May 3rd, 1:00 PM

Paper Session III-C - The Case for a Military Spaceplane

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THE CASE FOR A MILITARY SPACEPLANE

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Background

Since the dawn of the space age, the United States and most other spacefaring nations have headed down an essentially constant path to space capabilities. Launch vehicles have been developed from long-range missiles, and have become increasingly larger and more complex to provide greater payload capability. Space vehicles have followed a similar course, increasing in size and complexity to provide more capability and to maintain that capability for longer periods of time. This path has resulted in systems which provide tremendous capability, but at the cost of large budgets, lead times of many years to achieve new capabilities or even to sustain current capabilities, and capabilities that are relatively static once placed into orbit. Months are needed to assemble and launch a rocket even if already produced, and most satellites have only enough fuel for station-keeping or changing orbital planes by a degree or two.

A number of organizations, within the U.S and internationally, are looking at new ways to provide capabilities from space. Many such concepts in some ways "go back to the future" as they call for smaller, less expensive, more operable systems. Thirty five years ago, launch rates were considerably higher at the Air Force's two launch ranges, per-launch costs were lower as the systems were less complex, and military crews could perform some of the actual launches. Current technology provides the means to achieve considerable capability while returning to smaller systems with lower operations costs. While the capacity of any one launch vehicle or space vehicle may be less than that of one of our current launch vehicles or satellites, the overall capability provided could be greater and more militarily useful. The Military Spaceplane concept is one possibility. Conceived as a two-stage-to-orbit system of vehicles, some of which would be reusable, it provides relatively modest payload capabilities but is intended to lower the per-mission cost and to provide responsiveness unheard of in today's systems. Certainly the Military Spaceplane is not intended to replace all of today's launch vehicles and satellites, but may provide an opportunity to perform some of those missions more effectively and provide the ability to perform additional missions that cannot be performed today.

Mission Requirements

National policy, DoD policy, and Air Force Doctrine all describe four military mission areas in space: Space Force Support, Space Force Enhancement, Space Control, and Space Force Application. While all four are valid military mission areas, the actual capabilities and the policies regarding use of these capabilities have not been equally developed.

Space Force Support consists of the enabling operations for the other three area. The two major components are spacelift and satellite operations. In the context of current systems and operations, spacelift consists primarily of boosting space vehicles (satellites) to a designated orbit. Future capabilities consistent with the concept of spacelift in a support role may include on-orbit maneuver, on-orbit servicing or refueling, space vehicle retrieval, and return to earth. Satellite control is evolving from command and control of satellite buses to providing a communications network linking individual satellite system control facilities to their respective on-orbit constellations.

Space Force Enhancement consists of the operations conducted from space to support terrestrial forces, including air, land, and sea. Current Air Force systems and operations include navigation, communications, reconnaissance, surveillance, ballistic missile warning, and environmental sensing. Intelligence fits into this mission area as well. As the military's use of space evolves, this mission area may support Space Control and Space Force Application operations as well.

Space Control consists of offensive counterspace, defensive counterspace, and contributing capabilities. Offensive counterspace operations are intended to deceive, disrupt, deny, degrade, or destroy adversary space assets or capabilities. Defensive counterspace operations are intended to protect space assets or capabilities through active or passive means. Finally, contributing capabilities are those that enable counterspace operations. These include space surveillance, space reconnaissance, and other information necessary to operate in space.

Space Force Application is the use of weapons from or through space to terrestrial targets. Currently the Air Force's Intercontinental Ballistic Missiles (ICBM) and the Navy's Sea-Launched Ballistic Missiles are the only weapons in this mission area.

The history of military space is a long line of requirements, concepts, proposals, and programs intended to achieve a military spaceplane capability. As far back as the 1930s, Eugene Sanger's concept for a intercontinental bomber that could skip along the upper atmosphere would have provided Germany a military spaceplane if the technological issues could have been solved. Werner von Braun, even while working on expendable rockets as long-range artillery, realized that reusable launch vehicles were necessary to make any significant progress in space transportation.

