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## Paper Session I-A - Planning for the Performance of Future Space Bases

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# Planning for the Performance of Future Space Bases

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## Abstract

The United States Air Force and the Department of Defense are moving toward normalizing space operations, from specialized one-of-a-kind launch to standardized launch, much as they provide airlift today. Normalized launch will enhance our capability to meet contingency operations responsive to the rapidly changing world geopolitical situation. The current space infrastructure will not fully support future launch operation concepts. We must be more sensitive to environmental concerns, and improved performance standards are needed for future space facilities. The Air Force is taking the lead in bringing together the worldwide space community in developing a process for performance planning of future space bases.

## Introduction

DoD Space Policy emphasizes the need for assured mission capability in peace, crisis, and war. It appears that the Department of Defense (DoD) is placing increased emphasis on assuring access to space in support of US Military operations. Recent conflict highlighted emphasis on space systems during real military operations and revealed a number of potential single-point failures which could have prevented launch. The criticality of these space systems to success in modern armed conflict, as demonstrated in recent battlefield experiences, requires a national space launch system as responsive and flexible as the deployment mechanisms for other military forces. Tomorrow's space operations will require enhanced performance from the future space base, performance that is affordable, responsive, and provides launch on demand.

Space operations which supported DESERT STORM turned the spotlight on the quality of the space launch infrastructure, one of our critical national assets (Reference 1). Air Force Space Command (AFSPACCOM) is in the process of normalizing space operations, moving from the independent operation of separate launch systems and their support facilities and equipment, to an operation where facilities and related launch equipment are integral to the total operational launch system. AFSPACCOM will operate its space launch systems (Titan, Delta, Atlas, and other specific launch operations) in much the same manner as other major commands operate their multidimensional weapons systems (bombers, missiles, fighters, tankers, etc.).

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The Air Force should be prepared to expand the lift capability and launch rate capability of its space launch infrastructure should the nation decide to fully deploy new systems currently being considered. This space launch infrastructure is defined in the Air Force Civil Engineering and Services Space Master Plan as, "Facilities, utilities, and other entities of the physical plant which support both military, civil, and commercial space operations" (Reference 2). New systems are needed which can be operated at significantly lower costs (costs reduced by an order of magnitude) to make the deployment of military assets affordable in the coming decades. Engineers are working to reduce facility costs, and though they cannot achieve an order of magnitude saving solely from within the infrastructure, they can certainly contribute. One way to reduce infrastructure cost over time is to consider the full life cycle of facilities and build to performance and maintainability standards that will prolong the life and usefulness of these facilities. Another way is to emphasize the functions that a facility performs. Facilities provide a supporting envelope that service and protect the operational package — rocket and payload. These facilities must provide support which is as reliable and available as necessary for the operational package to meet its performance requirements.

## **Infrastructure**

The current DoD space launch infrastructure is geared toward peacetime needs and until recently, had done a credible job supporting those needs. However, it is anticipated that the current infrastructure may not meet the responsiveness, launch rate, and cost demands imposed by future contingencies and anticipated commercial launch requirements. A major goal when developing new space systems will be to normalize and streamline military space launch operations. Operability requirements include simplified payload integration and timely payload substitution capability. Payload integration probably will not be conducted on the launch pad in the future. Payload substitution involves making last minute changes and still maintaining launch schedules. Standard interfaces will enhance simplicity and facilitate future payload launches on multiple launch systems. Infrastructure performance will be key to these operability issues.

Normalizing space operations will require an infrastructure that is integral to the space system and moving from a reactive to proactive mode of operation which: provides launch on demand, reduces the cost per pound, and meets surge requirements. Civil engineers must accept new responsibilities as they respond to the challenges of these operational concepts. They must think of space facilities in a manner similar to the integrated combat-turn facilities used in achieving high levels of performance for fighters.

