RAPID SPACE FORCE RECONSTITUTION (RASFOR)

Subject Summary

A rapid space force reconstitution (RASFOR) operational concept using rapid-response spacelift and light satellites (lightsats) is presented. Its focus is directed at immediate development and acquisition actions necessary to meet the requirements of the world of 2020 and beyond. RASFOR directly complies with two of the foundations of the US National Military Strategy--crisis response and reconstitution--which in turn have direct traceability to the grand strategy of the United States. Future conflicts will require more responsive military forces which are increasingly dependent on space assets to support their operations. They may be pitted against adversaries also having military space assets, giving challenge to our space systems during military operations. The proliferation of space technology may allow future adversaries to degrade or destroy our satellites. Also, unanticipated system failures and multiple area coverage requirements may require the immediate placement of satellites into orbit. To meet these challenges, RASFOR is essential to space operations--it can provide the space support tasks necessary to meet joint requirements in the future combat environment. Although alternative operational concepts exist (status quo launch, on-orbit storage, and repositioning), they are inferior to RASFOR.

Current spacelift assets cannot provide the support necessary to reconstitute critical force-enhancing satellites in a combat environment. One of the pitfalls of previous spacelift studies has been that participants have all had "back pocket" agendas to sponsor specific systems. To avoid this parochialism, this paper does not propose specific systems to solve our combat deficiencies in space, but rather, it provides a vision toward the solution.

Problem Statement

Is there a need for a rapid space force reconstitution capability to meet US military combat support requirements of the future? There are many situations that may challenge our existing satellites and require their replacement or augmentation. No matter how well designed and built a satellite is, it is still subject to the random failure of components (i.e., not involving actions by hostile forces) which may render subsystems, or the entire system, useless. External environmental conditions (e.g., micrometeors, solar flares) may contribute to these failures. If such a failure occurs on a satellite critical to ongoing military operations, it may be necessary to replace it immediately.

Shared Satellites

The "global reach" of US forces may require deployment to geographic areas not covered by existing space assets. Even though certain satellites have limited maneuver capabilities, it may not always be possible or practical to move satellites to cover deployment areas. A satellite may need to be placed in a unique orbit to cover the theater of operations.

If the US becomes involved in two conflicts at the same time, existing space assets may not be able to support both theaters. If the theaters are too close together, then they may have to share satellites--their demands may saturate or overload existing satellite capabilities. If the theaters are far apart, then they may compete for limited satellites. In either case, the integration and coordination of limited space assets can only add to the friction and fog of the operations. The solution is obvious, but not simple--put up adequate satellites to support *both* theaters.

Interference with Satellite Operations

In future conflict, the US cannot afford to assume our space assets will not be interfered with. Future planners may need to factor in satellite attrition, just as ground and air forces attrition is included in today's planning.[1] The former Soviet Union has demonstrated several types of anti-satellite (ASAT) technology,[2] and it is reasonable to predict this technology will be available to future aggressor nations.[3] The US strategy of fielding low quantities of high-quality satellites creates "an over-concentration of US assets in a limited number of necessarily costly satellites [which] provides inviting targets, contributing to an increased threat."[4] A satellite will probably not be "taken out" by an ASAT weapon unless hostilities are occurring, and the aggressor will probably only target satellites critical to the ongoing conflict. To maintain space support for the war fighter, the satellite will have to be replaced immediately.

Counter-Space Operations

Just as we must ensure US use of space, we must plan to deny use to any adversary (space control). Certain types of counter-space weapons employed by the US may need to be placed into orbit (or replenished) during hostilities. Part of the principles of the Air Force's contribution to national security is that "space superiority is joining air superiority as a *sine qua non* of global reach and power."[5] However, space superiority cannot be achieved unless the US can overcome the operational demands presented above.

Meeting the Challenges: RASFOR

The challenges facing space systems in the future all point to the need for RASFOR as an essential element of future combat forces. General John Piotrowski, former commander in chief of USSPACECOM stated that the US "must be capable of *reconstituting* degraded or destroyed spacecraft *on demand*."[6] Our current launch tools can meet peacetime requirements, but they are "much too slow to meet the demands of combat."[7]

A Proven and Recognized Solution

The use of RASFOR was clearly demonstrated during the Falklands War. Within a 69 day period of the war, the Soviet Union conducted 29 satellite launches--an extraordinary surge capability.[8] In contrast, US emergency launch times must be measured in months rather than days. As an example, consider the failure of a Defense Meteorological Satellite Program (DMSP) satellite on 3 September 1987. On 13 October 1987, an emergency launch call was issued, a DMSP replacement was "urgently needed." The replacement satellite was launched 3 February 1988--113 days after the emergency call and 153 days after the failure.[9] In the future, it is likely that a major regional conflict can be fought and won (or lost) in much less than 153 days.[10]

Limitations of Existing Reconstitution

During Operation DESERT STORM, a military satellite was moved from Pacific Ocean coverage to Indian Ocean coverage to augment communications capacity in the theater. It was the first time a department of defense (DoD) satellite had been repositioned to support US combat operations. Although this action fulfilled a combat support requirement, the continued approach of reconstitution through on-orbit storage and repositioning is flawed.[11]

The concept of the on-orbit storage of spare satellites (prepositioning) makes the spares as vulnerable as the active satellites. Enemy space forces can monitor and selectively target critical satellites and take them out at once. Storing spare satellites on orbit also uses up a portion of their useful life through exposure to the harsh space environment and the use of limited expendables (e.g., fuel for station keeping). Repositioning maneuvers also expend limited fuel resources; in certain cases, the required orbital changes may be so great and the available fuel so limited that the repositioning maneuver is not physically possible. Further, when a satellite is moved to a new area, it will weaken (or eliminate) the support in the old area. Finally, repositioning is not an instantaneous event. If a responsive spacelift capability is available, there may be certain cases when it will take less time to launch a new satellite (using RASFOR) than it will to reposition an existing one.

RASFOR Concept

The development of rapid-response spacelift can fundamentally change US space operations, but only if it is coupled with a parallel change from complex, heavy, long-life satellites to simpler, smaller, shorter-life satellites called lightsats. In war fighting terms, the big satellites are like B-17s in space--self-defending, capable, and an easy target for a determined foe. In contrast, the use of lightsats coupled with a rapid-response spacelift system could dramatically increase space combat capability. This combination of systems--rapid-response spacelift and lightsats--are the *force elements* necessary to accomplish RASFOR.

The operational concept for RASFOR is illustrated in figure 1, which outlines the actions supporting commands (US Space Command and individual service space commands) must take to provide RASFOR.[12] When space support is requested by a combatant commander (COCOM), the supporting command will observe existing space assets, assess their ability to meet the COCOM needs, and decide if RASFOR is required. Once the decision is made to use RASFOR, the supporting commands will prepare and execute the mission: launch the rapid-response spacelift vehicle, orbit the lightsat, perform on-orbit checkout, and finally, task the lightsat. During the RASFOR mission, the supporting commands will also perform dynamic engagement control functions, such as range tracking and control.

