced zonal analysis is crucial to aged aircraft safety and reliability.

### 3.3 Commercial Best Practice Work Cards

Intergraph enhances maintainer understanding and inspection process standardization through the development and deployment of “commercial best practice” work cards. These new work cards...
include improved graphics, detailed task descriptions, and all pertinent data to accomplish each task with minimal reference to other documents. The use of these superior work cards allows inspectors of any skill level to effectively and independently execute inspection tasks while ensuring consistency through all levels of the inspection program.

3.4 Improved Aircraft Safety

Prior to analysis, Intergraph MSG-3 researchers identify all Structurally Significant Items that have airworthiness and safety ramifications. This ensures the analysis of all critical structures and the development of tasks to avert failures.

Intergraph identifies all systems’ Maintenance Significant Items and places them in the appropriate category (safety, operational, or economic) prior to analysis. This comprehensive decision logic process thoroughly analyzes all safety and protective devices in their operating context and develops appropriate maintenance tasks to prevent any malfunctions.

3.5 Enhanced Reliability, Availability, and Maintainability

Intergraph’s MSG-3 approach improves reliability, availability, and maintainability through the development and use of FMEAs to thoroughly analyze the aircraft systems failure processes. The results include:

- A maintenance program that provides comprehensive aircraft coverage
- Significant improvement in the accuracy and quality of weapon system technical data
- Precise management of scheduled and unscheduled maintenance
- Integration of all maintenance activities while focusing maintainers towards a common goal
- Improved understanding of aircraft systems
- Documentation and implementation of “best practices”
- Compliant with Air Force Operational Safety, Suitability, & Effectiveness
- Provides logical base for Lean-Continuous Process Improvement (Lean-CPI)

Intergraph’s PBP&L program coupled with MSG-3 analysis results in a Lean-CPI driven maintenance program.

3.6 Complete Operational Service Life (OSL) Support

Intergraph’s MSG-3 maintenance programs will support the military warfighter for the entire aircraft operational service life (OSL). Users attain all benefits by performing comprehensive analysis on all aircraft structures and systems. Two significant aged aircraft factors are fatigue damage and corrosion prevention/control. During structural analysis, aircraft maintainers analyze aircraft accidental damage, environmental deterioration (corrosion), and fatigue damage to manage the aircraft health. MSG-3 analysis determines the precise timing of all applicable scheduled maintenance actions to ensure aircraft will be available when needed throughout their OSL.

3.7 Intergraph Maintenance Program Training

Intergraph developed the Intergraph Maintenance Program Analysis and Logistics Architecture (IMPALA) training modules to instruct Intergraph and customer employees on how to perform
MSG-3/RCM2 analyses. Intergraph has successfully combined the best of MSG-3 and RCM2 into our analysis processes for comprehensive asset management. The IMPALA modules are:

- MSG-3/RCM2 Familiarization
- Structural Analysis with Interval and Rating Scale Development
- Systems Analysis with FMEA Development
- Standard and Enhanced Zonal Analysis Programs
- Task Building with “Commercial Best Practice” Work Cards, Task Consolidation, and Individual Tail Number Bridge Packages
- PBP&L with MSG-3 Maintenance Program Reliability Monitoring
- Intergraph Maintenance Program Software Tools

3.8 MSG-3 Maintenance Program Database (MPDB)

The MSG-3 Maintenance Program Database (MPDB) is a comprehensive compilation of the MSG-3 structural, systems, and zonal analyses; task and interval builder with editor; report section; and all technical justification. It serves as a dynamic analysis record, including rationale, for the entire aircraft OSL.
4. **Performance-based Planning & Logistics Program (PBP&L)**

Initial MSG-3 analysis realizes 80 percent of weapon system scheduled maintenance improvements. To gain the other 20 percent, the sustaining organization must implement a robust reliability program to continually monitor and trend aircraft discrepancies. Monitoring and tracking system degradation is crucial to maintaining inherent safety and reliability, and to properly adjust a MSG-3-based maintenance program.

Intergraph designs reliability programs to improve asset reliability and support dynamic MSG-3-based maintenance programs. PBP&L is Intergraph’s reliability architecture, specifically designed to improve aircraft reliability, availability, and maintainability.

**4.1 Intergraph PBP&L Process**

Intergraph’s skilled team of PBP&L analysts use a combination of experience, analytical skills, and software tools to quickly identify negative trends or problem areas – from across the aircraft fleet to specific tail numbers. Once Intergraph identifies system degradation, we thoroughly research the nature of the problem to isolate root cause(s). We study all viable solutions or repairs using return-on-investment analyses, recommending only the most economical and effective solution to our customers.

