Apr 26th, 1:00 PM - 4:00 PM

Paper Session III-C - Technology Applications to Improve Launch Vehicle Responsiveness

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Scholarly Commons Citation
Hollopeter, James, "Paper Session III-C - Technology Applications to Improve Launch Vehicle Responsiveness" (1990). *The Space Congress® Proceedings*. 5.
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Technology Applications to Improve Launch Vehicle Responsiveness

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ABSTRACT

The Advanced Launch System (ALS) Program is a development effort to identify and validate new technologies required to improve the nation's space transportation capabilities. Among the many initiatives of the ALS Program is the requirement to dramatically improve the overall system responsiveness.This would provide tactical spaced-based support to the commander in the field in response to a crisis situation. This paper discusses the many technologies, both new and existing, being evaluated for implementation on ALS.

Of major importance is the technique of trading vehicle weight for reduced system cost and improved system operability. Renewed emphasis on the users' requirements have shown that operability and low cost go hand-in-hand. We found that the system features required to achieve operability characteristics like launch-on-time, reduced down time after failure, quick reconfiguration to new payloads, and design for supportability, if incorporated early in the design, will not only enhance operability but will save total system cost because of the efficiencies designed into the system.

Technological advancements such as Integrated Health Monitoring (IHM) and Built-in-Test (BIT), as well as other innovations including off-line processing, launch vehicle final assembly at the launch site and an integrated information processing capability are discussed in detail in this paper.

INTRODUCTION

The Advanced Launch System (ALS), in order to become a routine segment of the defense apparatus, must move space transportation from the realm of scientific experimentation that it has operated in for the last 30 years, to a condition that routinely satisfies the needs of its user, namely to deliver payloads to low Earth orbit reliably and affordably. The ALS therefore must operate like aircraft transportation services and be ready to fly on schedule (Figure 1). This will require the ability to file standard flight plans just as aircraft do today. One method to achieving this goal can be by the use of a new and advanced adaptive guidance, navigation and control system which will provide the mission flexibility required by the users to meet their operational needs. ALS must not only meet the "You call, we launch" motto, but also be able to deliver a range of payload to various orbit destinations on short notice without the long mission planning cycle that is currently required.

The ALS must also take advantage of the capabilities of an integrated computerized information and communication system. Multiple checkouts characteristic of today's launch systems can be eliminated by combining electronic information systems technology with built-in test (BIT) and integrated health monitoring (IHM). In this way the status of the system can be monitored continuously after initial vehicle element checkout through launch. In addition, a database of information can be maintained on subsystem component trends. This will provide operations managers the means for making decisions to fly after a flight failure based on a predetermined strategy without the currently accepted practice of waiting through prolonged stand-downs to resolve anomalies.

The ALS infrastructure has been designed to absorb the surge requirements of three launches in five days with 30 days notice and reconstitution within 60 days through off-line vehicle and cargo processing. Time-consuming critical path tasks such as hydraulic leak checking and ordnance installation and verification are simplified, eliminated or moved off-line through the use of technologies such as electromechanical actuators and laser initiated ordnance. Cargoes are processed and encapsulated off-line and integrated with the vehicle prior to transport to the pad. The result is an austere launch pad design that can be refurbished in a few shifts rather than several weeks as required today.

The GDSS ALS design philosophy emphasizes reliability to minimize life cycle costs and has made weight growth

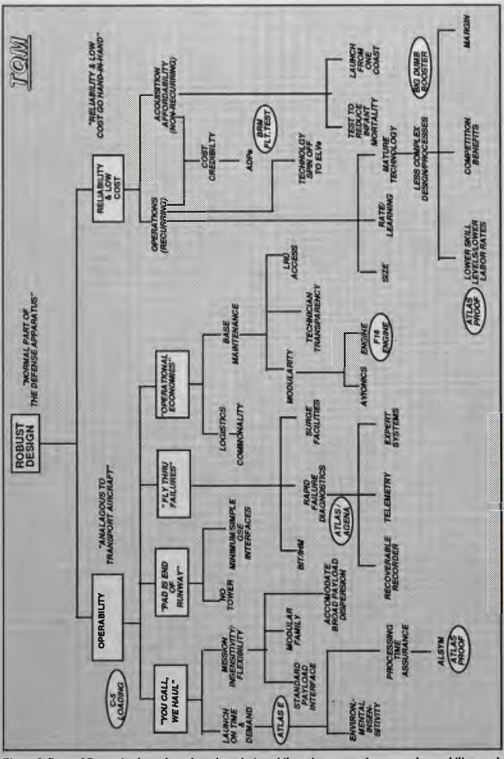


Figure 1 General Dynamics has adopted a robust design philosophy to meet the cost and operability goals.

available to the typically expensive engines, avionics, and other high value vehicle subsystems to allow tradeoffs of greater weight for higher reliability and lower cost. This provides the methodology for meeting a portion the $300/lb of payload to low earth orbit recurring cost goal mandated by Congress for the ALS Program.

