Finding the Balance in Standard Bus Design

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ABSTRACT: Government, Industry, and Research/University centers are pushing standard bus designs as a way to achieve Operationally Responsive Space and include faster response, lower cost, and adequate performance with respect to mission requirements. This paper investigates the Standard Bus Design trades as they relate to mission performance/utility and areas where standard bus designs may not support the required mission utility. The focus will be on developing acquisition strategies that the government could employ to promote system interoperability without sacrificing mission performance.

INTRODUCTION

In the last several years there have been a number of initiatives started that have attempted to reduce cycle times and/or program costs associated with the development and fielding of space systems in support of the government. This paper investigates the concepts and issues associated with standardization techniques and the resulting impacts on mission performance and utility. Technology and market forces coupled, with the government's desire for quick access to space, have placed emphasis on the need for Operationally Responsive Space (ORS). A standard bus has been associated with this program and there needs to be a clear understanding of what a "standard bus" is supposed to accomplish and what a "standard bus" acquisition strategy implies to the government and associated Industry partner's business cases.

STANDARDIZATION

Standardization means many things to many people. Currently, there is no common definition for standardization in the aerospace industry. The word "standard" has recently been applied to new initiatives in smaller satellite arenas, specifically ORS. However, the most critical issue is not the size of the spacecraft, but the requirements of a program. A large satellite can have standardization, if there are not numerous restrictions in the system requirements.

There are many standardization initiatives currently in work, but they appear to be disconnected. In order to truly implement standardization across aerospace products, there needs to be a Standards Program Office or an agreed upon set of requirements that define standardization.

Standardization can occur at various levels, and different kinds of standardization can occur at each of these levels, as shown in Table 1.

Table 1: Different types of standardization can be implemented at different levels

Level	Standardization	Typical Drivers
Architecture	Mission interface Space to Ground interface (Comms, TT&C, mission planning)? Space to space interface (Comms, servicing, docking, etc)?	Customer
Spacecraft	Bus, payload interface, launch interface	Prime Contractor
Subsystem	Algorithms, specifications, electrical interface (data, command, or power), mechanical interface (subsystem	Major

	module or panel)	Subcontractor
Component	Electrical interface (data, command, or power), mechanical interface (bolt pattern, form), performance	Subcontractor
Piece-part	Performance, form factor	Manufacturer

For example, at the architecture level of a mission, multiple spacecraft may be interchangeable if the command and control interfaces to the spacecraft are standard. The spacecraft do not need to be standard for this interchangeability, only the interface to the ground control portion of the system. Electrical interfaces, including data, command, and power, may be standardized at either the component level or the subsystem level, depending on the spacecraft architecture. An RS-422 data and command interface with 28V unregulated power could be the standard panel interface, which is then converted to each non-standard component as required. Obviously, different parties will drive the standardization at the different levels.

LESSONS LEARNED

Standardization has been attempted on a variety of aerospace programs in the past several decades, with limited success. This lack of major success is due in part to the lack of government support and minimal return on investment to contractors. One of the key lessons learned is that it is difficult to have standard buses for varied mission objectives. It is much easier to have standard subsystems, as they give you more leverage in the requirements and the design.

The Iridium spacecraft program is often used as a positive example of satellite standardization. Iridium was unique from the beginning because it was a constellation of communications spacecraft that were conducting a well-defined mission. delivery schedules and price targets drove the need for innovation in the satellite manufacturing techniques and processes. Also, much engineering was re-used from existing programs and improvements to standardization were made to subsystem parts and production processes. This program shared a variety of subsystems with other programs, which allowed for maximized discounts from vendors. This, in return, lowered the recurring costs of the satellite buses. There were also multiple spacecraft per launch vehicle and each of the satellites used a standard attach mechanism. Iridium program learned that to design in modularity,

you must design for manufacturing and qualify all processes for manufacturing design.

Another way to improve spacecraft design and lower costs and schedule impacts is through investment in human assets. Once program personnel have the knowledge to produce a quality spacecraft in a reasonable amount of time, that knowledge must be maintained and documented or the entire learning process is lost and has to be repeated on the next program. This necessitates the importance of crosstraining these skills to all employees, regardless of program customer and size, to focus on standardization and process improvements. Recent college graduates are a good resource for companies, as they are up to date on the latest in technology and processes and are accustomed to completing projects in a relatively short amount of time.

MISSION AND FUNDING ANALYSES

It is difficult to optimize performance with standard elements. It is easier to optimize reliability and cost by using standard systems and simplifying satellite requirements. Two principle market characteristics have driven the use of standards: funding and mission requirements. Each is discussed in the following sections.