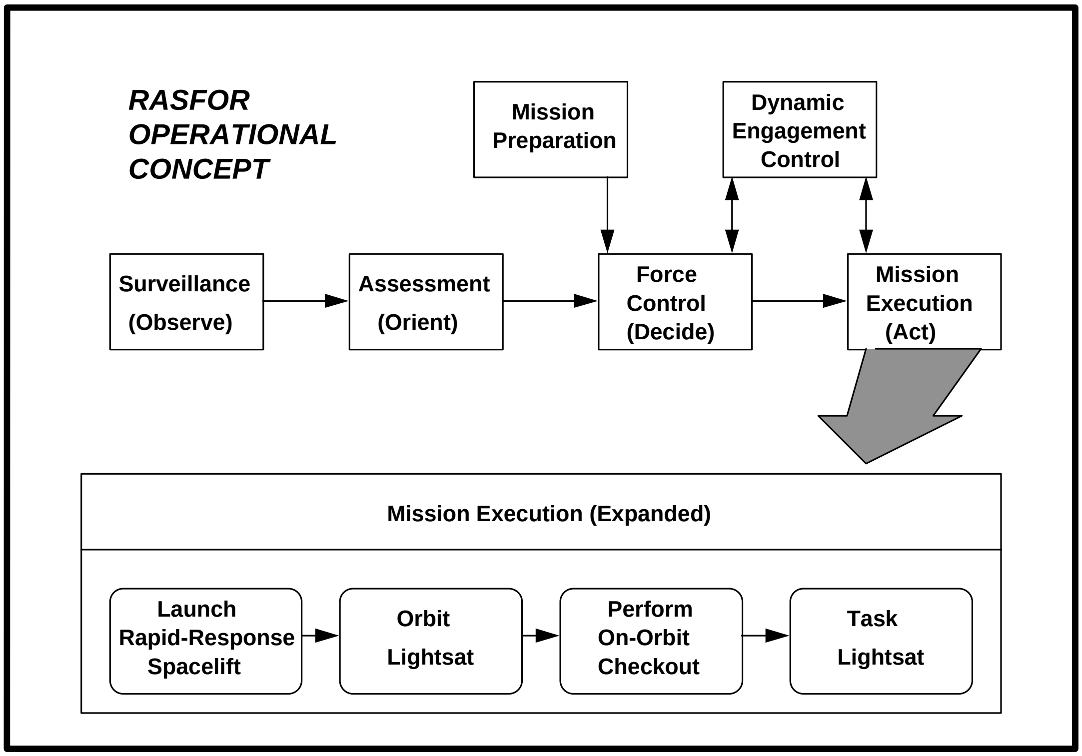

Figure 1. Rapid Space Force Reconstitution Operational Concept

Historical Background

Intercontinental Ballistic Missile (ICBM) Heritage

One of the major problems with our current space launch vehicles (SLVs) is that most of them are derivatives of ballistic missiles--they were never designed to deliver satellites to orbit. For the most part, these SLVs are based on 30 to 40 year-old technology.[13] These ICBM core vehicles evolved over the years, primarily in response to growing payload requirements.[14] The expense of spacelift helped to fuel a vicious cycle for satellites design. First, high development and launch costs led to the procurement of high quality (long life) satellites in low quantities. In turn, the requirement for long satellite life led to numerous reliability design features, including subsystem redundancies, adding complexity and weight to the satellite. This added weight required more performance from the SLV, which in turn drove up the spacelift costs. The increased spacelift cost brings us full circle back to the need for high quality satellites.

Although the booster community delivered incremental performance increases for their satellite customers, today's SLVs have only undergone one, possibly two, generations of evolution since the late 1950s. In contrast, jet fighter aircraft have undergone five generations from the F-86 to the F-22,[15] and stealth technology has also undergone five generations.[16] Lt Gen Moorman, vice commander of Air Force Space Command, stated "the space community is launching the equivalent of the F-4 series fighter into space" and advised that "space launchers need the same relative modernization that our modern-day fighters have had."[17] There has never been a "clean sheet" design for an operational military SLV; in fact, the Saturn V and the Space Shuttle represent the only US spacelift vehicles designed "from scratch."[18]

Reactive Approach

In the past, the US has often waited until it perceived a *severe* threat--a crisis--before it acted. The resulting actions involved sudden major investment and effort to overcome the threat. To accomplish this de facto strategy, the US relies heavily on technological surges rather than consistent and incremental improvements.[19]

Implications

Simply put, US spacelift has not been put to the war-fighting test yet. Although US forces relied upon satellite-based force enhancement during the Gulf War, there was never a threat to these satellites which required rapid reconstitution. Of the four combat media--land, sea, air, and space--only in space has the US *consciously allowed itself to be inferior in war-fighting capability.* Maj Gen Robert Rankine, former vice commander of Air Force Space Division stated "our capability to accomplish *force enhancement* from space is superior to that of the Soviets--but only during hostilities that do not place the satellites themselves under attack."[20] Another senior DoD official noted "the Soviet Union is superior in the war fighting aspects of the launch infrastructure."[21] Since there has been no need for the rapid reconstitution of satellites in combat, there has been no effort toward RASFOR development.

Reconstitution must be accomplished in a timely manner if it is to provide the force enhancement when needed. The current published doctrine concerning the deployment of space forces (Air Force Manual 1-1) confirms this:

> Rapid-response spacelift must be available to emplace and replace critical space assets. The US military relies extensively on space assets for many critical missions. In a crisis, it may be necessary to concentrate assets quickly. Failure of these assets or their destruction by enemy action could lead to disastrous consequences unless they can be quickly replaced.[22]

In 1992, a comprehensive Blue Ribbon Review of Air Force space policy, organization, and infrastructure was conducted. One of its key findings states: "In the future, the need for space support in major conflicts will likely exceed peacetime capabilities in terms of capacity, interoperability and flexibility."[23] This points to the need for spacelift that is not only responsive, but is also capable of rates and volumes greater than normal peacetime operations.

To have a superior warfighting space force, we must be able to place satellites into orbit *when and where we want to*--we must have control over the space lines of communication. A key element of this control is access, making a rapid-response spacelift system an essential element of future combat forces.

Consensus Building: The Case of the Space Shuttle

One of the political challenges facing RASFOR is that the development of its spacelift element may require the consensus of numerous space agencies. This process, which is difficult even within individual agencies, is time consuming, and it often forces unfavorable compromises. A review of the decision-making process during the Space Shuttle development noted:

> While one of the long term strengths of the American system has been a willingness to make pragmatic compromises to achieve results acceptable to the widest range of viewpoints, in a heavily technological arena such an approach was of questionable virtue.[24]

Indeed, the topic of spacelift has been over-studied since the *Challenger* disaster, with no consistent national launch strategy being developed, let alone a definite decision to pursue the rapid-response spacelift capability required for RASFOR.