ALS can achieve these capabilities affordably by using innovative approaches on high investment cost items such as facilities. The ALS facilities concept incorporates modularity so that the facilities can be expanded easily as the need evolves and funding is made available. To accomplish this, the various buildings required at the launch site have been designed to be expanded in a modular manner similar to the approaches used in North Slope drilling sites.

The use of an all liquid hydrogen and oxygen propulsion system, IHM, BIT, laser initiated ordnance, vehicle hold-down with engines running before launch, full engine-out capability, redundant avionics modules, electromechanical actuators for thrust vector control, and many more innovations all contribute to meeting the operability and affordability goals set for ALS.

System requirements analysis and design tradeoffs are performed using product development teams consisting of representatives from design, operations, producibility, logistics, cost, reliability and others. This concurrent engineering approach ensures that all system effects are evaluated and user requirements are met.

HISTORICAL PERSPECTIVE

The pioneer launch vehicles - Atlas, Delta, and Titan always had either performance goals, time constraints, or weight constraints imposed on them during their developments since they were focused on only one mission requirement and evolved from a weapon system. These launch vehicles never had the luxury of using weight or performance margins to reduce complexity, to reduce cost, to improve operability, to increase reliability or to enable broad growth capability. They were not designed to be " robust ". This has led to the current practice of taking extraordinary caution during the preparation period prior to launch with no flexibility to accommodate a payload change on short notice. Every launch has become a customized, special case situation with unique mission planning requirements and unique interfaces for each payload.

ALS has the advantage of learning from the lessons taught on Saturn, the Shuttle, and the other expendable launch vehicles. The ALS can adopt a robust design philosophy and today's technologies to reduce operating cost and to increase reliability and operability. ALS design teams can employ this technology today better than their counterparts of the '50s, '60s and '70s, due to improvements in analytical tools available.

This approach for the ALS Program has allowed a thorough examination of the cost drivers and risk areas inherent in any new development. An in-depth study of areas like unreliability and associated failure costs have exposed how cost sensitive on-going operations of a space transportation system can be.

ALS OPERABILITY CAPABILITIES

The ALS design must meet the operational requirements that treat the launch vehicles and upper stages as a routine member of the national defense system. This requires designs that guarantee launches on schedule, without the customary delays for repairs or weather. The analogy to military transport such as the C-130 best fits the requirements for readiness expected of the ALS. Analogous requirements/characteristics of an ALS space transportation system include:

"YOU CALL, WE HAUL"
- 95% Probability of Launch with 90% Confidence
- Broad Spacecraft Requirement Envelopes & Interface Standards

"END OF THE RUNWAY"
- Clean Pad - Rise-Off Umbilicals Mated/Checked Out in Factory
- All Ground Support Provided Through Launch Platform - No On-Pad Vehicle Service Towers

"FLY THROUGH FAILURE"
- Recoverable On-board Recorders
- Built-in-test & Automated Test
- Facilities Designed for 35% Higher Operational Rates

"OPERATIONAL ECONOMIES"
- Base Level Maintenance & Logistics
- Engine/Avionics Modularity & Ease of Removal/Replacement
- Commonality
- Technician Transparency

The above summary is similar to transport aircraft requirements. The design solution for aircraft is a failure-tolerant, forgiving design. We have adopted this robust design philosophy for launch vehicles. Figure 1 illustrates the key role "robust design" plays to tie all the requirements together.

