

SRS, INC.

A White Paper

Introducing the Capability and Function of

LMMO

ANALYSIS AND VISUALIZATION

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LMMO

*Prognostics, Analysis, and Visualization capability for the establishment of
Proactive Logistics, Maintenance, and Operations Activities*

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Preface

As a response to Department of Defense (DoD) Joint Vision 2020 logistics and sustainment goals, the military services have begun to seek out and develop the tools necessary to succeed in the 21st century. The capability addressed by LMO (Logistics, Maintenance, and Operations) Analysis and Visualization is Proactive Maintenance. The following CBM definitions come from the US Air Force (USAF) eLog 21 initiative. While these definitions are from the USAF, the capability requirements presented are neither military service specific nor are they industry specific. This paper demonstrates the success LMO has had in meeting USAF requirements, but this is in no way a limitation of the capabilities being discussed. LMO is service branch, industry, and data agnostic. LMO can process any type of data to provide outstanding visualization, analytic, and prognostic products for our customers.

***Condition-Based Maintenance (CBM)** - a set of maintenance processes and capabilities derived from real-time assessment of weapon system condition obtained from embedded sensors and/or external test and measurements using portable equipment. The goal of CBM is to perform maintenance only upon evidence of need.*

- has evolved as follows -

***Condition-Based Maintenance Plus (CBM+)** - expands upon the basic concepts, encompassing other technologies, processes, and procedures that enable improved maintenance and logistics practices. These future and existing technologies, processes, and capabilities will be addressed during the capabilities planning, acquisition, sustainment, and disposal of a weapon system.*

Introduction

As the DoD progresses toward logistics and sustainment goals outlined in Joint Vision 2020, various enabling technologies and concepts must come together to make Condition-Based Maintenance Plus (CBM+) a reality. SRS, Inc. recognizes that a profound requirement for adequate analysis of collected data currently exists. Analysis and prognostic (predictive) capabilities are absolute necessary first steps for successful implementation of CBM+ plans and goals. It is also necessary to present the analysis in a useable format (visualization).

SRS has developed a powerful tool with the creation of Logistics, Maintenance, and Operations Analysis and Visualization (LMO, pronounced “elmo”). The visualization tools, functionality, prognostics, and analysis offered by LMO provide the missing link necessary to accomplish the sustainment and logistics goals desired under the CBM+ program. As an example, in addition to exceptional full-platform data analysis, LMO provides full-platform *data minding*, which refers to continuous analysis updates as new data is added to the database.

Analysis for proactive logistics, maintenance, and operations activities must be timely and comprehensive. To achieve maximum effectiveness for the data end-user, such analysis should be accomplished by a *disinterested* third party. Analysis options proposed by *overly interested* parties are rightly viewed with healthy skepticism. Original Equipment Manufacturers (OEMs), Performance Based Logistics (PBL) providers, and Contracted Logistics Support (CLS) providers *should not* be tasked with providing analysis of data from either *their own or their competitor's* products and services. Independent verification of product and service performance is vital to the success of your proactive logistics and sustainment goals. For the Federal Government (or any other major product end-user) to exercise meaningful oversight capability,

data analysis and prognostics operations must be made available while observing reasonable separation from OEM, PBL, and CLS activities. In the event that an LMO customer is an OEM, the independent analysis and prognostics provided by LMO will enable management personnel to obtain objective information regarding company activities. In all instances, LMO information will be free from potential conflicts associated with competing influences in the management strata and will permit top-level management to make major decisions based on the most current, complete, and unbiased data available.

Background

SRS association with the search for a solution to reactive maintenance and sustainment issues began in late calendar year 2002. Mr. Eric Towe, co-founder and current CEO of SRS, was at that time serving on active duty with the U.S. Navy in Dayton, Ohio. Mr. Towe's program office position allowed him to leverage his combination of knowledge encompassing general flight operations, flight training operations, aviation safety, aviation operations/maintenance standardization requirements, weapon system acquisition, and logistics/sustainment activities. Able to understand myriad issues from various angles within the program office, Mr. Towe served as a Subject Matter Expert advisor, a Project Manager, and as Air Vehicle Integrated Product Team (IPT) Lead. After leaving active duty, Mr. Towe continued his service in the program office as a contract employee performing duties as a Subject Matter Expert and as a Project Manager.