The U. S. Air Force has added its share of paper to the pile. The Dynasoar program of the early 1960s intended to develop a manned spaceplane. Unstable requirements that varied over time from reconnaissance to strategic bombing, as well as insufficient budget and an insufficient technology base, ended this program and in so doing set a path followed by many subsequent programs. The Manned Orbital Laboratory program of the late 1960s was less ambitious on the launch side, but intended more extensive on-orbit operations. Concurrent with these was a proposal to build a military base on the moon, with reusable launch vehicles for transportation to and from the earth. The Space Shuttle absorbed most of the attention during the 1970s, but there were still military requirements being generated for various classified and unclassified capabilities. Requirements documents were written, and in a number of cases approved, for military space flight, tactical space systems, military aerospace vehicles, global prompt conventional strike, space control, and tactical military operations in space.

There are a number of currently approved requirements to which a military spaceplane system could contribute. Joint Vision 2020 documents the overall U.S. military vision for the future. Of the concepts included, a number would be enhanced by a spaceplane systems, including Full Spectrum Dominance, Dominant Maneuver, Precision Engagement, Full Dimension Protection, and Information Operations. The USSPACECOM Vision 2020 provides a similar vision for the unified military space future. Operational Concepts supported by a spaceplane include Control of Space, Global Engagement, and Full Force Integration. The USSPACECOM Long Range Plan (1998) gets more specific, identifying a need for "Recoverable, Rapid Response Transport to, Through, from Space; 2-6 hours by 2020."

Air Force Doctrine identifies a number of Core Competencies that could be enhanced by a military spaceplane, including Air and Space Superiority, Precision Engagement, and Information Superiority. The AFSPC Strategic Master Plan (1999) also gets more specific, identifying "unresponsive spacelift" as a deficiency, and identifying a military spaceplane system as a mid-term (2008-2013) solution. The current US Space Command Space Control MNS contains a requirement to "Improve responsiveness of launch vehicles to support emergency replenishment of space assets," clearly a mission that could be supported by a military spaceplane.

A number of studies have also recommended the military continue down the road to an operational spaceplane. The Future of the U.S. Space Launch Capability (Vice President's Space Policy Advisory Board, 1992) stated that the "reusability of space launch components has a potential high payoff." The Space Launch Modernization Plan (1994), even while recommending the Air Force develop a new generation of expendable launch vehicles for the immediate future, said that "NASA should be assigned the lead for reusables with DoD maintaining a cooperative reusable program." The USAF Scientific Advisory Board's Space Roadmap for the 21st Century Aerospace Force (Nov 1998) recommended the Air Force "continue the current Space Maneuver Vehicle demonstration…develop system concept…ensure NASA-led effort addresses Air Force lift requirements."

Current Shortcomings

Current launch systems have evolved to complex systems suited for deploying large satellites on schedules set far in advance. Typical timelines from identifying a launch need to launch day vary from 90 days for a medium class vehicle to 180 days or more for a heavy class vehicle. Small launch vehicles can be less, but they are not often used for operational missions. This lack of responsiveness does not lower costs, rather it does quite the opposite. Months of preparation and buildup of vehicles on the launch pad takes a "standing army" of technicians, engineers, and managers. Costs vary from $10-20M per launch for small vehicles up to the $350M range for heavy lift.

The Atlas V and Delta IV families of vehicles developed by the Evolved Expendable Launch Vehicle program are, as the name suggests, evolutionary systems. Responsiveness will be increased over current vehicles, in come cases cutting the time to get to launch in half. Costs will also be reduced, with a program goal of saving at least 25% on the overall DoD launch manifest. The greatest percentage savings will be in the heavy lift payload class, which is the fewest in numbers. The lack of significant growth in the launch market may make it difficult to achieve the desired savings over the long term.

On-orbit operations are also limited in current systems. Boosters with or without upper stages may deliver a satellite to its final orbit, or the satellite may have to use integral thrusters and fuel to achieve the final orbit. In all cases, changing a satellite orbit to meet operational objectives requires use of on-board thrusters and fuel. Given the limited amount of fuel on board, satellites can not significantly modify orbits, and any maneuvering results in shorter life due to depleting fuel required for station-keeping.