ALS PHASE II OBJECTIVES

The ALS Program is structured to validate system design and cost estimates, and to introduce current state-of-the-art technology into the nation's space transportation systems. The Air Force/ NASA Joint Program Office (JPO) has set down the following requirements with priority numbers (#) assigned:

- **RESPONSIVENESS & OPERABILITY**
  - Integration of payload in 30 days or less (#1)
  - Capability to launch 7 payloads (3 vehicles) in 5 days (#2)
  - Capability to substitute a payload up to 5 days before launch (#3)
  - Resiliency for reattaining surge capability in 30 days (#5)
- **COST**
  - Improved reliability (#4), operating simplicity, and reduced development, production, and operating costs
  - Capability to provide launch services at a cost of $300/lb (#6)
- **PERFORMANCE**
  - Capability to launch geosynchronous and polar orbit payloads from either coast
  - Capability to launch 160,000 lbs to polar orbit or 220,000 lbs to 28.5 degrees inclination in low earth orbit
  - Designed-in 10% margin on payload lift capability
  - Engine out provides > 0.98 mission reliability
  - 3 sigma variations in performance/ operating/environmental parameters
  - Cargo shroud designed with a dynamic volume of 33 feet in diameter by 80 feet in length
  - Capability to launch 5,000,000 lbs of payload per year to low earth orbit
  - Flexibility: efficiently accommodate broad range of payload sizes, weights, and delivery points

The cargo to ALS interfaces must be standardized to allow rapid changeout of payloads should the tactical or strategic military situation dictate the immediate launch of an unscheduled priority payload. The ability of the C-130 loadmaster to quickly load various combinations of weapons and cargo is the readiness capability model for ALS to accommodate rapid mission changes.

To accomplish this, the ALS must achieve a simple interface at the launch pad that minimizes the mechanical, electrical and environmental connections. The pad design will have all vehicle ground support services supplied through the launch platform. Cargo services can be provided with a simple service mast also supplied from the pad through the launch platform.

The ALS family of launch vehicles uses common designs and identical subsystems which provide technician transparency across the family. Technician training investment is minimized and experience applies even as new vehicles are added to the inventory. A modular approach for avionics and propulsion components coupled with design for supportability which provides easy access for component removal/replacement will promote operational economies in maintenance and logistics. Commonality will further reduce the logistics tail by requiring fewer numbers of unique spares.

ROBUST DESIGN MEETS ALS REQUIREMENTS

Our studies have shown that one key system philosophy, Robust Design, embodies all these challenging requirements. Robust design can be thought of as flowing down in a series of relationships in which each successive level provides the means to achieve the end objective as shown in figure 1. Operability coupled with high reliability and low cost (which we have found go hand-in-hand when the cost of failure is included) are the driving requirements for ALS.

Robust Design sets the stage for implementation of total quality management, TQM. Larger tolerances, simpler processes, larger design margins and "forgiving" hardware and systems allow us to achieve overall system goals.

DESIGN FOR OPERATIONS & SUPPORT

In keeping with the ALS philosophy of robustness, operations drivers and associated design implementation were identified (Figure 2).

An example of reducing system cost is through the use of common GSE, tools, and procedures for manufacturing and operations. Common equipment and procedures:

- Simplify training.
- Simplify procurement.
- Promote safety (Equipment familiarity)
- Reduce costs (Hardware/Manpower)
- Standardize interfaces.

Operations Driver For Robust Design	Design Implementation Example
Enhance maintainability	Partitioned System Software
Reduce cost of security	Secure Military Base Launch Sites
Shorten construction time, lower cost	Modular Facilities Construction
Flexibility for surge, contingencies	Integrated Mfg-to-Launch Personnel System
Shorter timelines, fewer people	Processing Automation
Reduce cost, simplify GSE/tooling	Widened MFG/Ops Tolerances
Reduce system Cost, and inconsistencies	Common GSE, Tools, Procedures for Mfg and Ops
Reduce software development cost	Expert System Software Generator
Total system integration	ALSYM / Operations Test & Training Center
Simplify test and checkout	Conservative Safety Factors
Design in quality	QFD

Figure 2 We Have Identified Operations Design Implementation Examples for Robust Design

- Allow use of personnel for both final assembly and launch processing operations

OVERALL SYSTEM DESIGN

Trading subsystem weight for system cost and operability improvement has been a General Dynamics philosophy throughout our ALS activities. This approach has led to the concept for providing an affordable launch vehicle program that can be structured to meet the Air Force's funding constraints and the short term mission needs, with planned growth to meet the long range space transportation needs of the country. The high energy associated with our all-LO2/LH2 vehicles is the enabling characteristic because it results in shallow recurring cost versus payload weight sensitivities. This allows upsizing our vehicles to capture cost reductions - achieved through simpler but heavier designs - at a net reduction in vehicle recurring cost. This same simplicity greatly improves system operability through both Vehicle and Operations Segment features.

Our generic approach to defining cost/weight relationships, which reflect the ALS simplicity philosophy, applies to any element of significant cost at the component, subsystem, or system level. The starting point is a traditional aerospace Cost Estimating Relationship (CER). Points on it - such as Design Concept #1 (Figure 3) - are typically performance-optimized, and complex. The SSME is a good propulsion system example.