Utility versus Cost

In the small satellite world, small describes not only the size of the satellite, but also the size of the market. With the recent enthusiasm for the small satellite market, and build-up of momentum within the government for small satellite programs, there is still very little funding. As a market, the big money is still in larger satellites with more advanced payloads. These big programs continue to drive the market. And the market drives standards.

Existing aerospace standards can be adopted from other markets (e.g. RS-422 driven by electronics markets), imposed by the customer (e.g. SGLS ground link for command and control, standard testing regimens, etc.), or developed over time by common engineering considerations (28V bus). The first type cannot be changed, but can be replaced. The last two types have significant momentum, and are driven by the market (customer needs, established procedures, common practices, etc.), which requires large capital expenditures to provide incentives for change and to invest in the intellectual and physical capital required to implement the standard. This requires either funding from the customer, to whom all costs are eventually passed, or short term returns to the contractor in order to provide the incentive for the required investment.

Long-term returns historically will not provide the required incentive. It is difficult for contractors to provide the reduced cost of an nth unit by the 1st or 2nd vehicle without investment incentives, locking down requirements very early in a program life cycle, or establishing block buy contracts.

More than simply reductions in satellites costs, there must also be a reduction in space mission costs. It is not only the spacecraft or launch vehicle where costs can be minimized, but also the operations and number of people involved in the program must be improved and reduced from today's standards.

Utility versus Mission Requirements

When these standard buses are developed, they are developed for standardization, not mission optimization, which leads to gaps in required mission performance. Although standards may have long-term or multi-program advantages, implementation of standards that negatively affect mission performance on individual programs will not be warmly accepted without appropriate direction, funding and incentives.

Collective Requirements

The development of standards requires accommodation of a range of options or performance levels. Although standards can be implemented at global levels, local levels, or anything in between, each implementation must include minimum performance levels. Because the minimum performance levels must meet the worst case among the anticipated applications, they will nearly always be higher than specific applications. This is compounded when the applications are broad and have very differing needs, as illustrated in Figure 1.

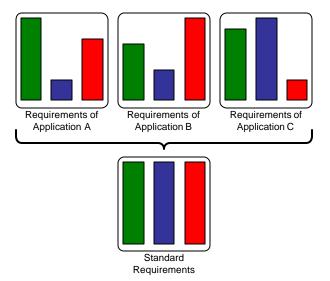


Figure 1 - Minimum standards must meet the requirements of each anticipated application, resulting in higher performance requirements for standards than individual applications

The use of standards for unanticipated applications could result in the standard far exceeding some requirements and not meeting others. For example, a spacecraft bus that meets the launch load requirements for a large group of launch vehicles must be robust enough to handle the worst vibration and acoustic loads of the group, resulting in a heavier structural design. The standard design removes the ability to squeeze the last little bit of performance from the design, such as reducing structural mass to minimum safe margin levels.

Performance Focus

The U.S. aerospace industry is primarily a performance driven industry. The industry is characterized by high value, low volume products with multi-year development. The difficulty of placing space assets into orbit fundamentally shifts the focus of the market. It is much more important to accomplish a mission at minimum risk of failure, than to use the lowest cost provider that may introduce risk to the mission. However, some of the foreign aerospace industries achieve mission success by building more spacecraft for a certain mission and compensating for any failures with extra vehicles already in place. Typically, the benefit of increased performance is more heavily weighted than the cost of increased performance. These factors result in performance being the largest competitive advantage, and therefore the focus of the contractor. If companies want to position themselves for higher performance at lower cost, they can do such things as create separate cost centers or develop incentives for standardization and smaller program involvement. Also, leveraging economies of scale can lower cost and possibly reduce risks with commonly used and space proven components.

Many spacecraft programs are categorized in the larger class of platforms because of technology needs, which mean large payloads and therefore, large buses. There are technology advancements, which allow our thinking to change in some respects and look towards smaller spacecraft as the buses for critical payloads. However, there are few customer requirements that are pushing that change in the aerospace industry. Figure 2 takes a look at the major payload needs and what classes of launch vehicles they can be transported on into space. Even though most of these are hosted on large satellite buses to date, that does not need to be the case in the future.

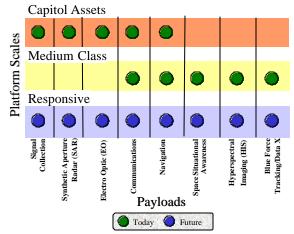


Figure 2 – Most satellite payloads can function on smaller, standardized, responsive platforms

Sacrifices Required for Standardization

Standardization, obviously, is not free. The initial investment to develop the standards and the cost of implementation can be significant; however, existing designs could provide a cost effective transition to improved future designs. Where existing designs are sufficient, they could be used as initial standards and pathfinder technologies for more effective future designs that are tailored to standards from the ground up. There must also be an organized effort to define a need for standardization (i.e. budget), as well as requirements for such an effort, to make this a priority for companies in the aerospace industry.