Given the need for responsive launch to be defined in terms of days or hours, rather than months, it appears that significantly different approaches will be required to meet the need. The need for affordable launch, with a goal of under $10M per launch, leads to a similar conclusion. Significant orbit changes can not currently be accomplished in any amount of time for any cost, and building bigger satellites with big enough thrusters and fuel capacity make the launch problem even greater. While there may be a number of approaches, or combinations of approaches, that could meet some or all of the projected future military launch needs, the Military Spaceplane system is one that merits a further look.

System Concept

The Military Spaceplane concept consists of a system of systems. The four major components are the Space Operations Vehicle (SOV), and three "upper stages": the Space Maneuver Vehicle (SMV), the Modular Insertion Stage (MIS), and the Common Aero Vehicle (CAV). In addition to these, the payloads to actually accomplish the space support, force enhancement, space control, and force application missions are also required.

The Space Operations Vehicle concept is a reusable, unmanned single stage booster. While an orbit-capable SOV is the ultimate goal, a sub-orbital vehicle could perform the mission initially. This is accomplished through a "pop-up" maneuver, in which the SOV launches to near-LEO altitude, separates the upper stage which then continues to the final orbit or trajectory with its own propulsion while the SOV recovers to earth. This significantly reduces the weight, propulsion, and thermal challenges on the SOV, but increases the demands on the SMV, MIS, or CAV. There are a number of options for launch and landing, the most likely being vertical launch and landing or vertical launch and horizontal landing.

The Space Maneuver Vehicle concept is a reusable, unmanned orbital platform. While primarily intended for use as a maneuverable satellite bus, the SMV can also act as a reusable upper stage. This allows much greater flexibility in boost vehicles, as the boost vehicle need not be capable of achieving orbit. Use of the available fuel to reach orbit necessarily limits the on-orbit maneuvering capability, but may allow for less expensive missions where that capability is not required. If boosted to orbit with a full fuel load, the SMV can vary a number of orbital parameters to perform a variety of missions. Plane changes greater than 20 degrees are possible, apogee, perigee, and orbital period can be varied, fly-bys of medium earth orbit (MEO) and geosynchronous earth orbit (GEO) are possible, and the SMV will be able to rendezvous with an existing satellite and maintain position or maneuver around it. Capabilities even further in the future may include microsatellite recovery, or on-orbit servicing. The SMV would have an autonomous reentry and landing capability to recover the platform as well as the mission payload.

The Modular Insertion Stage is a more traditional expendable upper stage. The MIS can deliver a payload to a MEO or GEO orbit that the SOV can not reach, or that the SMV either can not reach or is too large or heavy for the SMV. As with the SMV, the MIS could be boosted by the SOV or an expendable vehicle. As part of the overall Military Spaceplane architecture, the MIS propulsion system also powers the Common Aero Vehicle.

The Common Aero Vehicle (CAV) concept is a multipurpose reentry vehicle capable of delivering a variety of payloads from space to earth. As with the SMV and MIS, a variety of boost vehicles could be used. The CAV is powered by the MIS propulsion system, which provides sufficient boost to propel the vehicle to most points of interest in the world if launched in the correct azimuth. As the CAV incorporates aero surfaces as well as the engine, it is a maneuvering vehicle rather than a purely ballistic one. The CAV can deliver various conventional weapons, sensors, or other payloads over long ranges.

While not part of the Military Spaceplane system, mission payloads are critically important to the accomplishment of the mission. SMV may carry internal payloads just as an aircraft might, or may deploy microsats when the mission requires it. In either case, these payloads must be considerably smaller than today's satellites. This is not to say that mission capability is necessarily degraded from today. The SMV platform can provide power, station-keeping, communications, and other support functions. The payload need only perform the actual mission, and since it does not need to survive in the space environment for years and will be returned to earth for refurbishment and reuse, it does not need all of the redundancy and environmental protection of today's satellites. The resulting systems should be smaller, lighter, more power-efficient, and less expensive while potentially providing greater capability due to the ability to place payload or constellation in orbits specifically designed for the mission at hand.