By challenging requirements which drive high performance and eliminating as many as possible, designs such as Concept #2 (Figure 3) can be developed. Typically, these are heavier and cheaper for a given set of requirements and can be represented by CER #2.

By progressively incorporating design and process simplicity while still meeting the basic requirements, heavier cheaper options, such as Design Concept #'s 3 & 4 can be developed. They lie on CER's #'s 3 & 4.

Connecting the locus of points for a series of design concepts (#1-4), which meet the same set of requirements, results in the cost characteristic curve shown. Note that at the higher weight values the curve flattens and then turns up. From this we can see that simplicity yields lower cost, but that eventually the law of diminishing returns applies!

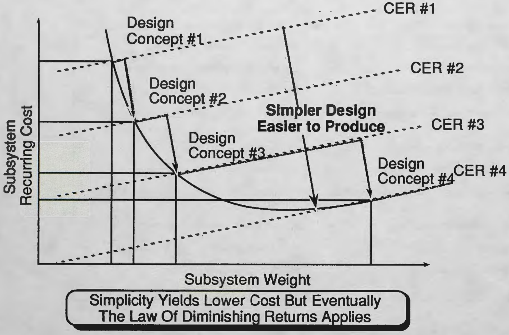


Figure 3 Traditional Cost Estimating Relationships Can Be Adjusted By Incorporating Design And Process Simplicity

Our goal is to develop such cost/weight characteristics for every system, subsystem, and major component. By comparing these cost and weight characteristics for various subsystems against a common scale we can see how significantly their sensitivities and ranges of variation differ.

The 100% points on both axes of Figure 4 correspond to our baseline vehicle. Similarly, the data point in each subsystem is plotted at its appropriate coordinates. Each data point is also shown at a position along its own subsystem cost and weight characteristic which corresponds approximately to where we believe our current baselines lie.

The width and height of the various regions reflects our experience with defining low cost, simple hardware suitable for ALS, as well as our experience with traditional flight vehicle hardware. The tall, narrow range of engine variation reflects the opportunity for substantial cost reduction at relatively small weight growth. The wide, shorter range of structure variation shows both the potential for cost reduction, and the large weight swings associated with any significant cost change. The avionics range shows that subsystem weight is insignificant but that there's little more to be gained in cost reduction by weight increase anyway.

For structures, which constitute approximately 60% of the vehicle inert weight, the potential benefit from adding or subtracting weight depends largely on the position of the design point on the cost/weight characteristic curve. In this example, it is clear that on the subsystem level, a modest decrease in subsystem cost is still possible, but at a substantial weight penalty. Conversely, moving to the left on the curve, that same increment of weight could be removed from the structure, but at a higher cost penalty than what could have been saved by adding the weight. Thus, on the subsystem level, the obvious choice would be to drive the design point to the optimum (point of zero slope). However, on the system level, it is possible that the cost penalty for subtracting an increment of weight from the structure may be overshadowed by the cost benefit of adding that increment to an item with a steeper slope such as the engines. Thus, it is essential that the decision to add or subtract weight from a subsystem be based an understanding of total system implications.

Although further weight increase offers little benefit in avionics subsystem cost reduction, there is a significant system cost reduction which results from an increase in avionics subsystem cost. This would seem paradoxical at

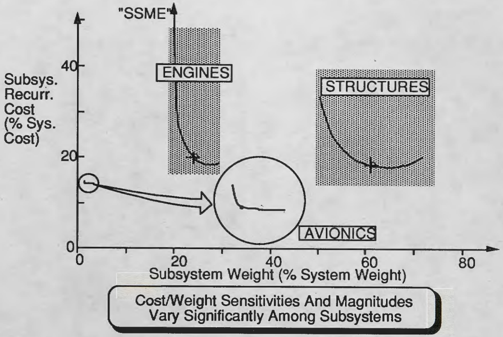


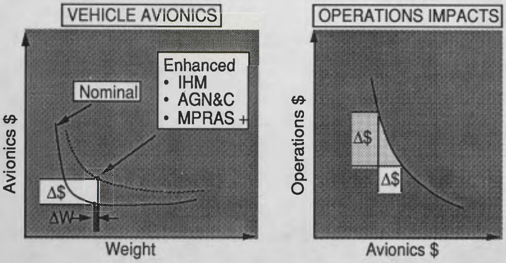
Figure 4 The Trade of Weight for Dollars is Different for Each Subsystem.