While a detailed case study of the space shuttle, or space transportation system (STS), is beyond the scope of this paper, a brief review of some of its political problems is germane to RASFOR. After all, the STS was originally conceived as a rapid-response spacelift system, capable of 2-week flight turnarounds and 25 or more missions per year using 5 reusable orbiters.[25] However, after running through numerous political wickets, the final product bore little resemblance to the original concept.

When funds were reduced under the Nixon Administration, the National Aeronautics and Space Administration (NASA) tried to gain support "on a cost-effective, rather than on scientific, technological, or other grounds."[26] This strategy was a mistake made by "government bureaucrats who played the political game and sold the Shuttle as an inexpensive program, in the process sowing the seeds of disaster."[27] During development, the STS was kept alive through a forced marriage between NASA and DoD mandated by President Carter. This arrangement forced a dramatic change in STS configuration and mission profile increasing program costs.[28] This also resulted in sole reliance on the STS for US heavy spacelift--the US had all of its space-access eggs in one basket. Following the *Challenger* accident, the resulting spacelift crisis led to the rapid reinstatement and modification of four classes of expendable SLVs.[29] The final assessment of the STS, made by the Vice President's Space Policy Advisory Board in November 1992, was that "the Shuttle is very expensive relative to its role in the US space program." This expense is listed at about $5 billion per year to support only seven or eight flights per year[30]--over $700 million per flight (many analysts list this cost even higher). The cost of the most expensive of the "crisis response" replacement SLV programs, the Titan IV, is listed as at least $350 million per launch.[31]

Design Approach

Long Life of Satellites

The primary reason why the US has not pursued RASFOR has its roots in the US design approach to spacecraft. Unlike the former Soviet Union (FSU), the US has always stressed *quality* over *quantity*. US satellites are designed to have long service lives, with the strategy being to *endure*, whereas the FSU strategy has been to *surge* using its robust spacelift capability. US satellites are also designed to be more capable, which required the FSU to have more satellites in their constellations to do the same job. The resulting high satellite replacement rate forced the FSU to develop a spacelift infrastructure capable of launching five times more frequently than the US.[32] Historically, many US satellites' lives exceed prediction, thereby allowing a launch-on-schedule strategy to build up assets in space.[33] Because of this, there has been no drive to make RASFOR a reality.

Research and Development Approach

In addition to their ever-increasing performance requirements, the satellite community has also made demands on the physical configuration of the boosters. Payload interfaces, shrouds, and pyrotechnic devices have at times varied greatly from launch to launch. Since these engineering changes can only be flight-validated during an actual launch, many SLV flights become research and development (R&D) milestones.[34]

This R&D approach often resembles the 1950s b-movies, where space launches are performed by groups of scientists in white lab coats. It is in sharp contrast to the normal concept of military operations, in which the standardization of training and procedures are paramount. There is limited standardization in the assembly and checkout of boosters, and even less during payload processing.[35] In many cases, special test and support equipment is required for launch preparations. Personnel training is also a challenge, because the procedures on which an operator becomes qualified on one launch may change for the next launch.

This R&D approach to spacelift has at least four negative operational impacts: reduced error margin, increased support requirements, increased processing times, and increased operating costs. The R&D methodology often pushes the design limits of the vehicle, thus reducing its margin for error.[36] New "black boxes" and increased thrust requirements may put vehicles at the edge of their performance capabilities, making each launch very risky. To help reduce this risk, an elaborate vehicle processing support network is used. This network often requires unique test equipment and procedures, and it is usually manned by an army of contractor engineers and technicians. In addition, a contingent of government workers is required to plan and monitor the processing. This methodical, "check everything twice" approach may reduce risk, but it does so at great cost to schedule. Procedures written at a contractors facility may not work at the launch pad, making "redlines" and workarounds common. Lack of standard test software also contributes to increased processing times. The need for unique support equipment and procedures, highly-qualified personnel, and long processing schedules results in high operating costs for each launch.

Cost

One of the greatest challenges facing the military today is the reduced budgets under which it must operate. This is reflected in the current DoD space investment strategy, which has a fundamental goal "to make future DoD space systems more cost effective while retaining US technological superiority." It emphasizes "reduced procurement and life-cycle costs consistent with operational requirements,"[37] but follows the paradigm that the technological superiority will satisfy operational requirements. This misguided approach has led DoD to continue the evolutionary process of spacelift; in essence, a decision to throw good money after bad. This is not a temporary measure; the decision will extend life of the current launch vehicle fleet to the year 2030[38]--banking on many subsystems embodying *sixty- year-old* technology.

The problem with this proposed strategy is that it ignores other elements of cost. In choosing the status quo approach to spacelift, DoD is sentencing spacelift to remain non-responsive and manpower-intensive into the twenty-first century. An old Chinese proverb says: "Where there is no gain, the loss is obvious."[39] If US military spacelift remains the same while others proliferate, how can we do anything but lose? Economists refer to "opportunity cost" as the cost of selecting a given approach and the resulting benefits foregone by not using the best alternative.[40] Unfortunately, the opportunity costs of this decision may be the loss of US lives during conflicts with enemies having war-fighting capabilities in space. To avoid this, current and future studies concerning spacelift costs, especially those that make cost "the primary measure of merit,"[41] must address the opportunity costs faced by peace-time systems in a combat environment.

Developing and implementing RASFOR systems will not be cheap, however, these systems can help to lower spacelift costs. By nature of its requirements, the rapid-response spacelift element will have increased reliability to avoid costly losses. This increased reliability, along with a possible in-flight abort capability, can reduce range safety requirements and costs. Also, a RASFOR system with reduced infrastructure and standardized procedures will have lower operating and manning costs.

Most importantly, RASFOR provides a way to break away from "business as usual" by introducing a fundamental change in the way the US designs satellites. If satellites can be launched rapidly, consistently, and reliably, then the dependence on long-life satellites no longer makes sense. In fact, RASFOR will allow new technology to be implemented faster, since the time between satellite design generations will decrease, and the overbearing emphasis on reliability can be eased. This will result in smaller and more capable systems with shorter lives.[42]

Technological Feasibility

As previously mentioned, the FSU demonstrated effective RASFOR during the Falklands War. Their system, previously assumed to be crude by US standards, clearly demonstrates that technology is *not* a barrier to RASFOR development. While existing technologies may suffice, existing systems do not. To approach RASFOR development as the modification of existing SLVs will be a mistake. The entire system--launch vehicle, payload interface, infrastructure, launch operations, personnel, etc.--must be approached in a "clean slate" manner. There are many examples of spacelift systems with RASFOR characteristics; these systems range in maturity from conceptual to operational. It is not the purpose of this paper to advocate any specific technical solution; therefore, these systems will not be discussed.[43]

A Spacelift Panacea?