The nation's present launch infrastructure is largely based on 1960's technology. Advances in propulsion, electronics, materials, manufacturing processes, miniaturization, and modularization offer the technological opportunity to develop vehicles and infrastructure support that meet the deployment and replenishment requirements of "assured mission capability" at greatly reduced cost.

## **Environmental Considerations**

Another concern is the environmental carrying capacity of Cape Canaveral and Vandenberg. At what point do we overload the capacity of the air or earth to absorb the wastes we generate? We anticipate operating launch vehicles and support equipment which use fuels that may require continual repermitting. Programs which provide environmental abatement will quite likely increase operational costs.

Speaking recently to a group of engineers on the subject of the engineer's responsibility for the environment, LTG H.J. Hatch, Chief, U.S. Army Corps of Engineers, described a critical challenge when he stated, "knowledgeable scientists and engineers have attempted to articulate a new concept of global development — actually, a philosophy of survival — that has come to be known as 'sustainable development'." He further described sustainable development as a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change work together to enhance both current and future human needs and aspirations. Gen Hatch went on to say, "civilian and military leaders alike have linked the need for sustainability to the very crucial issues of national and collective security and political stability in a rapidly evolving multipolar world" (Reference 3).

There are many environmental implications for development of future space bases. We must look very carefully at the increased production and handling of propellants — hypergols, hydrazines, liquid and slush hydrogen, and liquid oxygen. Also, we must be prepared to describe accurately and quantifiably the effects of our operations on the ecosystem of the base and surrounding land and sea. We must continue to pay the costs of protecting the environment from the adverse effects of future operations. Plans for future space bases should first attempt to, "avoid adverse sustainability impacts, then minimize or reduce them, and finally, offset the unavoidable ones by environmental restoration." This planning process "represents a hierarchical sequence of preferred alternatives that should be followed for every proposed action" (Reference 3).

## **Managing Change**

Air Force Space Command installations and facilities are constantly changing to meet operational requirements, support special projects, and field new or modified systems. This constant state of change requires a management process that ensures: installation comprehensive plans are responsive to mission requirements, specifications are achievable and are met, changes are documented, lessons are learned and disseminated, performance standards are updated, and the impacts of change on other facilities and systems are understood and acceptable.

Looking at the past with 20-20 hindsight, we can see that fragmented oversight of multiple funding resources, and changing command functions and responsibilities, made management of change difficult. For example, facilities funded by R&D appropriations (3600) were not subject to many requirements associated with typical military construction appropriations (3300). The



merging of AF Systems Command and AF Logistics Command into Air Force Material Command, and the evolution of Air Force Space Command as the requiring and operational user of space launch facilities have provided greater focus on the change management process.

The space launch system can be greatly improved by strategic planning which integrates the support infrastructure with operational requirements. Future planning must optimize infrastructure performance and emphasize continuous improvement in the management of command resources. This planning should involve a full range of constructors, users, operators, and maintainers, and must consider safety and environmental concerns. Emphasis should be placed on facility and equipment performance over a full life cycle, not just the initial Research and Development phase of their use. A process is required which assists management in achieving, at the lowest life cycle cost, required performance, realistic schedule, operational efficiency, logistic supportability, and readiness. Infrastructure requirements are not always fully considered simultaneously with new system development.

### **Planning for Performance**

AFSPACECOM Civil Engineers have taken the lead in modernizing the current space launch infrastructure and facilities for the Air Force portion of the nation's space capability. This effort required both technical and philosophical initiatives. Technical evaluations revealed a need for facility policies that consider life cycle, configuration management, performance standards (Reference 1).

A change in philosophy is needed which translates civil engineering concepts of reliability, availability, and maintainability into warfighting capability. Facilities and related launch support equipment are integral to the total operational system. This support infrastructure must meet higher availability standards than the system it supports, and it must be capable of supporting repetitive on-call launch when needed to meet operational requirements. Civil engineers need to feel greater responsibility for the stringent and demanding requirements of operational mission performance success.