Standards appear to be most effective in markets where components and interfaces are relatively static or functionally isolated, allowing a standard interface to provide sufficient performance. However, a satellite nearly always attempts to advance the state of the art with each new program, inserting new technologies and optimizing performance. This requires creativity and flexibility to find ways to extract more performance. Standardization in the aerospace industry must be carefully done to ensure adequate performance and flexibility. Flexibility can be shown in such areas as payload accommodation, size, weight and power.

At the subsystem level (the level of the unit that must meet the standard, whether bus, payload, or component) the freedom to modify the design or interface to enhance performance is limited when standards are implemented. This limitation can result in loss of performance. Traditionally, standardized interfaces or designs require a certain level of overhead, such as an increase in mass, volume, power consumption or other resources. This overhead is principally the result of designing for collective requirements and one of the costs of implementing standards.

At the system level (the level that accepts standard subsystems) some sacrifices in subsystem performance, if acceptable to the program, can result in much greater flexibility. For example, a standard payload interface provides cost, scheduling, and risk advantages to the payload and bus. The greatest advantage may be in the flexibility the standard provides to allow replacement of one payload with any other payload that meets the same standards. This flexibility hinges on the acceptability of the performance sacrifice.

Manufacturing Perspective

The use of standard parts, assemblies, processes, and tests has been used in many industries to reduce the cost of mass producing products. The level of non-recurring engineering to develop new designs, interfaces or processes can be significant. Standards of this type also enable experience to be gained by personnel, which often leads to risk reductions. If spacecraft were able to implement more standards of this type, the manufacturing, assembly, and testing could realize large savings. The problem, however, is that multiple copies of identical spacecraft are rarely purchased. This benefit of standardization is unlikely to be realized until spacecraft are purchased in large lots or payload accommodation techniques are redefined and enable the use of the same spacecraft bus for multiple missions. while meeting mission requirements.

Logistics

There are a number of logistical advantages from standardization that benefit mission utility. At the component level, standardization of interfaces provides flexibility to select components from multiple vendors without significant changes to other portions of the design. The ability to replace a faulty component with an alternate, especially if required later in the development cycle, can also reduce mission risk. Reduction of unique parts, or standardization of a particular part across a system or assembly, can reduce mission risk as well, if the parts used are proven and reliable. At the program level or multi-program level, standardization can provide the same types of advantages. In this case, the primary beneficiary is the customer. For vendors, standardization allows them to forecast their needs and realize some sort of production level that can motivate them to invest to manage nonrecurring costs and reduce recurring costs.

Additional advantages are available from the ability for consistent, common training and accumulation of

expertise and experience. Increasing the number of units that meet standards enables these advantages.

Optimization Focus

The implementation of standards causes a change in focus from performance to cost. There are a number of benefits to standardization, each of which essentially results in reductions in cost. This cost reduction, as has been illustrated, comes at the cost of some performance sacrifice, that must be approved/excepted by the customer and eventually the end-user

PROPOSED SOLUTIONS

Market for Standardized Products

The market for standardized products in the aerospace industry has yet to be established. Some of the key requirements to make a satellite program cost effective for a company include quantity buys, inventory of satellites and concurrent satellite build. To prohibit loss of knowledge and assets; there must be a limited amount of time between spacecraft builds. This is due mainly to technical retention and production line efficiencies.

Contractor Size and Interest

The size and interests of the contractors has a great deal to do with their interest in standardization and responsive space initiatives.

Large contractors can invest more resources into developing standard products. Some are less likely to want standard products, which may create increased competition. It is more difficult to sell their advanced capabilities with standard systems. Mission success could benefit from standardization because engineers will be more familiar with particular components and therefore more aware of problems. The extra cross program reviews will put more eyes on every aspect of the program.

Smaller contractors, with a superior product that meets standard requirements, may have an easier time increasing market share, as long as real or perceived risk is not greater, in which case the established contractor would still have the advantage. The small companies have much smaller infrastructures and personnel, which drives them to focus on one project or one standard system, at a time.

Medium sized contractors seem the best positioned for the small satellite market because they have more resources, but a lower overhead cost structure. This provides them with the ability to develop and produce products at a lower cost to the customer with more success. The larger companies can challenge the medium sized contractors' advantages if they have different cost centers for the standards market, performance incentives for like programs and multi-buy procurements across programs.