Full benefit of the Military Spaceplane system can be realized only upon completion of the entire system and the appropriate payloads. Many of the benefits of the upper stages (SMV, MIS, CAV) can still be realized without the SOV. As the SOV is the greatest development challenge, it will likely take the longest and cost the most. Rather than wait for the SOV, there are several concepts for interim boost capabilities. While a traditional expendable launch vehicle such as one of the EELVs could be used, the responsiveness and cost make this option the least attractive from an operational standpoint. There are several launch options using surplus ICBM stages or existing solid rocket boosters as ground-launched boosters, improving cost and responsiveness but providing less lift. Other options involve launching solid boosters from aircraft, allowing the launch point to be optimized as well as increasing operational flexibility and security. While these options decrease on orbit flexibility by using SMV or MIS propulsion to achieve even low earth orbit, they can provide an earlier, responsive, affordable capability.

Operations Concept

Air Force Space Command has developed top-level concepts of operations for the SOV and the SMV, and various studies have further defined options for basing and operations. The current concept of operations allows for an SOV capable of achieving low earth orbit (LEO) or one capable only of sub-orbital performance. While an orbital capability would clearly be more versatile, a sub-orbital capability would still enable every mission intended for the spaceplane, thus the nearer-term concepts call for a sub-orbital SOV. Using the pop-up launch profile will allow a sub-orbital SOV to launch from a CONUS base, separate the upper stage at maximum altitude and velocity, and recover to another CONUS base. Current concepts call for capacity to lift 15,000 pounds, with a Δv ideal of 10,500 fps, allowing the SMV or MIS to reach orbit using their internal propulsion with a 1200 pound payload. Two CAVs could be launched due east, one in any other azimuth. While a standard mission would be completely preplanned and automated, en route mission changes must be accommodated in the command and control system. At least three operating bases are necessary to allow a launch to all of the azimuths of interest and allow recovery to a second base. One pair of bases should be in an west-to-east orientation to facilitate low inclination launches, and the third base north or south of those to facilitate polar launches. SOVs could be kept on alert for quick response launch-on-demand missions, assuming storable fuels and payloads with minimal support needs. A more likely scenario would involve a day or two to prepare the vehicles and payload, mate all the components, and actually launch the sortie. As with aircraft, launch-on-schedule missions would provide opportunities for launching non-time-critical payloads and for personnel training. A design life of 100 sorties for major subsystems and an emergency surge rate of 3 launches in 24 hours are envisioned.

The SMV can be used to reach LEO from a sub-orbital SOV or an expendable booster, or as an on-orbit platform. As an on-orbit platform, it can support a 1200 - 2000 pound payload for up to 12 months, and return with it. While 1200 pounds may not sound like much when compared to many current satellites, in this case it includes only the payload, e.g. sensors, transponders, and processing. The traditional bus functions such as structure, power, propulsion, guidance, and communications for vehicle control are resident in the SMV. An SMV that reaches orbit with a full fuel load could perform a mission in low MEO, and could perform a mission in GEO where a fly-by is sufficient rather than a co-orbit. The operating bases for landing SMVs will be the same as those for the SOV. As with the SOV, the SMV could be kept on alert, but more likely would be maintained in a state of readiness allowing for launch within a day or two. As different missions require different payloads, a high readiness state would require either mating the payload as part of the launch preparation, or maintaining multiple SMVs with different payloads. A design life of 20 - 40 sorties and a turn time between missions of 2 - 3 days or less for the SMV and payloads are envisioned.

The CAV can be employed in several different ways for a variety of missions. After separating from an SOV or expendable booster, a CAV can travel much of the distance to a target ballistically. Where necessary to avoid reentry trajectories towards Russia or other nuclear power, or to avoid defenses, the CAV can maneuver with integral aero surfaces on a programmed flight path. The CAV can also use that maneuver capability to bleed off airspeed before releasing one or multiple sensors or munitions, or to deliver a penetrator with significant kinetic energy to a precise location.