With its evolving role as an operational command, AFSPACECOM is exerting its leadership by bringing together, for an exchange of views, Air Force Systems Command, Air Force users, NASA, industry representatives, and civilian interests such as Florida Spaceport Authority. In the future, members of the international space community also may be included. The purpose of such exchange is to explore strategies for common planning and common facility performance standards as an approach to reducing the costs of space support. AFSPACECOM is providing much needed focus on defining infrastructure performance for the space support base.

Specific performance standards for facilities are needed which incorporate new technologies and concepts, materials, and lessons learned through post-occupancy evaluations. The following life cycle steps must be considered:

- **Concept.** Thought must be given to facility configuration and performance standards and then incorporated into the Mission Needs Statement (MSN) and the Operations Requirement Document (ORD) as they are developed.
- **Plan.** Research, standards and configuration, and other requirements are placed into the Program Management Directive (PMD).
- **Design.** The design may be implemented with the aid of advanced research, testing, and evaluation. In some cases, all operational requirements may not be known at design completion; flexibility is required.
- **Acquire.** A variety of fund sources may be used; 3080, 3300, 3600, 3400, and others. Each fund source may require a different approach in applying performance standards to the business strategy.
- **Operate and Maintain.** This phase concerns efficient operation and it involves energy usage, equipment life, recurring maintenance, equipment replacement, emergency requirements, environmental and safety concerns, etc. A facility may go through several phases, including mothballing and reconfiguration, during its life cycle.
- **Close.** Facilities may be abandoned, demolished, placed on standby, mothballed or preserved because of their historic value. Closure of facilities creates environmental and safety concerns, and mothballing and historic preservation require continued O&M commitment. In all cases, closure should be considered during the initial design phase of a facility's life cycle.

Performance standards are applied to programs through a process involving informed people empowered to make facility performance decisions at critical stages in planning, design, and construction. Partnerships and interactions between the system developer, test program manager, and operational user; contractors; and internal and external research must be considered to assure development of an infrastructure that is fully responsive and integral to the launch system. Performance standards reduce the life cycle costs of launch support and increase overall system reliability, maintainability, and supportability. These performance and cost enhancements can be achieved by the following methods:

- A civil engineering process that is responsive to change.
- Quality construction that applies the most current regulations, codes, guides and standards to all launch support facilities, not only to new construction, but also to modification of existing facilities.
- Planning for facility performance which considers total life cycle and involves functional requirements, system reliability, corrosion control, availability, safety,

security, environment, and continuous improvement, etc., during the design, construction, and operations and maintenance processes.

- Designing in interchangeability, flexibility, and maintainability by implementing specific standards tailored for each launch or launch support facility project.
- Utilize lessons learned from previous projects when designing new facilities and modifying existing facilities, to highlight both successes and failures in material selection and construction techniques.

## **Fuels**

Dr. Gerald Leigh of the New Mexico University Engineering Research Institute, states that the Air Force is developing programs that will make much greater use of hydrogen fuels. The National Aerospace Plane (NASP), the development of NASP Derived Vehicle concepts, and the joint Air Force/NASA plans for developing a family of hydrogen-fueled, launch vehicles for the National Launch System indicate a greater use of liquid or slush hydrogen. New methods will be required to produce and store hydrogen fuels as well as new equipment and lines to transport them. Dr. Leigh states that, "current environmental problems related to frequent launch of chemical fuel rockets are already urging the rapid transition to environmentally benign hydrogen fuels." He points out further, that once the Air Force becomes extensively involved in the use of hydrogen fuels for flight vehicles, it would be logical to use them for surface vehicles and installation energy needs (Reference 4).

It is anticipated that future space systems will use liquid or slush hydrogen and liquid oxygen as their primary propellants and will require their storage at launch sites. Sufficient amounts of propellant beyond actual vehicle requirements will be needed for planned multiple launches, quick turnarounds of NASP Derived Vehicles, and to compensate for accidents, surge, and boil-off. Other fuels may include solid propellants, hypergols, and hydrocarbons. The implications for the Civil Engineer are significant.