first, but in fact provides to be a good example of system level optimization. The starting point depicted in Figure 5 is a "nominal" avionics system which fully meets basic subsystem requirements. Moving up to an enhanced system requires little weight and moderate cost. The enhancements include Integrated Health Monitoring (IHM), Adaptive Guidance, Navigation and Control (AGN&C), and an embellishment to our Multipath Redundant Avionics Suite (MPRAS) to provide extended reliability. With the enhanced system available in the baseline vehicle, many operations tasks are significantly streamlined. Because the operations cost to avionics cost ratio is approximately 2:1, the result is a win-win situation: a system cost reduction combined with an operability improvement.

Much of our Robust Design philosophy is very similar to the "Big Dumb Booster" concept of the early 60's. Figure 6 illustrates that our ALS philosophy goes beyond that of the "Big Dumb Booster" ideas by taking advantage of matured technology and by adding engine out from lift-off, starting all engines and checking them out before release, and adopting liquid hydrogen and liquid oxygen propellants with environmentally clean exhaust products.

The rocket engine contractors have adopted similar design philosophies. They are striving for a simple design that includes the following approaches:

- Reduced performance and relaxed requirements on allowable engine weight permit simpler, lower chamber-pressure propulsion designs (about 2000 psia as compared to 3000 psia for the current Shuttle Main Engine)
- Eliminated the requirement for boost pumps, throttling capability, and closed loop control
- Use of less-costly, low-pressure pumps, which are made possible because of the reduced ALS engine pressures
- Increased use of castings in place of machined and welded forgings
- Use of materials that cost less and are easier to machine as a result of the ALS engine's reduced pressure, lower temperature and higher allowable weight specifications
- Designed to require fewer parts, e.g., a simplified combustion chamber that significantly reduces the number of unique parts and weldments compared to the SSME



Investing In Added Vehicle Avionics Reduces Operations And System Costs While Enhancing Operability

Figure 5 Increasing Avionics Capability Can Reduce Operations cost By a 2 To 1 ratio

- Designed with much greater than usual tolerances to virtually assure manufacturing quality
- Use of generous margins to achieve process control without inspection to meet the DoD Total Quality Management goals

The use of Robust Design precepts by the vehicle and engine manufacturers therefore leads to an ALS design that is less costly, more reliable and more resilient than any current launch vehicle system.

The following summarizes system design philosophies adopted by General Dynamics on the ALS Program:

- Optimize system for low cost, high reliability and improved operability
- Operations/production drive vehicle design
- Trade vehicle weight for improvements in system cost and reliability
- Modular approach for flexibility, robustness, cost reduction and future technology insertion
- Introduce maturing technologies to existing ELV's to reduce costs and improve operability
- Focus technology demonstrations on high-payoff areas
- Simplified design increases supplier selection

The ALS design has therefore led to the selection of a family of launch vehicles that embraces all the above system concepts to produce a low cost and low risk design. This family of launch vehicles can be built up from a very few common elements to meet the need for a very resilient and flexible transportation workhorse.

MATURE TECHNOLOGY

The ALS Program incorporates the use of advanced development projects that provide sufficient early information to support the incorporation of a developed technology into the concept designs. The following is a top level sample of the mature technology currently under study as part of the ALS Phase II Program:

- Manufacturing, Integration, Test & Launch
- Automated Manufacturing & Launch
- Adaptive Guidance, Navigation & Control
- Forged Parts
- Low-cost Engine (Figure 7)
- Modern/Redundant Avionics
- Built-in-Test
- Booster Recovery Module

BDB APPROACH	ADOPTED IN ALS	REMARKS
• Structurally Stable Tanks	• Yes	
• Simple Structure	• Yes	
• Large Design Margins	• Yes	
• Design Simplicity	• Yes	
• Streamlined Operations	• Yes	
• Low $/lb to Orbit	• Yes	
• Ablative Nozzles	• Partially	
• Non-Gimballed Engines	• Partially	
• Storable Propellants(S/P)	• Clean LH2 & LO2	• Storable Propellants Not Environmentally Acceptable
• Pressure-Fed Engines	• Low Cost Pump-Fed	• No Test Experience With Large Press.-Fed Engines *
• Not Included	• Engine-out from Lift-off	• Added Reliability & Reduced Life Cycle Cost
• Not Included	• All Engines Ignited before Release	

Figure 6 The Big Dumb Booster philosophy has been applied in the GDSS approach to robust design of the ALS launch vehicle family.