There are many avenues to correct reliability issues, depending on problem sources or root causes. MSG-3 task and interval adjustments, process improvements, training, supply improvements, and maintenance Reliability Enhancement Visits (REVs), are all possible remedies to correct degradation.

REVs are planned maintenance actions or repairs accomplished during scheduled inspections or opportune downtime. All required resources, including manpower and support equipment, are planned in advance so aircraft can be properly and expediently repaired at a suitable time. The overarching objective is maximum safety and availability while minimizing costs and downtime.

After repair or process improvement, Intergraph’s PBP&L process continually monitors and tracks system health to verify that implemented solutions restore safety and reliability to inherent design levels.

**4.2 PBP&L Reliability Improvement Tool**

Intergraph’s Maintenance Data Collection (MDC) analysis tool is a proactive approach to quickly identifying opportunities to improve reliability. It provides:

- Daily feeds from legacy MDC systems and Air Force Knowledge System (AFKS)
- Maintenance data cleansing for fact-based reliability decisions
- “Dirty Dozen” top-twelve poor performing aircraft
- Complete system degradation “drill down”
- Fleet versus aircraft mission capable rates
- Comprehensive search using work unit codes by aircraft or fleet
- Supply analysis “drill down”
- Automatic and custom report generator with graphic displays
4.3 PBP&L Data Repository

The PBP&L data repository is an “electronic file cabinet” and process management tool that centralizes reliability improvement data.

- Instant management insight for all reliability efforts
- Reliability issues tracked cradle-to-grave
- Comprehensive search capability
- Historical failure data for depot aircraft
- Comprehensive report generator
- Accessible from the C-5 Strategic Airlift Group’s “Aging Fleet Integrity and Reliability Management” (AFIRM) Web site

![Maintenance Analysis Data Repository Block Diagram](image)

*Figure 2: PBP&L Data Repository Block Diagram*

4.4 PBP&L Parts Analysis Tool (PAT)

The PBP&L Parts Analysis Tool (PAT) is a proactive detailed analysis of parts issued or backordered by base, fleet, tail number, or system work unit code

- Daily AFKS feed
- Aids in system reliability tracking by adding the complete supply system “drill down”
- Allows reliability group to intervene before MICAP conditions occur
5. **Intergraph MSG-3 and PBP&L Programs**

The Warner Robins Air Logistics Center (WR-ALC), at Robins Air Force Base, Georgia, recruited Intergraph to perform a MSG-3 review of the C-5 Galaxy, one of the largest aircraft in the world. They needed assurance that all areas of the aircraft would be thoroughly covered and have the proper level of scheduled inspections. Additionally, they wanted a top-down review process allowing them to focus on systems health rather than individual components.

Intergraph is conducting a thorough MSG-3/PBP&L analysis, developing a complete breakdown of all structures and systems on the C-5. All structural items are classified as either safety of flight or other structure. All C-5 safety and reliability issues are being successfully addressed, so they can be defended against all levels of scrutiny. As a result of the comprehensive organizational and depot-level structural, systems, and enhanced zonal analyses, WR-ALC will improve C-5 fleet aircraft maintenance inspections, repair processes, and overall aircraft mission capable rates. A key element of the Intergraph effort has been to re-baseline the C-5 maintenance program by extending aircraft inspection intervals for all C-5 models.

Based on independent return-on-investment analyses, Intergraph’s implementation of MSG-3 and the associated extensions of the C-5 inspection intervals will substantially reduce PDM costs while increasing aircraft reliability and availability over the weapon system’s operational service life. Integrated with a strong PBP&L program, this vanguard initiative will also deliver to the warfighter significant improvements in C-5 mission capability and reliability.
For more information, visit our Web site at www.intergraph.com/sgi or contact:

Michael Reslie  
Senior Business Development Manager  
Office: 478.322.3336  Cell: 478.335.1043  
E-mail: michael.reslie@intergraph.com

Stephen Turner  
MSG-3/PBP&L Program Manager  
Office: 478.926.3355  Cell: 478.320.4121  
E-mail: stephen.turner@robins.af.mil

Michael Rovinsky  
MSG-3/PBP&L Program Manager  
Office: 478.322.3251  Cell: 478.952.0571  
E-mail: michael.rovinsky@intergraph.com

Headquarters  
Intergraph Corporation  
170 Graphics Drive  
Madison, AL 35758

For more information about Intergraph, visit our Web site at www.intergraph.com/sgi.

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