Implementing Front-end Logistics Support for NASA Program

Second Generation Reusable Launch Vehicle (2GRLV) Will Replace Space Shuttle as Nation's Space Transportation System

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Recently, I had an opportunity to observe first hand implementation of front-end logistics support within the Second Generation Reusable Launch Vehicle (2GRLV) program at the National Aeronautics and Space Administration (NASA) Marshall Space Flight Center (MSFC). NASA could be considered a sister Service since it was spun off from the Army and they do business much like the Department of Defense. My observations on the 2GRLV program follow. I hope that these may be of use to Army program managers as well as the acquisition logistics community at large.

NASA-developed artist's concept of the Second Generation Reusable Launch Vehicle (2GRLV).
Photo courtesy NASA

A Replacement for the Space Shuttle

The introduction to NASA's Integrated Space Transportation Plan states, "The overall goal of the 2GRLV program is to substantially reduce technical and business risk associated with developing safe, affordable, and reliable RLVs." The 2GRLV program is currently in the Systems Engineering and Requirements Reduction phase. The program office is developing key technologies in several major areas such as propulsion, airframe, and flight mechanics. Major activities in each of the technology areas include developing models, conducting architectural trade studies, and evaluating different concepts. All these activities emphasize minimizing life cycle cost.

Three major contractors will present their system concepts for evaluation in mid-2003. These system concepts must address not only the launch vehicle, but all the resources required to support operation and sustainment of the vehicle such as processing facilities, flight operations, and fleet size. Although the contractors have been given maximum

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freedom to create radically different concepts, the most likely concept seems to be a two stage to orbit, fly-back vehicle. New reusable kerosene first-stage engines are receiving some attention.

The selected concept will be used as the baseline for developing a replacement system for the current Space Transportation System (commonly known as the Space Shuttle). NASA is working closely with the U.S. Air Force to identify areas for partnership in the 2GRLV program.

Key Performance Parameters

As with the Department of Defense, NASA has experienced a significant amount of “belt tightening” in its budgets. Thus, emphasis has been placed on minimizing operating and support costs for all programs. From the start of the requirements generation process, the 2GRLV program has placed high priority on system supportability. The 2GRLV program charter, requirements document, and system management plan all place life cycle cost and launch availability as key performance parameters. From the inception of the program, by assembling and supporting the RMS Working Group, the program office acknowledged the importance of applying an integrated Reliability, Maintainability, and Supportability (RMS) engineering and analysis approach.

Dennis E. Smith, manager of the Second Generation Reusable Launch Vehicle (2GRLV) Project Office at NASA’s Marshall Space Flight Center. Photo courtesy NASA Marshall Space Flight Center

On the other hand, some program elements remain that could benefit from a tutorial on RMS and its extensive influence on system availability and life cycle cost, particularly in light of the fact that failure to meet the program objectives in these areas could be the basis for canceling the 2GRLV program.

RMS Analysis

The RMS Working Group has clearly demonstrated a firm grasp of the RMS disciplines, processes, and tools. This tightly knit team is planning and performing RMS analysis early on, often referred to as front-end analysis. The group's goal is to determine the expected reliability of the system, the projected maintenance requirements, and resultant support structure (repair levels, spares, support equipment, facilities, etc.).

Taking a proactive stance, the RMS Working Group has moved aggressively to develop an advanced RMS modeling and analysis capability. They also have established top-level RMS requirements that supported achieving the program goals, while still giving the competing system contractors maximum freedom to propose their system concepts.

In addition, the group has identified the RMS-related data products that would be needed to properly evaluate and compare these system concepts. Taking their efforts still further, they have also determined RMS analysis and evaluation tasks, identified required input data, and specified desired outputs.

Besides conducting a thorough investigation of available software tools needed to support the RMS analyses, the group has assembled a baseline comparison system database on the predecessor system, the Space Shuttle. This work of identifying and acquiring the needed data and tools lays the foundation for a world-class RMS analysis and evaluation capability within the 2GRLV program for the next two design and development phases.

Planning is critical in any endeavor. The RMS Working Group has meticulously and expeditiously developed a detailed plan of specific RMS-related programmatic and analysis tasks required in the near term (12 months) and longer term (two to five years). (The chart on p. 17 displays the RMS Schedule.) These tasks were mapped to resource requirements and placed on a timeline. The task participants, task lead, and required tools were also displayed. Armed with this information, the group was able to provide the program manager for 2GRLV with a clear picture of RMS requirements.

Team Interaction

The RMS Working Group has implemented the “team” concept well. All RMS efforts are done within an integrated team of experts representing all pertinent areas including RMS, safety, mission assurance, and technical risk management. Other experts are called in as required. The team has good visibility within the program office and does an excellent job of including the competing system contractors and engine subcontractors.