Will RASFOR cure all the ills of spacelift? No. Rapid response is not required for all launches; a routine (versus urgent) launch on need should apply to most launches. RASFOR systems may also have payload weight limitations (such as the support equipment needed for manned space flight) preventing its use for heavy spacelift. To be cost effective, a separate class of newly-designed medium and heavy lift SLVs should also be pursued to provide a flexible spacelift capability.

Evolution Versus Revolution

As previously discussed, our current military spacelift vehicles have evolved for over 30 years from their ICBM roots. This evolutionary approach has developed well beyond the point of diminishing return, requiring great expense for incremental performance increase. This continued pursuit of "one more modification" is a cancer upon our nation's space force, with a tremendous appetite for resources which when fed, only makes the system weaker. It is time to break this vicious cycle.

A more radical approach to spacelift is to pursue exotic technologies offering revolutionary performance increases. Anti-matter, anti-gravity, electromagnetic, and other such propulsion technologies may be available in the distant future. However, existing spacelift deficiencies require immediate attention if we are to provide combat space support to war fighters. Neither the evolutionary nor the revolutionary approach can resolve spacelift deficiencies; a new approach is required. However, before presenting this new approach, it is important to examine a key misconception within the current view of US military space.

The Misconception: Technology and Capability

We have an illusion of superiority, thinking that superior technology equates to superior combat capability. Indeed, an August 1993 White Paper from US Space Command stated that "It's important that the US maintain its superior space capabilities."[44] Unfortunately, the paper didn't address the circumstances under which the *asserted* superiority exists. The future environment of space operations may be that of a shooting war. A better approach, then, is to state: It's important that the US *develop* superior *war fighting* space capabilities.

The De-Evolution of Spacelift--A Paradigm Shift

The primary problem with our current spacelift system is that it ignores a fundamental truth--*no one can build a perfect system*. Murphy's Law will always apply, and during war it will be augmented by Clausewitzian fog and friction. Our current spacelift operations seem to embody the belief that if enough money, studies, people, and quality assurance are thrown at a system, it will become perfect. However, this approach overlooks another fundamental truth--a system doesn't need to be perfect if it is designed to be *robust and fault-tolerant*. Applying these two truths to our spacelift shortfalls points to a solution away from our current systems and toward the technologically "inferior" systems of the former Soviet Union (FSU):

> If the Soviets use technology that is primitive by our standards but meet their mission requirements while we fail to satisfy ours, then their technology is better by any sensible standard of military utility. In fact, if the cruder Soviet system allows greater latitude for error and thereby yields greater reliability, then for all practical purposes it is a better system.[45]

This backing away from current razor-thin, high-technology design margins to the robust "duct tape it before launch" approach of the FSU[46] represents a significant paradigm shift--a "de-evolution"[47] of technology required to increase *operational utility*. This approach can lead to a rapid-response spacelift system emphasizing standardized procedures, short sortie generation times, robust design margins, and simplified launch site operations.

This is not to say advances in technology are bad. However, the application of these advances must be balanced against *operational utility* and *design margin*. Just because a system can be designed within one percent of structural failure doesn't mean it has to operate that way. Engineers may need to throw away their complex computational fluid dynamics design software and learn to use a slide rule again--the point being that common sense and intuition should be emphasized over blind faith in computer simulations. Technicians and maintenance personnel should also have a say in the design process to help reduce complexity of operations.

System versus Vehicle Approach

The primary goal of the de-evolution approach to RASFOR is to emphasize operational utility in the design of the *system*. While specifications may accomplish this, they often miss the "big picture" by getting lost in the specific details of the vehicle. The development of the F-111 aircraft is a good example. Although it is now a very capable weapon system, strict adherence to arbitrary design specifications needlessly drove up development costs and delayed its schedule. If the overall mission and concept of the F-111 system were more clearly stated and followed, many of these specifications would have been reconsidered to the benefit of the program.[48]

Similarly, in developing RASFOR, the entire system must be considered. Even if a vehicle can be developed to launch in hours, it is of little use if it takes months to assemble, checkout, or emplace at its launch facility. Taking it one step further, the operational ends of RASFOR are worthless if the satellite it carries takes a long time to check out on orbit. The use of lightsats, with fewer subsystems and lesser mass, can dramatically reduce the time required for on-orbit operations.

Risk Reduction versus Risk Distribution

Under the evolutionary approach to space operations, risk reduction was accomplished by tedious quality assurance checks and extensive system redundancies. One of the greatest benefits of a RASFOR approach is operational risk is distributed--the dilemma of having all the eggs in one basket is avoided. This concept of risk distribution can prevent the recurrence of previous billion-dollar losses, such as the Titan IV SLV incident of August 1993.[49] Also, this concept will drastically reduce the need for quality checks and redundancies, thereby reducing procurement and operating costs.

Simplicity

In pursuing a RASFOR system, simplicity must be emphasized to avoid the pitfalls of complicated evolutionary systems. Simplicity of equipment and operations can significantly increase the utility of spacelift. Specific methods to reduce system complexity include the standardization of equipment and procedures. Boosters and satellites can be developed with common modular elements and standard interfaces. These measures will reduce costs of procurement by introducing larger production buys with fewer configuration changes.[50] Repeatable procedures can reduce training requirements and reduce the chance for error.

A major contributor to the complexity of current systems is infrastructure, which includes many elements: transportation, handling, and test equipment; storage, assembly, and launch and facilities; and command, control, and range operations centers. These required elements not only complicate spacelift system operations, but they also carry their own logistics and maintenance problems. During RASFOR system design, a conscientious effort should be made to make maximum use of existing military infrastructure, thus reducing the need for specialized equipment. Simpler systems with less infrastructure can also reduce the manpower required for operations, thus saving costs and reducing the chance of human error causing the system to fail.

The Proper Use of Technology

The purpose of this paper is not to bash technology, nor is it to make light of the tremendous accomplishments of our national space programs. However, it is intended to warn against the US resting on its space laurels. We cannot continue to contend that, during war, our advanced technological capabilities and industrial base can make up for short-sighted strategic plans made during peace. During the development of RASFOR, technology must be seen in its proper light--as a *possible means* to a solution, *not* the solution itself. The technology offering the greatest simplicity and operational capability must be selected, even if it is not the most "advanced" of choices.