During his time in the program office, Mr. Towe developed several tools to help himself manually manipulate data to meet the program mission. Using available but underutilized data, Mr. Towe achieved some noteworthy success in reducing program costs. The manual research and analysis activities employed by Mr. Towe expended large amounts of time, necessitated development of multiple manual analysis tools, and unfortunately required redundant communication of results to convince stratified layers of concerned persons (Government project team members, OEM staff, and occasionally vendor engineers) that a stated problem either did or did not actually exist. These discovery exercises were made more difficult because data essential to analysis was fractured, inaccurate, and previous analysis was usually lacking. Typically, a given part or system had only undergone analysis if a significant failure had previously been identified.

Because all platform data is not routinely analyzed, significant failure rates of critical systems often go unreported. Differing opinions between the end user and the OEM demonstrate how difficult it is to even reach a consensus as to what constitutes a critical system, let alone a failure. Maintenance personnel have a tendency to emphasize failures that require excessive repair time. Operators have a tendency to emphasize failures that impact mission completion. Requirements personnel must address and prioritize issues that are raised both above and below their particular position in the decision chain. Program office (platform-specific) personnel must address all of these issues and correlate them with their own logistics, engineering, and acquisition strategies. Whether or not a problem is addressed is also a function of the platform budget. Less than adequate manning and a heavy workload restrict freedom to randomly explore unreported issues. Unofficial "until it breaks, don't fix it" methods of operation can be common. Time is simply not available to accomplish meaningful analysis of all relevant platform data.

In early 2005 Mr. Paul W. Smith's warranty and analysis marketing activities brought him together with SRS. Rapid development of key ideas followed. SRS drew upon program office

experiences to manipulate off the shelf technologies and design a solution that would meet the needs of personnel working in multiple program office disciplines. The impetus for these activities was to help end-users shift from reactive maintenance, acquisition, logistics, and sustainment activities to proactive maintenance, acquisition, logistics, and sustainment activities.

CBM+ solutions are needed across DoD and industry to accomplish these goals. Many steps are required to complete this journey, but a necessary first step is effective and affordable analysis and visualization of all pertinent data. Potential data solutions treat the analysis portion as a given, but this is a mistake. SRS has demonstrated an ability that can readily meet CBM+ data analysis requirements and present data in a usable manner (visualization). The LMO Development Team is not associated with any current OEM, PBL, or CLS provider. We can supply our clients with the independent analysis required to achieve meaningful, affordable, and responsible oversight. Best of all, LMO is available *NOW*.

The following section provides information regarding an un-funded proof-of-concept accomplished for joint military program office at Wright-Patterson Air Force Base in Dayton, Ohio. This information is being presented to demonstrate some of the specific capabilities that LMO can provide.

JOINT USAF/USN PROGRAM OFFICE Proof-of-Concept

Activity Timeline

In October 2005, SRS made an initial presentation to a group of Logistics, Project Management, and Contracts Program Office personnel at Wright-Patterson AFB. This presentation pointed out issues of diminished oversight capability associated with Performance Based Logistics and Contracted Logistics Support activities. The personnel in attendance were pleased to note our understanding of their difficulties and were curious to find out how we would be able to assist their office with our solution. Key people from the program office were assigned to work with SRS personnel to determine the scope of a proof-of-concept project to demonstrate LMO. We were tasked to show the program office “something they did not already know.”

Because the SRS presentation was unsolicited, priority for coordination activities was not high. An unexpected gear-up landing at one of the subject platform bases followed closely by Thanksgiving, Christmas, and the New Year’s Holiday slow-downs, brought almost all activity to a complete stop. A spate of high priority (non-LMO) program office meetings after New Year’s and a six-week period of Temporary Duty on the east coast for the key Government-assigned liaison person put us well into March 2006 with little positive activity.

Program office logistics personnel meanwhile conducted manual data analysis of the system associated with the subject platform gear-up landing. The program office analysis involved downloading system information, converting data, manually editing out misidentified activities, constructing pivot tables, and performing manual analysis of the remaining data. The program office analysis was conducted over several months by up to four personnel, all working the issue as their individual workloads permitted.

On 18 April 2006, program office personnel provided the LMO Team with all USAF maintenance data for the subject platform from 2000 through 31 March 2006. Our team immediately set about converting the files to database information and commenced analysis to find information previously unknown to program office personnel. During the course of analysis,

the LMO Team was specifically requested to redirect and provide a special analysis of the Landing Gear System (LGS) information.