Responsive Development

The concepts of rapid development of new spacecraft or rapid configuration and launch of warehoused satellites are more easily implemented with some standards in place. Rapid development is more easily implemented when performance and interfaces are standard, and do not require extensive non-recurring engineering to develop a new project. This can only be implemented if the standards have been developed and standard hardware and software have been developed and the customer has agreed to the limitations that the standard entails. If these conditions are met, and the requirements of the new application are satisfied by the existing designs, then the project can take advantage of these existing designs to reduce development time and development cost.

The development of a munitions-style satellite, where a spacecraft can be configured for several payloads for pre-defined missions, can take advantage of standards. A standard payload interface and standard, configurable software can enable several missions to be completed with on-demand hardware. Such a program functions like munitions programs that are configured for various types of warheads, using the same core delivery package. This type of program would require significant development, as it is quite different from existing programs and processes. The United States had a 30-minute notice to launch capability in the 1960s with the ICBM program, which drove the cost of the program. Is the infrastructure and support cost of a responsive capability something that we are ready to support again?

Acquisition Strategies

The best implementation of standards requires the well thought out and well tested requirements with broad enough application to be useful, but limited enough to reduce overhead and inefficiency from trying to be all things to all needs. The standards must meet the overlapping and competing needs of the customer, supplier, and overall industry. Changes in competitive focus that result from implementation of standards must be balanced to ensure broad acceptance. All of this requires investment. Without the investment required to produce a smart standard, the usefulness and acceptance will be limited.

The acquisition process should be changed from a technology demonstration model to a logistics model. Emphasis should be placed on cost and reliability, with more room for negotiation when it comes to the requirements.

Customers and suppliers both can benefit from standards. Increased economies of scale on both the supply-side and demand-side¹ can reduce costs and risks. As discussed earlier, however, the primary focus of the aerospace industry is on performance. The small satellite industry may be more cost focused than the aerospace industry as a whole, but the market for these types of small satellites is small and uncertain enough that the investment required for effective implementation and broad acceptance currently may not be justifiable.

Acquisition of standard subsystems versus buses

Standardization does not need to be applied to the overall system. It can be applied at the subsystem level, which uses standard components¹. The component suppliers compete with each other for market share of the common or standard part. Differentiation between suppliers can be in higher than standard performance (reduced mass, reduced power, higher throughput, etc.) or in meeting the requirements at a lower cost. Parts obsolescence is a potential problem with standard buses that are built many years before their use. This may contribute to an increase in cost in standardization, if parts are not easily upgraded. Table 2 shows types of standards and how different levels of standardization can support different program parties.

Table 2: Different levels of standardization affect different involved parties

Type of Standard	Effected Parties	Notes
Multiple program standard vehicle (e.g. EELV, common satellite bus)	Customer (reduced cost, increase competition of prime contractors) Prime contractor (partial leveling playing field)	Cost savings and operational efficiency or flexibility desired by customer is a disincentive for contractors, but can be offset by large purchases, or the ability for each contractor to capture a share
Standard spacecraft interface	Customer (reduced cost from reduced NRE, after 1 st units)	Sacrifice of optimal performance for reduced risk and cost

	Prime contractor (reduced NRE and risk, after 1 st units)	
Standard component or component interface	Prime contractor (ease of replacement, greater competition from subs) Subcontractor (partial leveling of playing field)	Cost savings and operational efficiency or flexibility desired by prime contractor is a disincentive for subcontractors, but can be offset by large purchases, or the ability for each subcontractor to capture a share

Benefits of Standard Satellite Buses

Even though there are challenges with standardization at the system/segment level, there are benefits that can not be denied. With this initiative, there is more potential for rapid development of new designs based on standardized components. However, block buys are necessary to see this benefit. Smaller, standard buses are great platforms for technology maturation. Highend technologies can be proven on lower cost satellites, so that the high-end assets have reduced program risk and development times. This might also help with technology advancement towards smaller sized payloads for highly critical needs. These programs are also a great place to train young, energetic engineers. They learn about the entire system and see results in a relatively short timeframe.

CONCLUSIONS

For standardization to be successful, it needs to balance mission performance/utility, cost and overall mission success. There are many instances at the subsystem and/or component level where standard interfaces and designs have proven useful. The customer can realize cost savings and mission utility by creating sound acquisition strategies that allow contractors to realize adequate profit margins (it is difficult to get the nth unit cost on the first production unit). In support of standardization, large companies need to respond to new market entrants by creating "Enterprise Zone" cost centers responsible for addressing the emerging Operationally Responsive Space market segment.

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