One of the most promising advances of the next decade fit well to the RASFOR approach--microtechnology. NASA's Jet Propulsion Laboratory had already been able to reduce the size of a certain transducer from the size of a soda can to a mere cubic millimeter. Not only does the microtechnology save weight, space, and power, but in some cases it may provide instruments that are actually more sensitive than their larger predecessors.[51]

Military First

Contrary to the recommendations of numerous spacelift studies having been conducted since the *Challenger* disaster, combat capable space systems should be pursued without the influence of civil and commercial interests. While civil and commercial space programs entail large expenditures, they represented only 0.24 percent of the 1992 gross domestic product[52]--hardly a threat to US economic viability. In contrast, existing and proliferating foreign military space capabilities present a feasible threat to US national security. This is not to say civil and commercial space industry cannot benefit from the more capable military systems produced through de-evolution. However, their benefit should be derived only after the military system has been established.[53] To do otherwise will open the door to a long and complex consensus building process[54] further delaying the deployment of a critical combat capability.[55]

Operational Options

In the development of RASFOR, there are several "optional" areas to consider with potentially large payoffs in terms of operational utility. In actual launch operations, the concept of making the lift vehicle have an abort capability may have merit. The current approach ("lighting the candle") entails 100 percent commitment when the booster is ignited--the system either flies or it dies. An abort-capable vehicle can have built-in subsystems to rescue the payload, and perhaps even the entire vehicle, if sudden loss of the main propulsion system occurs. The decision to pursue this capability should be based on trade-off studies considering complexity, reliability, operational requirements, payload and vehicle availability, and cost.

The implementation of RASFOR can introduce a new option for heavy lift--on-orbit assembly. While this option may require the development of robotic orbital transfer and assembly vehicles, it also offers many advantages over the current one-shot method. As discussed in previous paragraphs, the risk of the full system will be distributed over several launches. Also, if a subsystem fails during on-orbit checkout, only that portion will need to be replaced via RASFOR. If the RASFOR has a parallel launch capability, or if its launch turnaround time is sufficiently short, then the entire heavy system can be on line in the same or less time than currently possible.

For the case of heavy systems that may not be able to be broken down into smaller subsystems (such as a space station structural element), RASFOR may be used in conjunction with conventional heavy lift under what may be termed the "90/10 split" method. In this approach, the majority (possibly 90 percent) of the payload is "dumb" weight--structure, fuel, supplies--while the remainder (possibly 10 percent) of the payload is the "smart" weight--electronics, sensors, solar cells. The 90/10 split puts the "dumb" payload on conventional heavy lift and the "smart" payload on rapid-response spacelift, thus providing the capability to rapidly replace any "smart" subsystems failing to check out on orbit.

Benefits

The benefits offered by rapid space force reconstitution systems are numerous: increased capability, operational utility, and flexibility, and decreased vulnerability, risk, and cost.

Increased War Fighting Capability

The primary objective for developing and employing RASFOR system is straightforward--*provide responsive and flexible space support to the war fighter.* This support is a key enabler for space-based systems serving as force multipliers to increase the nation's warfighting capability. RASFOR system can provide an increased satellite sortie generation rate that may be required to replace failed satellites, or to augment existing constellations.

The use of lightsats can provide more capable and less vulnerable satellite systems. Having a distributed constellation of many lightsats versus a few conventional satellites can be compared to a networked system of personal computers versus a larger mainframe. In both cases, the loss of an element in the distributed system will have a much less dramatic effect on overall system performance than a loss in the mainframe environment. Also, problems within the system are easier to diagnose and repair. From an adversary's viewpoint, the distributed system presents a challenging situation--there are more targets of less value, making the overall system less vulnerable to attack. A distributed lightsat system, coupled with an RASFOR system will present the enemy with a modern-day Hydra: for every satellite "head" they cut off from the constellation, the RASFOR system can be used to "grow" its replacement.

Smaller satellites designed with shorter operational lives can also provide more capable support to the warfighter. The director of the NASA Center for Space Microelectronics Technology addresses the advantages of smaller systems:

> Instead of launching every decade, we launch every year or two years, which maximizes the possibility for insertion of new technology. and you minimize your risk by distributing the launch over five launches instead of one.[56]

Figure 2 illustrates the capability advantage possible using shorter-life lightsats. As applied technology continues to advance in the future, satellite capability will parallel these advances. Both short-life (example: 2-year life) and long-life (example: 10-year life) satellites incorporate available technology advances into their next generations of design. However, the short-life systems are able to go through five generations of improvement for every one generation of the long-life system. The final result is that the short-life system will have a capability advantage over the long-life system for eight years of its life.

An operational RASFOR system can provide a more polemic function to warfighters--it can serve as a platform for aerospace control and force application.[57] For example, RASFOR systems can be outfitted with payloads to perform offensive or defensive counterspace missions, or to conduct strategic attack missions. Such applications can make it possible to deploy precision-guided conventional munitions anywhere on the plant's surface within hours.[58]

Finally, and perhaps most importantly, RASFOR can provide the warfighter with *flexibility at the grand strategic level*. The MILSTAR satellite system has been criticized as being a cold-war system without a mission. Indeed, many of its subsystems were designed under the national security strategies reflecting a bi-polar world under nuclear detente.[59] Because of the global changes occurring during its long development period, the US is faced with a system meeting requirements that may no longer be valid. Implementing a military space structure using RASFOR (with short-life satellites) will provide a more responsive system that can adapt more readily to changes in national security strategy.

Improved Development Process

RASFOR elements have several advantages in development and procurement over conventional spacelift and satellite systems. The emphasis on simplicity, standardization, and operational utility for the spacelift system, coupled with reduced subsystems for smaller and shorter-life lightsats can lead to shorter development and procurement cycles. Standardization of system elements can result in increased development program stability and allow for multi-year procurements and incremental funding reducing program costs by as much as 35 percent.[60] In addition to cost savings, this approach also provides increased flexibility for future space systems. Also, standardized lightsat buses can provide the core for low-cost technology test beds to reduce program technical risks and their system costs.[61]