On 25 April 2006, results from both a full-system and LGS-only analysis were available and being assembled into a briefing for program office personnel. Once again, low priority and intervening essential activities delayed a presentation until 6 July 2006. At that presentation the LMO Team provided information generated by the full system analysis as well as the LGS-only analysis. A synopsis of that presentation follows.

Full Platform Data Analysis

Analysis Highlight #1 - Landing Gear Sequencer Harness - In-flight Aborts

		C -- In-Flight - Abort	
13 Landing gear	13CAB -- Harness, Gear Sequencer 32-60-02	2001	1
		2002	2
		2004	4
		2005	16
		2006	19

This figure indicates a noticeable increase in activity during the first calendar quarter of 2006, demonstrating a negative development whose impact may require intervention.

Analysis Highlight #2 - Integrated Guidance Flight Control Data Adapter - In-flight No Abort

		D -- In-Flight - No Abort	
57 Integrated guidance flight control	57ACB -- Adapter, Data 23-80-02	2001	13
		2002	82
		2003	80
		2004	73
		2005	109
		2006	56

Note The subject platform is in full rate production. The increase in activities during the first calendar quarter of 2006 as compared to all of 2005 cannot be explained by the addition of new aircraft to the fleet.

Analysis Highlight #3 – Aileron and Trim – In-flight No Abort

		D -- In-Flight - No Abort	
14 Flight Controls	14A00 -- AILERON AND TRIM	2000	2
		2001	1
		2002	18
		2003	17
		2004	34
		2005	18
2006	19		

Initial indication is a dramatic increase in flight control difficulties. A drilldown into associated maintenance activities shows fourteen of nineteen maintenance actions are associated with routine post-maintenance inspection. Maintenance personnel misidentified the Work Unit Code. Rapid access to information quickly resolves any concern about a potential flight control issue.

Analysis Highlight #4 – Landing and Taxi Lights - All

	2005	2006
	Quarter 4	Quarter 1
44BBB -- Lamp, Landing and Taxi Light 33-40-02	117	227
44BBA -- Light Assemblies, Landing and Taxi 33-40-01	16	46
44AAA -- (N) Panel, Caution, Warning, Advisory (Forward) 31-50-01	49	43
44A00 -- LIGHTING SYSTEM	6	36
44AA0 -- COCKPIT LIGHTS	16	29

Note that information is broken down by quarter rather than by year. While not an expensive component, the activity represents a dramatic increase in utilization of maintenance man-

hours. This presents managers with an opportunity to consider merits of a particular component and explore alternative components whose cost and increase in time between replacement can be correlated to save program dollars.

Analysis Highlight #5 – Canopy Latching Mechanism – All

Visits to the aircraft due to this issue increased by a factor of 3.3 between fourth quarter 2005 and first quarter 2006. Parts cost may not be a significant factor, but again the cost of maintenance man-hours may drive acquisition and logistics personnel to explore changes to reduce maintenance cost. More than one visit per flying day fleet-wide average to perform this maintenance on a relatively new pressurized aircraft should be an attention-getter. Such an issue could be identified in the future as the weak link in a safety chain leading up to an accident.

11 Airframe		
11EBB -- Latching Mechanism, Canopy 95-10-16		
2005	Quarter 4	26
2006	Quarter 1	86

Analysis Highlight #6 – IFF Mode S Transponder – All

The removal rate for this item can be determined from the next level of drilldown. The removal rate for first quarter 2006 at AFB 2 was 12 units. This rate of failure falls into the frequency category of “Probable,” significantly greater than 10 per 100,000 platform operating hours. The cost of this item exceeds \$12,000 per unit. The monetary loss results in a criticality rating of “Marginal.” This results in a

65 IFF transponder				
	AFB 1	AFB 2	AFB 3	AFB 4
2004	39	27	9	
2005	54	27	8	2
2006	10	23	3	4

Probable/Marginal MRA value of “9” in the USAF and “IIIB” in the USN. In both cases, the failure rate is listed as undesirable. The USAF MRA value requires Program Executive Officer approval for risk acceptance.

The value of the analysis revealing the issues noted above is difficult to overstate. These issues had not previously received adequate attention because they were not reported as significant problems by operators, maintainers, or the OEM. Analysis of only previously identified problem areas is inadequate. Ongoing full-system analysis is critical for operational safety, proper system health monitoring, cost avoidance, cost saving, and responsible program oversight.