The MIS would be used for the same mission as current upper stages. After separating from an SOV or expendable booster, the MIS delivers a payload to orbit. Differences from current upper stages include faster response through storable propellants and design for fast assembly and checkout. From a sub-orbital SOV, an MIS delivers a planned 2000 pounds to a low inclination orbit, or 1200 pounds to a polar orbit. The MIS will be capable of several restarts to maximize flexibility in achieving various orbits.

Military Capability

The Military Spaceplane is inherently a Space Support system. Without specific payloads, it provides only transportation, much as a fighter aircraft without weapons. Specific payloads can be developed to provide additional mission capability in the space support mission area, as well as the other three space mission areas: Space Force Enhancement, Space Control, and Space Force Application. The Military Spaceplane system provides several desirable attributes beyond those of current launch and on-orbit systems: safety, reliability, testability, operability, and maintainability.

The reusable elements of the Military Spaceplane system, the SOV and SMV, have an inherent capability to control their flight path and land, greatly increasing the options for safely ending a flight in the event of an anomaly. Additional safety improvements are the desired use of non-toxic fuels, and the anticipated reliability and testability of the systems. While not a simple system, reliability will improve as experience is gained with the system. Today’s launch and space vehicles are partially tested on the ground, then launched and never recovered. Failures are currently analyzed using only factory data and procedures, and whatever instrumentation and status data might be available. Even successful launches and functioning satellites may be near the edge of failure; there is no way to know. A reusable system allows the opportunity to inspect the system after every mission. Weak areas and near-failures can be identified and appropriate actions taken before the next flight and incorporated into future designs. Testability will also improve safety and reliability. The reusable components of the system can be put through a full test program, much as aircraft are today. Systems can be tested in nominal and non-nominal conditions without jeopardizing an operational mission or completely using up an expensive asset as is done with ICBM testing.

Operability and maintainability improvements derive from the desired use of non-toxic fuels, relatively simple launch preparation and recovery, a system designed to be maintained and reused rather than merely assembled and used one time, and mission planning and command and control systems that facilitate fast reaction. Supportability has not been a major consideration with most current space systems, beyond keeping launch and space vehicles ready for use between the time they are manufactured and the time they are launched. Reusable systems will need supply and repair sources for engine, avionics, and "airframe" overhauls.

The Military Spaceplane can effect a number of Space Support capabilities beyond spacelift if future satellites are designed with those capabilities in mind. Refueling of large satellites is one potential opportunity. The SMV payload bay could accommodate a refueling system and sufficient fuel load to completely refuel a satellite. The SMV could co-orbit a damaged satellite and provide damage assessment imagery. The SMV could potentially recover high value microsats, carry out simple repair actions, or reposition a satellite to correct or optimize its orbit. In addition to providing a launch-on-demand capability, the Military Spaceplane should provide more cost-effective launch and reduce life-cycle costs for launch and space vehicle. Consider that every launch today completely uses up hardware components built to some of the most stringent requirements possible. All of the manpower involved in assembly of that vehicle is likewise expended on that single launch. The expenses involved in this mode of launching tend to limit the launch rate, resulting in amortizing the non-recurring costs over a smaller number of launches. Space vehicles currently have to be maintained on-orbit for their entire lives, whether their capability is required full-time or not. Designing and building a satellite for 10 years of service involves considerably higher cost due to higher-grade parts, added redundancy, testing and other factors than would a system designed for a few weeks or months of use when needed. While current satellites do amortize the cost of the bus, power, guidance, propulsion, and communication systems over the life of the satellite, the SMV could provide a platform that provides all of those support systems for several different payloads over its life. Limiting a new payload to just a sensor, emitter, or other mission system and appropriate processing greatly simplifies the mission-unique systems, reducing development time, cost, weight, and other negative factors.

The primary benefits of the Military Spaceplane to the Space Force Enhancement mission area are in providing fast reaction Intelligence, Surveillance, and Reconnaissance (ISR) capabilities, the ability to provide a quick gap-filler to augment an existing communications, navigation, or other constellation, and to quickly replace a degraded or destroyed satellite in a constellation. Major benefits in ISR capabilities include the ability to place sensors in orbits that optimize coverage for a specific theater, the ability to decrease revisit times by placing additional sensors in orbit, and to vary overflight times to prevent adversary forces from avoiding sensor coverage based on their knowledge of fixed orbital parameters. While not achieving the flexibility of airborne ISR assets, the SMV can provide much greater flexibility than today's space assets, and provide deep coverage without placing aircrews in harm's way.