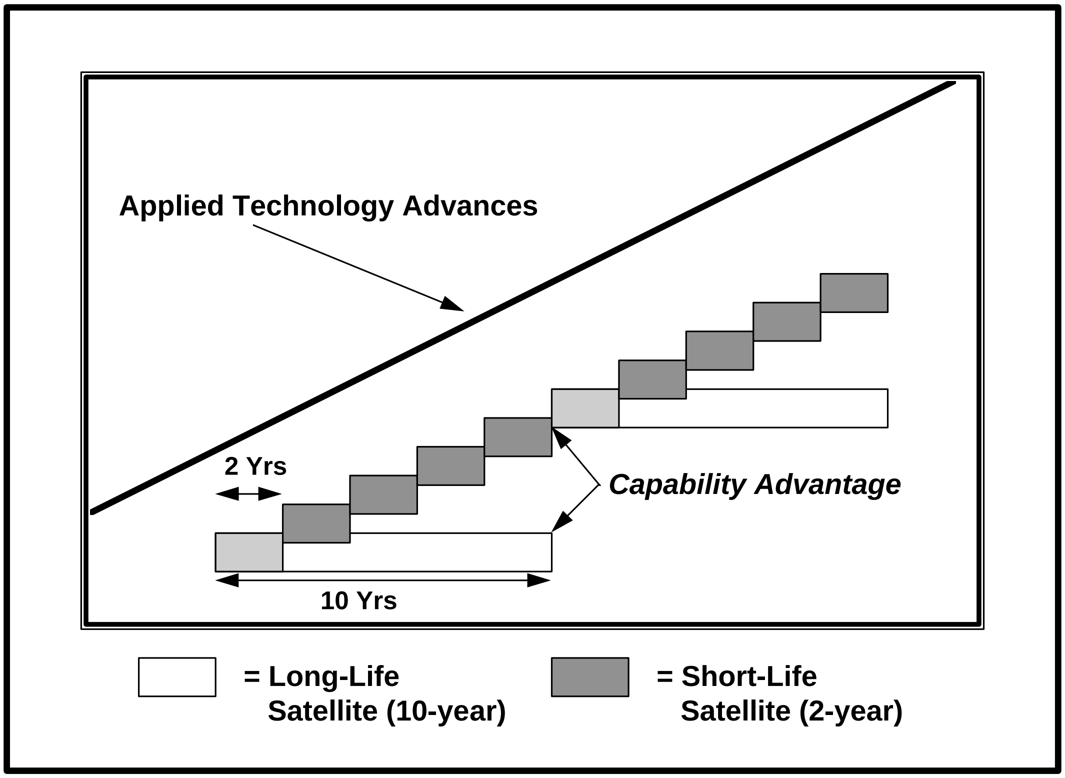

Figure 2. Capability Advantage of Short-Life Satellites

Strengthened US Space Foundation

Although the primary objective of RASFOR systems should be to develop military spacelift capabilities, the implementation of such a program will definitely strengthen the national space-related industrial base. Civil and commercial applications are very likely, including non-space related spinoffs such as medical instruments.[62] However, benefits to the non-military sector are not guaranteed. Industry may have to take some initiative, and even some risks, to benefit from RASFOR systems; the US government must fully support any such initiatives.

The development of turbojet-powered civilian transportation aircraft offers an example that can be applied to the RASFOR system development. The Boeing Aircraft

Company developed and produced the B-47 and B-52 strategic bombers for the US Air Force. These aircraft were designed and built to provide a critical *military capability* - nuclear deterrence. Their design and procurement were not contingent upon commercial aircraft needs, and therefore no consensus building outside of military circles was required. The experience gained by Boeing during the program was applied, at great risk to the company, to the development of the Dash 80.[63] This aircraft was the forerunner of the Boeing 707 commercial transportation aircraft, in essence being the forefather of all Boeing 700-series jets. The development came full circle back to the military when the Air Force decided to use Boeing's aircraft in a version modified for aerial refueling--the KC-135. This success story illustrates that the approach of military first, commercial application second makes sense for RASFOR development.

Conclusions and Recommendations

Doctrine

Space doctrine is still in its infancy. The current version of Air Force space doctrine states that "space forces offer a new operational horizon from which all military forces can benefit by adding to their responsiveness and effectiveness."[64] The irony of this doctrine is that it carries through with its theme with regard to all military forces *except* their own--the issue of increasing the responsiveness of space force support is almost ignored. Most of this doctrine details how to transmit data from space to surface forces and how to deny an enemy's capability to do the same. Little thought is given to how we will react when enemy tries to deny our space forces.[65] The unstated assumption is that US satellites will always be in place when we need them and that existing reconstitution methods (prepositioning, on-orbit spares) are sufficient; no proactive approach to space force reconstitution during combat is presented.[66]

Although the spacelift element of space force reconstitution is mentioned in current doctrine, it is given very low priority. Assured access to space is given lip service in Joint and Air Force doctrine; both acknowledge the problems with current spacelift systems, but do not consider the ramifications of these deficiencies in a combat environment.[67] This lackadaisical treatment of space force reconstitution in current doctrine could lead to disaster in our next space war. This deficiency can be corrected by implementing the following recommendations.

1. **Proactive Reconstitution**. Rapid space force reconstitution (RASFOR) is needed to ensure that these critical assets are always available when and where they are needed. *The essential nature of RASFOR must be emphasized throughout space doctrine*. In a combat environment, the capability to rapidly replace or augment satellites is essential to providing complete and flexible support to joint warfighters. Without this capability, a properly-armed enemy can eliminate our satellites (active and spare) to nullify all force enhancement derived from them. If satellites are not available during wartime, then current space doctrine falls apart. An operational RASFOR system can ensure satellites will always be available when needed--it must be recognized as the key enabler for space doctrine. Therefore, *RASFOR must be added as a tenet of US space doctrine.*[68]

2. **The Space Campaign**. The options provided by a RASFOR system must be clearly understood by campaign planners, especially its ability to react to short-notice crises. *RASFOR must be integrated into space campaign doctrine*.[69]

3. **Requirements**. The scope of operations RASFOR must perform is unknown. Specific requirements must be determined as a basis for RASFOR development, and these requirements must be coherent with future combat scenarios. *As a minimum, the ability of the current US space force to meet two simultaneous major regional conflicts must be evaluated to determine if RASFOR is required.*[70] Other realistic scenarios must be considered, and the best and worst case features of space warfare must be included.

4. **Development and Acquisition**. Once clear operational requirements have been determined for a RASFOR system, its force elements must be developed and acquired. As the service entrusted with aerospace control and exploitation, the Air Force must take the lead in this effort. However, the *participation of all armed services in the requirements definition, development, and acquisition of RASFOR systems is paramount to their success in combat.* The design approaches previously discussed must be emphasized during development, to include the extensive use of prototype or X-vehicles.

5. **Priority.** *RASFOR must be developed with a military-first approach*. RASFOR technologies and systems must be made available to commercial spacelift and satellites (as appropriate for security considerations). However, it must be emphasized that *the system will not pay for itself* and *technological spinoffs, while predicted*, *are not guaranteed*.

6. **Schedule.** Acquisition of RASFOR systems must support an implementation timeframe of the years 2002-2007. This timeframe coincides with the projected availability of satellites (existing or in production) to fulfill military needs.[71]

7. **Employment.** Based on the advantages offered by RASFOR systems, the US must consider a fundamental space force structure change to lightsat constellations. The actual employment of RASFOR systems *must include a balance of elements dedicated for continuous alert*, and elements dedicated to routine replacement (with the option of moving to alert status during a crisis). For payloads exceeding the lift capabilities of RASFOR systems, the 90/10 weight split method with on-orbit assembly can be used. Finally, RASFOR systems must maintain the operational flexibility to use their spacelift elements as force application platforms.