Given the dynamic nature of major programs, the RMS team has been implemented with flexibility in mind. In fact, the team recently decided that coordination and team activity must become more efficient in the future to allow more time for RMS task execution. The open communication and well-grounded relationships among team members will smooth the way for such changes.

One improvement would be to develop a more integrated link between the RMS engineers and the system engineers. There are still system engineers who doubt the need to consider RMS as equal with performance, schedule, and cost when making design trade-offs. Additional interaction is also needed between the RMS and cost teams. Given that at least 60 percent of the life cycle costs will be from support of the system during its service life, it appears inconceivable that life cycle costs can be estimated without the benefit of expertise and analytical results from the RMS community.

Concept Phase

During the concept phase of any major system, data—the raw material for analysis—are necessary to reduce program risk. The RMS team has done a significant amount of data gathering. Since no solid 2GRLV system concept currently exists, most of these data come from the predecessor system, the Space Shuttle, and similar systems/subsystems that are analogous to anticipated 2GRLV concepts.

Much of the analogous subsystem data came from the Air Force. A significant amount of analysis has already been done to identify reliability and maintenance drivers on the existing Space Shuttle. The Program Office gathered lessons learned and conducted root-cause analysis to ensure the 2GRLV program does not repeat the mistakes of the past.

Unfortunately, data voids still exist. NASA chose not to buy the technical data package for the Space Shuttle, and no centralized database was ever developed for recording all the data pertinent to Space Shuttle operations and support. Although expensive, establishing a comprehensive logistics management information database for the 2GRLV program would, in my view, create an effective and permanent data repository for any type of RMS analysis throughout the life of the system.

The RMS team also did an excellent job specifying RMS-related data required from the contractor. For the 2GRLV program, these RMS data must be put on the contract in order to reduce program risk in the areas of life cycle cost and launch availability. The team also fully recognizes another important point. As with other engineering data, RMS engineering data must be available for review during the design process because such data yield little value as a design tool when delivered at the end of contract. Feedback in the form of RMS data is needed during the design process in order for the RMS team to influence design and reduce program risk. Too often, program offices fail to obtain interim access to emerging RMS data.

Likewise, vendors often fail to give adequate attention to RMS during design, and rush to create the RMS data as an afterthought at the end of the contract. The program office must set requirements and metrics that impress upon vendors the importance of integrating RMS in the overall system engineering process from the beginning.

System Testing

In addition to obtaining RMS design data in a timely manner, the acquisition of adequate RMS-related test data is also very important. The RMS data generated from engineering estimates will invariably have errors. The specific type and extent of these errors can be found either through actual test data or during the operational life of the system. Although system testing is expensive, discovery of problems during the system's service life is certainly more expensive in the long run. During engineering development, the RMS team will request a supportability demonstration and an adequate amount of test data to validate the achievement of system RMS requirements. RMS-related testing, however, customarily receives lower priority than other system test-data requirements. Since RMS will be a primary determinant of most of life cycle cost (a key parameter) for the 2GRLV, adequate RMS-related testing should be conducted. The cost of such testing can be minimized if RMS is integrated with other system testing whenever possible.

The RMS Working Group has shown innovation in the area of modeling and simulation. It has already developed fault trees for the Space Shuttle Main Engine of the baseline comparison system Space Shuttle. This subsystem is a major support cost driver for the Space Shuttle. A maintainability model is under development that will assist in estimating vehicle turnaround time based on accessibility factors of the Space Shuttle and comparative Air Force subsystems.