Historically, the production capacity of liquid hydrogen exceeded demand. This was particularly true from 1957-1969, when commercial demand was not significant. Since 1960, there has been a steady growth in the commercial liquid hydrogen market and modest fluctuating growth in the government market. Currently, the commercial demand accounts for approximately 75% of the total demand, a reversal of the mid-1960's (Reference 5). Can commercial sources fully provide the liquid and slush hydrogen fuel, and the electric power required under high demand conditions? If not, the Air Force needs to begin developing its own capability to produce liquid hydrogen on-site and normalize the use of liquid and slush hydrogens.

## **Future Launch Requirements**

Surge launch may be required for predesignated satellites in crisis or conflict scenarios to rapidly augment critical on-orbit capability. These surge operations may require prepositioned,



preintegrated, flight-ready launch vehicle/payload combinations in storage at the launch site. Prepositioned flight-ready vehicles would require regular ongoing checkout and maintenance to maintain flight-ready status. Upon notification, these launch vehicles and payloads would undergo a final check, followed by roll-out and countdown.

Maintaining these launch vehicles and their payloads would place an increased demand on power and other utilities because of significant differences between simple storage and maintaining flight-ready status. The facilities would require specialized equipment to interface with the vehicle and payload to provide continual monitoring and readiness, and the environment within these facilities must be controlled.

New launch systems may use a Mobile Launch Platform towed by a special tractor, for transporting the assembled vehicle to the fixed launch site. Its function would probably begin in the Vertical Integration Building where it would provide the base for vehicle assembly. It would provide physical, electrical, and fluid connections to the vehicle. After the launch vehicle had been fully assembled and checked out, the Mobile Launch Platform would be moved to the fixed launch pad and connected to pad facilities for final checkout and vehicle servicing. After launch, the Platform would be refurbished as required.

According to a briefing presented by members of the Air Force Scientific Advisory Board at HQ AFSPACOM, some thought is being given to using a NASP Derived Vehicle (NDV) for future space operations. The NDV would be single-stage-to-orbit, fully reusable, manned launch vehicle based on X-30 National Aerospace Plane technologies. It would use a standard runway for both takeoff and landing and could potentially increase launch economy, operability, and responsiveness. NDVs could combine the attributes of long-range aircraft and space launch vehicles to provide a range of capabilities including reusability, rapid payload launch, rapid turnaround, and all-azimuth launch capability (Reference 6).

The implications for infrastructure support require that immediate thought be given to how such a vehicle will be operated and maintained. For example, can the NDV operate on today's runways, or will special surfaces be needed to withstand the temperatures and downward thrust envisioned as part of takeoff? Fire protection takes on new meaning when considering closed cycle life support systems where evacuating the air may not be feasible. Do we have the fire suppression equipment and chemicals that will be required for slush hydrogen, hypergols, and other fuels associated with the NDV? How do we support the planned 24-hour turnaround of the NDV?

Perhaps new techniques and technologies will be required to meet any future requirements for an NDV. Again, as stated above, thought should be given to the need for liquid hydrogen in much greater quantities than currently required. Can commercial production of liquid and slush hydrogen meet the rapid turnaround requirements being planned? Will future demands require greater storage capability to support rapid turnaround? Should the Air Force begin producing its own liquid/slush hydrogen so that it is not solely dependent upon commercial production, and



perhaps equally important, dependent upon open routes — highways and waterways — over which hydrogen is transported?

## Design Requirements

If we expect to successfully employ new systems at Cape Canaveral AFS and Vandenberg AFB, they must be designed to operate reliably and effectively in the natural and man-made environments encountered at these sites. In particular, they must have a high degree of corrosion resistance. They must be built with exterior surfaces that will, with sufficient coating, withstand the corrosive environment found on both coasts. Launch schedules may not allow sufficient time between launches to strip and recoat certain launch equipment. The most cost effective solution may be a material, or a design consideration, e.g., the use of utilidors (utility corridors) that will withstand corrosion. There may be a requirement for new technology. Proper enclosures and coverings for electrical transmission equipment and switches must also be considered.