This concludes the initial list of issues raised by LMO full-system analysis. Since the July 2006 presentation, the subject platform program office has assigned its limited manpower to more fully examine each one of these issues.

Specifically-Requested Landing Gear System Analysis

- USAF data provided to the LMO Team comprised of:
 - 330,000+ total maintenance activities representing
 - 650,000+ maintenance man-hours
 - 56,024 Landing Gear System (LGS) maintenance records
 - 94,126 LGS maintenance man-hours
- The LMO Team searched the full database to retrieve LGS *mismatches* (data that had been improperly coded by field maintenance personnel and thus lost to analysis)

- The LMO Team discovered over 1,000 *mismatches*, LGS maintenance activity not associated with the LGS in any way, representing a 2% loss of pertinent data
 - Among the *mismatches*, the LMO Team discovered over 100 *jewels* (lost records that had significant analysis value relating to major system malfunctions and/or failures)
- The Nose Landing Gear (NLG) Spring Strut Cartridge, responsible for a 2005 gear-up landing, exhibited an *undetected* failure rate of 18.5 per 100,000 flight hours during 2001
 - The MRA for this failure rate is Probable/Critical, with a USAF MRA value of 5 (HIGH) and a USN value of IIB (HIGH/UNACCEPTABLE)
 - This failure rate is classified as undetected because it raised no alarms in 2001 and was not addressed as a maintenance issue at that time
- The NLG Spring Strut Cartridge had three issues that were discovered as *mismatches* during analysis. These *mismatches* were also categorized as *jewels*
 - In 2004, a broken cartridge was replaced, creating a failure rate of 1.4 per 100,000 flight hours. This rate corresponded to a classification of Occasional/Critical, translating to a USAF MRA of 6 (SERIOUS) and to a USN MRA of IIC (MEDIUM/UNDESIRABLE)
 - In 2005, just months before the gear-up landing, 1) an improperly installed cotter key was discovered and replaced and 2) an incorrect cotter key was discovered and replaced.
 - *None of these actions were properly associated with the spring strut cartridge Work Unit Code in the maintenance database.*
- A review of all LGS maintenance actions indicated that parts were replaced 42% of the time (23,390 of 56,024 activities)
 - Sixty-nine percent (69%) of part replacement activities (16,050 of 23,390) *were not identified by the proper LGS Work Unit Code (WUC)*
 - Improperly assigned WUCs were either system or sub-system generic, assigned codes identified as “not otherwise coded,” or they were simply incorrect
 - Multiple instances were discovered where maintenance was recorded under WUCs that did not exist
- Analysis confirmed previously identified problem areas involving the LGS
 - Analysis was used to show trends associated with system redesigns and various other issue mitigating activities
 - Improving, negligible, and worsening trends were displayed in a manner that simplified data review and interpretation.

Additional Warranty-related Data Analysis

Subsequent to the receipt of USAF platform data, the LMO Team also received 11.5 months of USN maintenance data. This data was analyzed to demonstrate additional LMO capabilities that

may be of assistance to contracting personnel as well as program leadership. The following warranty-related information was analyzed from the USN data:

- USN maintenance data covered 1 Sep 2004 through 12 Aug 2005
- 19,924.5 flight hours conducted during the data period
- **VHF Navigation Radio** - warranted for 24 months/2,000 flight hours
 - Four removals during the data period
 - Two of four units (50%) under warranty when removed
 - One unit less than three months beyond warranty expiration
 - At more than \$8,000 per unit, total value of warranted parts removed exceeds **\$16,000.**
- **DME Receiver** - warranted for 24 months/2,000 flight hours
 - Two removals during the data period
 - Both units (100%) under warranty when removed
 - At more than \$9,000 per unit, total value of warranted parts removed exceeds **\$18,000.**
- **Mode S Transponder** - warranted for 24 months/2,000 flight hours
 - Ten removals during the data period
 - Seven of ten units (70%) under warranty when removed
 - One unit less than three months beyond warranty expiration
 - At more than \$12,000 per unit, total value of warranted parts removed exceeds **\$84,000.**
- **UHF Transceiver** - warranted for 24 months/2,000 flight hours
 - Sixteen removals during the data period
 - Eleven of sixteen units (69%) under warranty when removed
 - Two units less than three months beyond warranty expiration
 - At more than \$13,000 per unit, total value of warranted parts removed exceeds **\$143,000.**
- **Engine Data Manager (EDM)** - warranted for 2,000 flight hours from DD250
 - Six removals during the data period
 - All units (100%) under warranty when removed
 - At more than \$30,000 per unit, total value of warranted parts removed exceeds **\$180,000.**
- **Data Adapter** - warranted for 24 months/2,000 flight hours
 - Forty removals during the data period