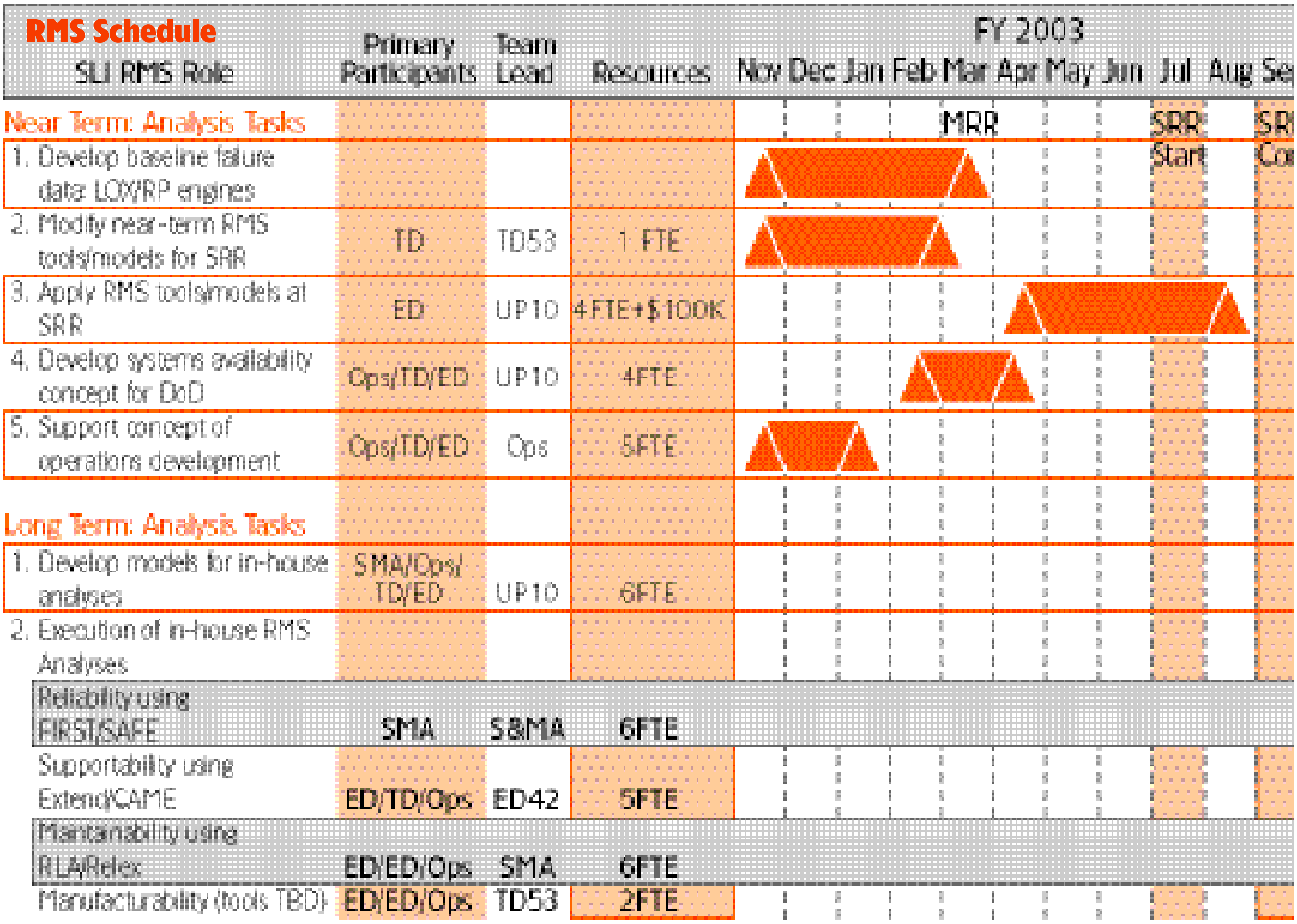
Also, a partial Reliability Centered Maintenance model has been developed. An ongoing process of developing additional models is taking place, and extensive use of discrete event simulation is planned. The experience gained in modeling Space Shuttle RMS will be used to establish RMS goals, allocations, and predictions for the 2GRLV system concepts.

The RMS team should pursue further promotion of its work. Marketing of RMS accomplishments and the significance of its work must be done to ensure that program personnel and NASA executives are aware of the benefits of RMS among all the other program priorities and politics. Important for the RMS team to remember is that persistence is the key. The 2GRLV must meet its life cycle cost goals, and the only way it can do this is through optimized RMS. Even though the RMS community is often seen as a bearer of bad news with its “pay me now or pay me later” message, the system engineers must be shown the impact of their decisions on the life cycle cost of the system.

Cost Savings

A major mandate of the 2GRLV program is to design a system which is much cheaper than the current Space Shuttle. The 2GRLV program has recently expressed concern over the viability of the system due to the lack of evidence in the contractor's concepts that cost is being adequately attacked.

Recent redirection within the program is an important step in saving the program from excessive life cycle cost. This new guidance, provided by the program manager, is a major thrust to consider the entire system—not merely the vehicle—when developing new concepts for replacing the Space Shuttle. The concept contractors and NASA engineers will look at the entire support system along with the vehicle. The program manager interprets the support system



in a broad sense to include, but not limited to, facilities, training, support equipment, parts management, mission planning, and support of this entire support system. The process of obtaining major cost savings requires advances in many support and technology areas as well as keeping the system design simple and robust, even if it adds weight to the vehicle.

Although the integrated RMS engineering and analysis approach will maximize the probability of achieving the 2GRLV life cycle cost and launch availability goals, some major cost drivers exist for which significant improvements must be realized to make the 2GRLV successful.

Sustainment of Thermal Protection System

Sustainment of Thermal Protection System (TPS) on the Space Shuttle is very labor-intensive, and the materials are too expensive. In addition, an excessive amount of infrastructure is dedicated to TPS maintenance and fabrication. A more durable and longer life TPS material is required. The TPS components must be standardized and made interchangeable, and extensive automated diagnostics and prognostics capabilities are needed.