The Space Control mission area is one where the SMV's capabilities can fulfill many unmet needs. Defensive counterspace, offensive counterspace, and contributing capabilities all either require or could be enhanced by a maneuvering platform. An SMV could place a defensive counterspace emitter, physical barrier, or other device near, or in the path of, an adversary space system to protect a friendly system. Similarly, an SMV could perform offensive counterspace missions, preventing adversary space systems from supporting adversary forces. These capabilities enable information warfare as well. An SMV payload could deny, degrade, or destroy an adversary's information through its space systems by jamming communications or spoofing sensors. Contributing capabilities could be enhanced as reconnaissance of an unknown or adversary space system are carried out with a sensor package in an SMV.

Finally, use of the SOV and CAV in a Space Force Application role can provide several useful capabilities. The only long-range, fast response weapon systems currently in the inventory are ballistic missiles. While these serve as a useful deterrent to nuclear attack, they do not provide capability in a conventional conflict. Long-range bombers can reach anywhere with refueling, but have to deal with restrictions on overflight, adversary air defenses, weather, and other factors. A CAV can strike a target over intercontinental ranges within an hour after launch without any of the operational factors of a bomber, and without resorting to nuclear weapons. As this capability extends to hard and deeply buried targets, the CAV could also provide a deterrent, to include some level of nuclear deterrent, with conventional weapons. While not capable of destroying large areas of soft targets, the CAV could hold missile silos at risk. As the Military Spaceplane and related facilities themselves are soft targets, it would be unwise to rely entirely on them for a nuclear deterrent, but they could augment nuclear forces if and when missile reductions are implemented.

Treaty and Policy Considerations

Ratified treaties and national policies must be considered in development and employment of space systems. There are several widespread misconceptions concerning military use of space, such as treaty prohibitions on weapons in space, or that all launch details must be publicized prior to launch. In reality, there are relatively few treaty constraints and many of those that do exist have loopholes or do not apply in times of conflict. Policy constraints, on the other hand, can and do limit what the Air Force can do in space. These policies can change as the political, threat, and technology climates change. Much of the current policy is a continuation of that developed during the Eisenhower administration. As much of the focus of space at that time was strategic missile warning, allowing unhindered access for Soviet and U.S. warning and reconnaissance space systems reduced the likelihood of one side launching a retaliatory strike based on a false alarm. With the growing use of space systems for tactical purposes, those policies should be reevaluated.

The Outer Space Treaty prohibits placing nuclear or other weapons of mass destruction in orbit around the earth, and prohibits any military installations on any celestial bodies. This treaty does not prohibit weapons of mass destruction which merely pass through space, as is done with ICBMs, nor does it prohibit orbiting conventional weapons. The operations concept for the Military Spaceplane does not call for placing any weapons in orbit, nor does it include any weapons of mass destruction. The CAV merely passes through space without orbiting, clearly meeting all of these treaty requirements.

The convention on Registration of Objects Launched into Outer Space calls for all objects launched to be registered with the United Nations, including orbital parameters and the object's function. While this would seem to limit the usefulness of a responsive launch system for military operations, the treaty calls for this information to be furnished "as soon as practicable," rather than setting any specific chronological guideline.

The Anti-Ballistic Missile Treaty is another consideration, as any weapons deployed from the CAV would have to meet the criteria set out in that treaty. These criteria control the interceptor speed and the regime used to test system performance. Should the ABM Treaty be modified, it is conceivable that munitions capable of intercepting ICBMs at some phase of flight could be developed for the CAV.

Conclusions

The Military Spaceplane concept is one possible solution to a range of military operational needs. Full implementation would call for enormous changes in the Air Force's approach to space, but the potential payoffs include performing whole new missions from the ultimate high ground while saving scarce funds on the missions performed today.