- Thirty-five of forty units (88%) under warranty when removed
 - Three units less than three months beyond warranty expiration
 - At more than \$6,000 per unit, total value of warranted parts removed exceeds **\$210,000.**
- **Radio Management Unit (RMU)** - warranted for 24 months/2,000 flight hours
 - Thirty-nine removals during the data period
 - Thirty-six of thirty-nine units (92%) under warranty when removed
 - Two units were than three months beyond warranty expiration
 - At more than \$6,000 per unit, total value of warranted parts removed exceeds **\$216,000.**
- **5ATI Electronic Attitude Direction Indicator /Electronic Horizontal Situation Indicator display (EADI/EHSI)** - warranted for 24 months/2,000 flight hours
 - Seventy-six removals during the data period
 - Sixty-eight of seventy-six units (90%) under warranty when removed
 - Four units less than three months beyond warranty expiration
 - Atmore than \$40,000 per unit, *total value of warranted parts removed during the data period was over \$2,720,000.*

The parts presented are only eight of one hundred twenty-two warranted parts (7%) on the subject platform. These parts represent **over \$3.59 million** in warranted hardware removed from aircraft during the data period. With less than 20,000 operational hours during the data period, the monetary amount associated with these eight parts was more than **\$179.00 per flight hour**. Due to limitations with the type and amount data provided, the LMO Team was unable to determine if the CLS provider properly discounted the Cost Per Flying Hour (CPFH) based on warranty returns.

Industry data from warranty-intensive sectors (the US auto industry in particular) indicates a less than 10% recovery rate for eligible warranted items (claims are simply not filed in most cases). Considering that warranty recovery activity has not been a high priority in Government operations, it is plausible that the subject platform CPFH does not accurately reflect reduced pricing due to warranty recovery.

Considering that USAF/USN subject platform fleet operations will approach 400,000 flight hours per year by 2013-2014, \$179.00 per flight hour translates into **\$71.6 million per year**. This substantial amount of money, *based on only 7% of the warranted parts of a single military aircraft*, barely scratches the surface of the potential savings that LMO analysis can provide for our customers.

Summary

The LMO proof-of-concept demonstrates qualifications as a multi-faceted analysis tool essential for responsible program oversight. In review, LMO offers the following capabilities:

1. Unbeatable analysis of maintenance activities, parts usage, labor hours, and any other data the customer desires

2. Analysis that not only encompasses an entire platform's history, but analysis that is also continuously updated by the addition of new data (*data minding*)
3. Multiple mathematical probability equations are applied to provide correlated, increasingly accurate, prognostic (predictive) calculations for parts usage, parts life, preventive maintenance planning, and budget forecasting
4. Assembles parts usage information, parts cost information, labor hours, cost of labor, and warranty recovery projections to provide an accurate, updated Cost Per Operating Hour
5. Provides a separate calculation of projected savings from warranty recoveries
6. Ranking of priorities and high drivers both platform-wide and within specific systems
7. When used with multiple platforms, provides priority rankings per platform as described above, but also compiles priority rankings from all platforms combined for use by high-level management personnel
8. Provides automatic alerts based on user-defined thresholds to prevent potentially significant issues from going unnoticed until a mishap has occurred
9. Tracks and identifies trends (negative, positive, or neutral) associated with continuous improvement initiatives
10. Provides trends, usage, and ranking information to suggest continuous improvement initiatives

Conclusion

Whether you represent an entity that is a large-scale end user or an OEM making product decisions that affect your entire corporation's bottom line, LMO can meet your needs. Condition-Based Maintenance Plus is only one of many programs under way across the full spectrum of Government and industry to transform the way we all do business. Soon to be gone are the days of constant reactivity. The future points to acquisition of increasingly proactive processes, as every industry strives to become more lean and efficient.

No matter your data analysis needs, LMO is there. Continuous analysis, prognostication, and total platform/program awareness are within reach. As goals are set for future transformation in any industry, one constant is the need for proper, timely, and effective analysis. LMO is *THE* tool to lead you into the future, and it is available NOW. Let us help you take the first steps to begin building your future today.