Development of Maintenance Concept

Significant life cycle support costs can be realized if a maintenance concept can be devised that does not require extensive disassembly and inspection of all the subsystems on the vehicle as is the case with the Space Shuttle. The current Integrated Vehicle Health Monitoring (IVHM) project is trying to achieve such a capability.

Design to Existing Facilities

Another key to keeping costs down will be a design that takes maximum advantage of existing support facilities. Obtaining future funding for large-scale construction projects similar to the existing Vehicle Assembly Building is unlikely.

Sustainment and Readiness

The 2GRLV program must also ensure that there will not be a need for a large sustainment engineering force such as with the Space Shuttle. Absolutely necessary is that the 2GRLV program adopt a maintenance philosophy similar to that used by the military to keep its aircraft at high readiness; or even better, to emulate commercial airline operations. Unfortunately, this change may be fought on the political front rather than in the engineering community. Nonetheless, without a major change in maintenance philosophy, virtually certain is that the 2GRLV program will not meet its life cycle cost requirement.

Autonomous Flight Operations

Although not an RMS issue, autonomous flight operations should also be aggressively pursued. However, despite the availability of proven technology, this is another politically charged issue.

Performance-based Logistics

DoD has recently focused attention on the concept of Performance-based Logistics (PBL). NASA has demonstrated a similar focus. As with the DoD PBL concept, the 2GRLV program manager has set out to minimize total life cycle cost while meeting system availability requirements. The program office has also made it clear that it intends to deliver a capability, not just a system. Performance will be based on both demonstrated technical capability and supportability for the life of the system. In so doing, the 2GRLV program office is certainly in step with the PBL tenet of designing a support system with equal rigor as the rest of the system itself.

Tying contract incentives to these objectives is also important. In addition, long-term product support providers and system integrators must be selected based on competition. Finally, implementing continuous improvement in system supportability and reduction in operating costs through dedicated investments in technology refreshment is important throughout the life of the 2GRLV system.

"-ilities"

The 2GRLV system engineers are focusing on the goal of overall system effectiveness since system effectiveness goes beyond performance to include RMS and cost. The 2GRLV program office and the RMS team must consider other "-ilities" in its efforts to design and deliver the objective 2GRLV capability.

Suitability is the degree to which a system can be satisfactorily placed in use, with consideration given to availability, maintainability, safety, human factors, logistics supportability, and environmental impacts. Suitability is a measure of the overall utility of a system to the customer.

Dependability is the probability that a system available at the start of a mission will remain operable and capable of performing its required function at any given time during a specified mission profile. Influencing factors include reliability, maintainability, and supportability.

Usability is the degree to which an operator can complete tasks effectively and efficiently. It is concerned with functionality, ease of learning, ease of use, and overall user satisfaction.

Durability is the ability of the system to resist wear, cracking, corrosion, deterioration, thermal degradation, etc., while continuing to function as designed, under specified conditions for a specified period.

Supportability

One area, often neglected in programs, is computer resources support. Most programs do not have the staff or availability of support organizations to properly address this complicated area of supportability. Yet, given that any 2GRLV concept will include extensive application of computers and software, significant resources (and cost) will be required to sustain all the automated capabilities.

Computer resources support includes maintenance and sustainment of all computer hardware, firmware, and software on the 2GRLV vehicle as well as on all ground support equipment and other operations elements. During system design and development, it also includes test and evaluation hardware and software. Computer resources support will require its own supportability plan. Support for computer hardware, firmware, and related media will include maintenance, supply support equipment, personnel, training, technical data, facilities, packaging, handling, storage, and transportability.

Software sustainment and upgrade will require the same level of detailed planning. Unfortunately, past experience shows that computer resources support is the area that receives the least amount of government insight. As a consequence, guidance to the contractor can be inadequate, often resulting in large cost overruns, schedule slippages, and reactive workarounds. Actions must be taken early in the program to avoid such problems with computer resources.

Supportability Exchange Program

The experience of working with the NASA 2GRLV program office convinced me of the need for an exchange program between the supportability engineering components of the Army at Redstone Arsenal and the RMS team at the NASA MSFC. Such an exchange program would promote interagency cross-fertilization of concepts, techniques, and lessons learned. It would also stimulate creativity and synergy, and ultimately advance RMS modeling and simulation capabilities.

Editor's Note: The author welcomes questions or comments on this article. Contact McPherson at Gary.McPherson @PeoAvn.Redstone.Army.Mil.

Defense Acquisition Management Framework Chart No Longer Available

The Defense Acquisition University will no longer stock nor update the old Defense Acquisition Management Framework Chart. A replacement chart reflecting the new 5000-series changes is currently under design and will be issued once the 5000 documents are revised. As a historical reference only, the obsolete chart can still be found at http://www.dau.mil/pubs/chart 3000/ch_3000.asp.