When planning new launch systems, facilities and their related equipment should be configured in such a manner that they interface with existing facilities, utilities, and equipment. Equipment such as HVAC, power production, and power conditioning, should be as closely matched to existing equipment as possible to provide greater maintainability, interchangeability, supportability, and interoperability. This equipment should also be adaptable for the needs of future missions.

As with the development of any new base, new launch sites will require accurate elevation, latitude, and longitude data which can be provided by the Global Positioning Satellite (GPS). It may be well to consider capturing this GPS data in a Geographic Information System (GIS) which can then build upon this mapping data with other inputs from the Base Comprehensive Plan, e.g., base perimeters, drainage system, roads, utility layouts, etc. GIS provides interactive facility data management, i.e., facility and equipment management, fuel and utility distribution, fire protection, and emergency response. GIS can provide environmental information (satellite imagery) to document baseline conditions and then provide realtime changes, particularly in light of potential interest by environmental groups or agencies monitoring the effects new systems might have on the ecology of the base and surrounding area. The Air Force would be well served to have a source of information upon which to make its decisions and to base its position with environmental agencies and interest groups.

The protection of new systems may become a greater issue as we look at present vulnerabilities, not only security issues but also natural disasters such as hurricanes and earthquakes. We've always assumed that our bases are a "safe haven." This assumption may not be valid in the future. We may become susceptible to civil unrest and disturbance, if not within the base itself, on the highways and waterways over which fuel and supplies are transported. As to the base, it also may be wise to consider hardened communications and utilities; redundant electrical, water, and fuel systems; isolation valves; and other measures necessary for survivability. Particular attention should be given to the production and handling of liquid and slush hydrogen,

e.g., automatic shutoff valves, robotic fire suppression equipment, and sensors for leak, pressure, and fire protection. Also, the Air Force must be able to generate more of the electrical power it needs as a prerequisite for assured launch.

New systems will need to meet enhanced logistics and readiness parameters such as responsiveness, availability, resiliency, reliability, maintainability, flexibility, and supportability. All of these parameters apply to ground facilities and equipment, as well as to launch vehicles. In the past, facilities have been built for an initial single purpose. Future facilities must be built with flexibility and resiliency features which provide for modification and reuse. There are a number of features which will make facilities easier to modify, more usable, and less expensive over their life cycle. For example, facilities should be built: to include utilidor or interstitial flooring which allow modification to electrical, communications, water, and sewage lines; to minimize the number and location of load bearing walls to permit easier reconfiguration of space; with removable outer wall panels that permit movement and exchange of large equipment; with surrounding space that can be used for later expansion; and, with junction boxes for interconnection with exterior emergency power and communication.

Any design for new systems must address the following capabilities in sufficient detail to ensure that a high level of responsiveness is achieved:

- Rapid and safe fueling/refueling of liquid fuel elements.
- Rapid and safe handling and transportation of vehicle elements, including Solid Rocket Motors and integrated launch vehicles.
- Extended launch hold capability.
- Rapid recycle time following a launch postponement.
- Rapid system turnaround following a successful launch.

## Conclusion

As we look to the future of space operations and the need to provide an infrastructure responsive to changing requirements, we must rethink the way we have traditionally done business. One of our primary objectives is to clearly define how we want a space base to operate, not piecemeal, but comprehensively. We need to have open dialogue among all concerned — acquirers, operators, maintainers, contractors, and those specifically concerned with the environment and safety. It will be necessary to change the mind set from R&D and one-of-a-kind systems, to sustained operations. The process will develop ties between partners and cause people in key functions to communicate and understand each other's problems. Planning for the performance of future space bases begins with a process of continuous improvement. The process must force long-range planning that considers the full life cycle of facilities and causes smart investments.

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