The above technology programs currently being completed by the three competing contractors, MSFC, KSC and the Air Force and NASA Laboratories will provide the engineering data to validate the costs and feasibility of the designs selected by the JPO for Full Scale Development. The supporting ADPs are grouped within five task areas as follows:

- Propulsion
- Avionics / Software
- Structures, Materials & Manufacturing
- Aerothermal / Flight Mechanics & Recovery
- Operations

The ADP tasks have been matrixed against key ALS Program objectives to show where each one supports achievement of operability, reliability, and low cost objectives. All the ADPs support validation of reliability and cost objectives because our studies show that improved reliability and low cost go hand-in-hand, and because the ADPs were selected with high value payloads and $300/lb recurring cost goals in mind.

The ADP projects are continually being assessed for their applicability to the current ALS configuration. By this process the JPO is assured of the extent of the ADPs to each of the competing contractors' recommended ALS design configuration.

OPERATIONS CONCEPT

The overall ALS operations segment concept is depicted in figure 8. Tasks are performed at the launch site in an integrated fashion including vehicle final assembly, pre-launch processing, and mission operations. This consolidated approach to ground operations is known as an Assemble-Integrate-Transfer-Launch (AITL) process. This process is designed to maximize commonality of design, information systems, ground support equipment, test equipment and processing procedures. This is accomplished through common data base elements linked via the Unified Information System (Unis); standardized planning (paperless) for final assembly, vehicle integration, maintenance, refurbishment and test; common manufacturing and operations aids; spares acquisition integrated with production, and structured requirements processes for all operations.

The concept is based on flying standardized missions, delivery of flight-ready components/ subassemblies to final assembly, cargo shrouds built up prior to payload encapsulation, and payloads/upper stages delivered in near flight-ready condition to the integration facility.

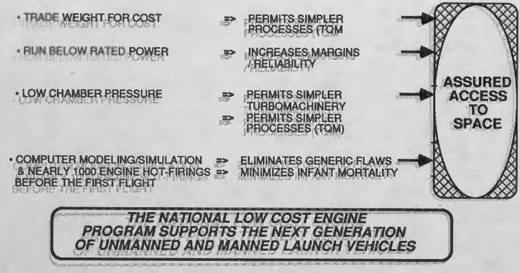


Figure 7 The National Low Cost Engine Program being managed by the MSFC will provide a major building block to support the ALS cost reduction goals.

MISSION OPERATIONS CONCEPT

The ALS Mission Operations concept consists of all the planning and analysis required to prepare the ALS for launch, as well as the actual real-time launch control and flight operations, and the post mission reporting (Figure 9). These activities include the seven mission operations functions from STAS: Payload accommodations/ integration, Preflight mission planning and analysis, Data load selection/generation, Training and simulation, Communications and tracking, Range support, and Post flight analysis. The data load generation includes the validation and verification of the software required for the ground and flight systems.

The mission planning cube (Figure 10) represents all the vehicle configurations used in the payload planning handbook. The key characteristic will be the rated lift capacity to the standard 80 X 150 nmi delivery orbit. Associated with each vehicle will be a set of characteristics that impact the cargo. These include allowable cargo dimensions and center of gravity/mass; allowable cargo structural and structural dynamics parameters; and cargo envelope thermal, acoustic, shock, and acceleration environments. A cargo center of gravity (cg) operating envelope of feet both radially and vertically from the cargo interface plane is available because of large vehicle structural and AGN&C margins. This is compared to current launch vehicle operating envelopes for cg's of an inch or so radially and a few feet vertically as depicted in Figure 10.

A standard ALS flight plan is selected by correlating the cargo weight / dimensions and desired delivery orbit inclination with vehicle lift capacity / cargo envelope. The flight plan includes flight software, autopilot constants, trajectory profiles, range support criteria and timelines.

Using this approach Mission Planning can be conducted within a two week period using the standard flight plans and software from the ALS library, compared with the 24-36 month process current launch systems require. For ALS, standardization and robust vehicle margins radically streamline the mission planning process. On ALS, the Cargo Integrator / Customer performs an analysis of the ALS vehicle capabilities, selects the appropriate launch vehicle configuration and verifies the availability of the launch vehicle and support systems. Then the ALS mission planning process is merely a selection of already available and validated flight software and plans. The reduced timeline assumes that the cargo flight support requirements are within the ALS capabilities presented in the Payload Planning Handbook. This implies that one of the previously developed standard missions to one of 5 standard inclinations and an 80 X 150 NM orbit will be flown.