Future Challenge

"The ultimate objective of military space operations is the effective employment of space capabilities in support of land, sea, and air operations to gain and maintain a combat advantage throughout the operational continuum and across the three levels of war."[72] Accomplishing this objective requires the employment of space forces when and where they are needed--an objective that can be met by rapid space force reconstitution. US space forces are *not* preeminent in their war-fighting capability. Development of a RASFOR system is an *essential* step the US must accomplish to be the number one power in the "high ground" of combat media.

Notes

[1]Christopher D. Lay, "Space Control Predominates as Multipolar Access Grows," *Signal*, June 1990, 78. The ASAT threat is not limited to the destruction of space assets. Lay states there are "many methods that can be used to degrade or disable a spacecraft. Some disabling methods can not be detected until the satellite is put to use."
[2]*Soviet Military Power Prospects for Change 1989* (Washington D.C.: Government Printing Office, 1989), 55-56.
[3]James T. Hackett and Dr. Robin Ranger, "Proliferating Satellites Drive U.S. ASAT Need," *Signal*, May 1990, 155.
[4]Ibid., 155.
[5]Global Reach Global Power, (Washington D.C.: Department of the Air Force, December 1992), 8.
[6]General John L. Piotrowski, "The Right Space Tools," *Military Forum* 5, no. 5 (March 1989): 46. Italics were added to quote.
[7]Piotrowski, 44.

[8]Lt Col Stephen J. Dunning, USAF, *U.S. Military Space Strategy* (Newport, R.I.: The United States Naval War College, 14 May 1990), 9.
[9]Gen John L. Piotrowski, USAF, address to the Michigan State Air Force Association Convention, East Lansing, Mich., 28 July 1989.
[10]John D. Morrocco, "US Uses Gulf War to Frame New Strategy," *Aviation Week and Space technology*, 23 August 1993, 40. The author notes that Operation DESERT STORM was conducted within a timeframe in which "coalition forces were allowed to build up their forces unmolested, a luxury the US cannot rely upon in the future."
[11]Lt Gen Thomas S. Moorman, Jr., USAF, "Space: A New Strategic Frontier," in *The Future of Air Power in the Aftermath of the Gulf War*, ed. Richard H. Schultz, Jr. and Robert L. Pfaltzgraff, Jr. (Maxwell AFB, Ala.: Air University Press, 1992), 242. Gen Moorman noted that, although this event illustrated the flexibility of some of our military satellites, "this feat nevertheless highlighted our need to be able to more rapidly augment our on-orbit capabilities."
[12]David E. Thaler, *Strategies-to-Tasks: A Framework for Linking Means and Ends*, Rand Report DRR-243-AF (Santa Monica, Calif.: Rand Corporation, 1993), 11. Figure 4 is based on a generic operational concept framework presented in this report.
[13]Department of Defense, National Aeronautics and Space Administration, and Department of Energy, *Ten-Year Space Launch Technology Plan* (Washington, D.C., November 1992), ES-1. The current Atlas II SLV is based on the Atlas ICBM; the current Titan IV SLV is based on the Titan ICBM; and the current Delta II is based on the Thor ICBM.
[14]Lt Col Randall G. Joslin, *Spacelift -- A National Challenge for USSPACECOM*, Air War College Associate Programs Research Report (Peterson Air Force Base, CO: 21 June 1993), 8.
[15]Ibid., 8.
[16]TSgt Phil Rhodes, "Stealth: What is it, Really?" *Airman* 35, no.9 (September 1991), 23. Systems developed in each stealth technology generation include: generation 1 -- the SR-71 (Blackbird) and B-1B (Lancer); generation 2 -- F-117A (Stealth Fighter); generation 3 - the AGM-129A (Advanced Cruise Missile); general 4 - B-2 (Spirit); general 5 - F-22 (next generation air superiority fighter).
[17]Moorman, 245.
[18]Joslin, 12.
[19]Maj Robert H. Chisholm, *On Space Warfare: Military Strategy for Space Operations*, Airpower Research Institute Research Report No. AU-ARI-84-3 (Maxwell Air Force Base, Ala.: Air University Press, June 1984), 21-22.
[20]Maj Gen Robert R. Rankine, Jr., "The US Military is not Lost in Space," in *Building a Consensus Toward Space: Proceedings of the Air War College 1988 Space Issues Symposium* (Maxwell Air Force Base, Ala.: Air University Press, April 1990, 48.
[21]Philip Kunsberg, "Space Infrastructure," in *Building a Consensus Toward Space: Proceedings of the Air War College 1988 Space Issues Symposium* (Maxwell Air Force Base, Ala.: Air University Press, April 1990), 69.
[22]Air Force Manual 1-1, *Basic Aerospace Doctrine of the United States Air Force*, (Department of the Air Force, Washington D.C., March 1992), 14. This quote is found in paragraph 3-6.c., which discusses the force enhancement role of aerospace forces.
[23]*Blue Ribbon Review of the Air Force in Space in the 21st Century*, (Washington D.C.: Department of the Air Force, 1992), 9-11, 15.
[24]Roger D. Launius, "Toward an Understanding of the Space Shuttle: A Historiographical Essay," *Air Power History*, Winter 1992, 6.
[25]Launius, 7.
[26]Ibid., 6.
[27]Ibid., 17.
[28]Ibid., 8.
[29]Rankine, 54.
[30]*The Future of the U.S. Space Launch Capability, A Task Group Report*, (Vice President's Space Policy Advisory Board, E.C. Aldridge, Jr., Chairman, Washington, D.C., November 1992), 21.
[31]Editorial, "Ignore DoD on Launch Strategy," *Space News*, 4-10 October 1993, 14.
[32]Rankine, 47-48, 53-54.