After the initial mission planning has been completed, a review of the initial plans and requirements is conducted to verify that all agencies agree with the plan of operation. A

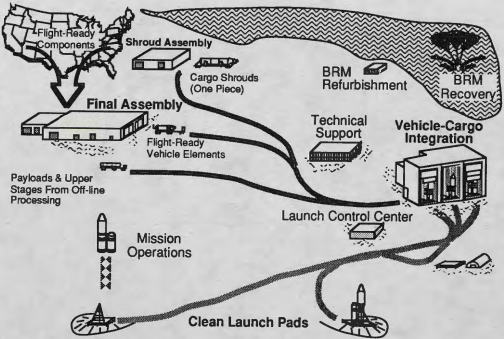


Figure 8 Our Assemble-Integrate-Transfer-Launch Concept Maximizes Parallel, Off-Line Processing.

short mission simulation and network interface verification exercise may be run. After the simulation exercise, a final electronic safety review will be conducted and the launch / flight operations and realtime support plans will be reviewed. Then an electronic launch readiness review is conducted to verify that the mission is ready to fly and the vehicle and cargo are ready to roll out to the launch pad.

INTEGRATED SYSTEM CHECKOUT

Vehicle checkout is a simple, standardized process. Verification procedures are resident in the Launch Control System at the LCC. The only functions required to be checked out in the VCIF are those that cannot be fully verified in the Final Assembly Facility. Consequently, only those interfaces that are first made in the Vehicle-Cargo Integration Facility are verified. These consist of the core-booster interfaces to ensure proper core vehicle attachment, guidance and control of booster engine TVC, fluid and avionic interfaces between the vehicle and the launch platform, and telemetry RF. Core-booster and launch platform to vehicle checkout is performed after vehicle integration and erection, and prior to vehicle-cargo integration.

The only checkouts required after the vehicle and cargo have been mated are to verify shroud separation commands across the vehicle-cargo interface, verify cargo servicing line connections between the mast and the forward adaptor, and to perform flight termination system end-to-end checks just prior to movement to the launch pad. (Figure 11)

LAUNCH OPERATIONS WORKSTATION

A standard workstation is used during launch control operations in the Launch Control Center, and is linked into the Unis network. It provides integrated access to data, video, audio and control functions. Low cost commercial hardware and software is used. It features high operability and and availability. This one workstation provides access to all systems and an extensive level of automation provides the lowest operational cost.

The Launch Operations Control Workstation is used for multiple purposes in the launch control center. A multiple window operating environment allows the user to access any information required for launch operations. Tanking control expert systems and real time video display and status are among the functions available on this workstation.

The user has access to other information such as weather, status of ground processing operations and other functions. During launch operations the user can monitor the status of the launch vehicle health through Integrated Health Monitoring.

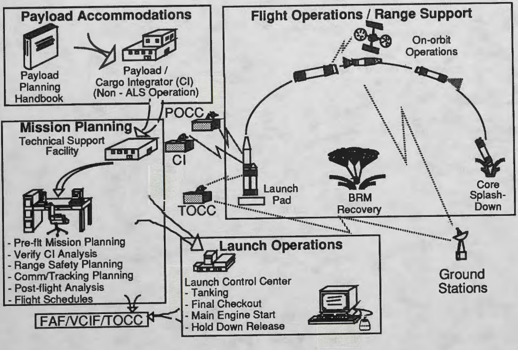
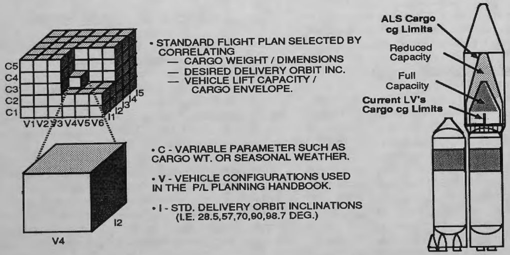


Figure 9 Our Mission Operations Concept Results In Streamlined and Standardized Planning, Analysis, Flight Operations, and Post Mission Reporting.



- STANDARD FLIGHT PLAN SELECTED BY CORRELATING
  - — CARGO WEIGHT / DIMENSIONS
  - — DESIRED DELIVERY ORBIT INC.
  - — VEHICLE LIFT CAPACITY / CARGO ENVELOPE.

- C - VARIABLE PARAMETER SUCH AS CARGO WT. OR SEASONAL WEATHER.

- V - VEHICLE CONFIGURATIONS USED IN THE P/L PLANNING HANDBOOK.