[33]Department of Defense, *Report of the Defense Science Board 1989 Summer Study on National Space Launch Strategy* (Washington, D.C.: Office of the Under Secretary of Defense for Acquisition, March 1990), 29.
[34]Joslin, 8.
[35]Lt Col James D. Martens, *Building Blocks in Space,* Airpower Research Institute Research Report No. AU-ARI-89-6 (Maxwell Air Force Base, Ala.: Air University Press, April 1990), 10.
[36]Kunsberg, 66.
[37]*Report on the Department of Defense Space Investment Strategy*, 24 January 1994 Service Coordination Draft, 1.
[38]Ibid., 21.
[39]Quoted in *Economics*, Fifth Ed, by Richard G. Lipsey and Peter O. Steiner (New York: Harper & Row, 1978), 156.
[40]Richard G. Lipsey and Peter O. Steiner, *Economics*, Fifth Ed (New York: Harper & Row, 1978), 156.
[41]DoD Space Investment Strategy, 38.
[42]Chisholm, 22.
[43]Three well-publicized candidates for rapid-response spacelift are the Pegasus, Taurus, and Delta Clipper space launch vehicles. The Orbital Sciences Corporation (OSC) Pegasus is a proven vehicle (first launched 5 April 1990) that can be air-launched from a modified Boeing B-52 or Lockheed L-1011 ("Pegasus Ready to Air-Launch from Stargazer," *Chemical Propulsion Information Agency Bulletin* 20, no. 1 (January 1994): 1, 6.) The OSC Taurus vehicle is a ground-launched derivative of the Pegasus; its first launch was from Vandenberg Air Force Base on 13 March 1994 ("US Defence Department Launched First Taurus Rocket," Reuters Information Services, Inc., 13 March 1993.) Technical details of these vehicles are summarized in: Steven J. Isakowitz, *International Reference Guide to Space Launch Systems* (Washington, D.C.: American Institute of Aeronautics and Astronautics, 1991), 217-230. The McDonnell Douglas DC-X (Delta Clipper) launch vehicle is a test vehicle for single-stage-to-orbit flight. Although the DC-X has not flown into space, it has flown successful hover tests (Michael A. Dornheim, "DC-X Makes Second Flight," *Aviation Week and Space Technology*, 20 September 1993, 39).
[44]*The Case for Space*, White Paper by HQ USSPACECOM/J5V, Peterson Air Force Base, CO, 9 August 1993, 2.
[45]Kunsberg, 62.
[46]Although previously thought to be crude, the spacelift systems of the FSU have proven to be very sophisticated. The reference to duct tape is not meant to demean their technology, but rather it is to serve as a tribute to the operational utility of their fault-tolerant systems.
[47]De-evolution is *not* the same word as devolution; according to Webster's, devolution is "a passing down through successive stages," implying a deterioration or degradation. De-evolution is a term intended to show the reversal or retracing of an existing evolutionary path. For this paper, it primarily refers to de-evolving the development current space launch vehicle to eliminate systems, infrastructure, and procedures that have compromised operational utility. This de-evolution will actually lead to enhanced, instead of degraded, vehicles.
[48]Bill Gunston, *Attack Aircraft of the West* (London, England: Ian Allen Ltd, 1974), 173-175. Mr Gunston presents a concise and interesting case study of the F-111 aircraft development. One of the requirements that should have been addressed was that of speed at low altitudes: "If TAC had not insisted on a low-level Mach number of 1.2, but instead chosen M 0.95 (which would have in no way harmed the ability of the aircraft to penetrate), millions of dollars would have been saved and the requirement would have been meet with ease."
[49]Bruce A. Smith, "Explosion Halts Titan 4 Launches," *Aviation Week and Space Technology*, 9 August 1993, 22. On 2 August 1993, a Titan 4 launch from Vandenberg AFB exploded at 101 seconds into its flight. The cost of the failure is estimated to be between one and two billion dollars. The effects of this incident go beyond just the economics; it "put Titan 4 launches on hold and threatens further delays in the deployment of key national security spacecraft."
[50]Martens, 10. This report provides an excellent commentary on the challenges of developing standardized space systems.
[51]Frank Morring, Jr., "Microtechnology has Uses Beyond Aerospace" *Aviation Week and Space Technology,* 21 February 1994, 87.

[52]Lt Col Larry D. James, *Dual Use Alternatives for DOD Space Systems*, Air War College Research Report (Maxwell Air Force Base, Ala.: Air University, April 1993), 17.
[53]DoD Space Investment Strategy, 39. This report notes that "In some cases, however, space technologies and applications are specialized for national defense, and there is no customer for them except the DoD."
[54]Jeffrey M. Lenorovitz, "White House Spurs Launcher Initiative," *Aviation Week & Space Technology*, 3 January 1994, 20. In this article, Richard DalBello (assistant director of the Office of Science and Technology Policy for the Clinton administration) sums up the biggest problem with current civil/commercial/military spacelift consensus building: "The hardest part of getting what you want is knowing what you want."
[55]An example of spacelift consensus building gone awry: The pursuit of a "next generation" spacelift system has been so mired in politics that it has done little more than change names from "Advanced Launch Development Program" to "Advanced Launch System" to "National Launch System" to its most recent incarnation --"Spacelifter" (this constant change has prompted some to ironically refer to the program as "Shapeshifter").
[56]Morring, 87.
[57]Air Force Manual 1-1, *Basic Aerospace Doctrine of the United States Air Force* (Department of the Air Force, Washington D.C., March 1992), 6-7.
[58]Lowell Wood, "The US Air Force in 2020," lecture to Air University Spacecast 2020 Team, Air War College, Maxwell AFB, Ala., 27 October 1993.
[59]Jim Abrams, "MILSTAR," The Associated Press, 16 March 1994.
[60]DOD Space Investment Strategy, 42-43.
[61]Ibid., 45.
[62]Morring, 87.
[63]R.G. Thompson, "Dash 80," *Smithsonian Air & Space*, April/May 1987, 62-64.
[64]Air Force Doctrine Directive 4, *Air Force Operational Doctrine: Space Operations*, DRAFT, (Department of the Air Force, Washington D.C., November 1993), 1.
[65]Ibid., 16. Figure 4-2 outlines defensive counter space options which includes an option to "reconstitute assets." However, this is one among many options; no further detail is given to this concept except the two words found in the figure. Also, the most of the other options are passive measures that are dependent on existing assets in orbit. If these assets are taken away, so are the options.
[66]Ibid., 23. The section "Crisis and Wartime Space Support" (paragraph 5.1.2.2) does not mention any form of reconstitution.
[67]Ibid., 12, 16. Reference to spacelift is hidden under a subsection titled "Other Considerations" (paragraph 4.3.4.1,) and it is not mentioned under the space role definition of "force support" (3.1.4.). The joint doctrine reference is found in Paragraph 5.a.(3) of Joint Pub 3-14, *Joint Doctrine, Tactics, Techniques, and Procedures (TTP) for Space Operations*, Final Draft, (Joint Chiefs of Staff, Washington, D.C., 15 April 1992), IV-40.
[68]The proper place to add RASFOR to current space doctrine is as a major heading under chapter 4 (Tenets of Space Doctrine) of Air Force Doctrine Directive 4.
[69]The proper place to integrate RASFOR into space campaign doctrine is under paragraph 5.1.2.2, Crisis and Wartime Space Support, in chapter 5 of Air Force Doctrine Directive 4; and under paragraph 5, Space Operations Mission Support, in chapter 3 of Joint Pub 3-14.
[70]In telephone conversations with officials at the Space Warfare Center, the National Test Facility, and the US Space Command J33Z (space exercise branch), the author determined that none of these organizations have conducted studies or exercises to determine if current US space forces could properly support the two simultaneous regional conflict scenario used as a basis for the 1993 Bottom Up Review.
[71]DOD Space Investment Strategy, 24 January 1994 Service Coordination Draft, 2.
[72]Joint Pub 3-14, III-3.