- I - STD. DELIVERY ORBIT INCLINATIONS (I.E. 28.5,57,70,90,98.7 DEG.)

Figure 10 Our Standardized Flight Plans and Robust Vehicle Margins Minimize the Preflight Mission Planning Process.

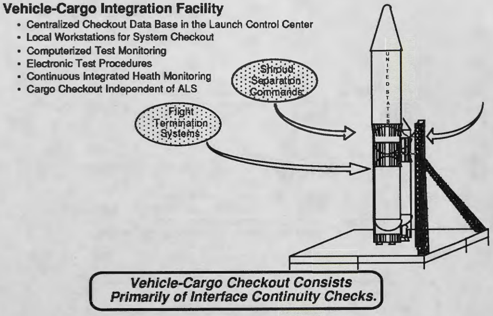


Figure 11 Integrated Health Monitoring Allows Vehicle-Cargo Checkout to Consist Primarily of Interface Continuity Checks.

LOGISTICS SUPPORTABILITY & STANDARDIZATION

Technician transparency is designed for ease of vehicle assembly, integration, maintenance and testing (Figure 12). This is a means by which a technician can perform identical work on most of the components of the ALS family of vehicles using the same tooling and equipment. Having common components and subsystems throughout the ALS family of vehicles will ease maintenance, integration and assembly and testing thereby increasing system availability and reducing support cost. Having commonality throughout also reduces the number and types of support equipment and spares needed.

The liquid booster has many features common to the core with the exception of propulsion system ducting and lack of a separate avionics system. The liquid booster will contain a subset of the core vehicle avionics. The expendable core propulsion module and the Booster Recovery Module use common interchangeable structure, common subsystem components, and different numbers of identical main engines. Either deorbit or recovery hardware is added as required for core or booster peculiar use.

RECENT ATLAS IMPROVEMENTS VALIDATE SOME OF THE ALS APPROACHES AND GOALS

The Atlas II Program has achieved several improvements that illustrate that the careful selection and application of the ALS Robust Design approach can have benefits on the current expendable launch vehicles. Simulation with ALSYM yields a certain confidence factor, and it is a valuable tool to evaluate sensitivities and tradeoffs. Full scale experimentation is costly, but there currently is no satisfying substitute for the real thing. Fortunately for ALS, Atlas is an operational cryogenic propellant vehicle that will borrow from ALS, simulate these ideas in the Atlas Simulation Model (ATSYM), and ultimately infuse some of the concepts in its design.

Following ALSYM simulation and testing in Atlas-Centaur, ALS design can be refined with lessons learned to reap the benefits of greater confidençe in the expectations of higher reliability, lower manpower, shorter timelines, and lower costs. ALSYM is a valuable tool to evaluate sensitivities and tradeoffs and is a valuable supplement to costly full scale experimentation.

The Atlas II has made significant strides in the last two years to respond to the competitive market place and to meet the Air Force's need for assured access to space.

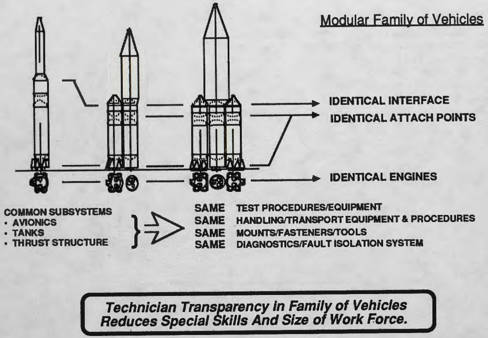


Figure 12 Our Modular Family of Vehicles is Designed for Technician Transparency to Minimize Special Skills and Size of Workforce to Process and Launch ALS.

SUMMARY

The Advanced Launch System can meet its low cost, high reliability and readiness goals by the disciplined application of robust design approaches to all facets of the ALS program. To do so it must be an operations driven design that trades subsystem weight for lower system cost, higher operability, and more reliable hardware. It must also employ mature technologies such as adaptive guidance, navigation, & control, built-in-test, and streamlined paperless processing. The system must be integrated using an electronic data management system to speed decisions and to track hardware and it must be validated using system level models which in turn are verified by prototyping of concepts on existing launch systems. The operations concept and facilities must be based on a standardized mission approach but must also be flexible enough to accommodate a family of vehicles and to react to changing operational requirements. Finally, the support infrastructure must be characterized by technician transparency and high commonality. If these are applied with foresight, the ALS can become a routine segment of the space transportation and defense apparatus.