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MASTER OF MILITARY STUDIES

The Space Maneuver Vehicle: Enhancing Space's Utility to the Warfighter

Submitted in partial fulfillment
of the requirements for the degree of
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Space is a critical enabler for our military force. Current space systems, however, have significant deficiencies in the ability to provide Space Superiority (the purpose of space control) and lack operational responsiveness. The rapid response, quick turnaround, and high on-orbit maneuverability of the Space Maneuver Vehicle can correct these shortfalls; it provides space asset protection that enables US forces to achieve and maintain Space Superiority. Its ability to co-orbit with friendly space assets and provide on-orbit servicing and repair will extend the service life of other satellites. The ability to deploy SMVs with a mix of intelligence, surveillance, and reconnaissance (ISR) payloads will provide an affordable, responsive and sustained presence to support diverse theaters of operation. The ability to integrate, operate, and recover and reuse the SMV with a variety of onboard or deployed payloads provides operational flexibility heretofore unattainable with traditional satellites. Finally, the SMV's operational flexibility will provide an opportunity fundamentally change the command and control of space systems in order to push control down to the theater CINC thus allowing the true integration of space into theater operations.

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EXECUTIVE SUMMARY

Title: The Space Maneuver Vehicle: Enhancing Space's Utility to the Warfighter

Author: Major Stephen L. Davis, USAF

Thesis: This paper argues that the Space Maneuver Vehicle (SMV) changes the current operational construct for the command, control, and operation of satellite systems.

Discussion.

Space is a critical enabler for our military force. Current space systems, however, have significant deficiencies in the ability to provide Space Superiority (the purpose of space control) and lack operational responsiveness. The rapid response, quick turnaround, and high on-orbit maneuverability of the Space Maneuver Vehicle can correct these shortfalls; it provides space asset protection that enables US forces to achieve and maintain Space Superiority. Its ability to co-orbit with friendly space assets and provide on-orbit servicing and repair will extend the service life of other satellites. The ability to deploy SMVs with a mix of intelligence, surveillance, and reconnaissance (ISR) payloads will provide an affordable, responsive and sustained presence to support diverse theaters of operation. The ability to integrate, operate, and recover and reuse the SMV with a variety of onboard or deployed payloads provides operational flexibility heretofore unattainable with traditional satellites. Finally, the SMV's operational flexibility will provide an opportunity fundamentally change the command and control of space systems in order to push control down to the theater CINC thus allowing the true integration of space into theater operations.

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Finally, I would be remiss without expressing my deep gratitude to my wife and children for their patience and support. Their sacrifices are a critical element of my service in the armed forces of this great nation.

INTRODUCTION

Space is a critical enabler for our military force; "Joint Vision 2020" identifies space as one of the five operational "domains"[1]. Current space systems, however, have significant deficiencies in the ability to control space and lack operational responsiveness. The rapid response, quick turnaround, and high on-orbit maneuverability of the Space Maneuver Vehicle (SMV) can answer these shortfalls by providing space asset protection that enables US forces to achieve and maintain Space Superiority. Its ability to co-orbit with friendly space assets and provide on-orbit servicing and repair will extend the service life of high value Department of Defense (DoD) and other satellites. The ability to deploy SMVs with a mix of intelligence, surveillance, and reconnaissance (ISR) payloads will provide an affordable, responsive and sustained presence to support diverse theaters of operation. Finally, the ability to integrate, operate, and recover for eventual reuse the SMV and a variety of onboard or deployed payloads provides operational flexibility heretofore unattainable with traditional satellites.

Operating individually or in mission specific constellations, the SMV's exceptional maneuverability and operational flexibility provides the theater commander a variety of options across the spectrum of conflict and range of military operations. Specifically, SMVs can provide:

- Protection of domestic and friendly-force on-orbit assets
- Lethal and non-lethal space control
- Payload deployment, redeployment, recovery, upgrade, refueling and repair

- Responsive ISR collection and dissemination
- High-resolution on-orbit Space Object Identification (SOI)
- On-orbit Information Operations (IO)
- Access to areas unreachable by air, ground, and naval forces

This paper does not include a complete utility analysis of the SMV. There may be other conceptual or existing platforms that can perform the same missions either more effectively and/or at a lower cost. In addition, this paper does not address the costs of the SMV, its payloads or launch costs. Instead, it focuses on the benefits the SMV will provide to United States and friendly forces in the effort to establish the critical first step of any military operation--gaining and maintaining space superiority. Finally, the paper does not address policy issues regarding weapons in space[2], space control, or anti-satellite (ASAT) operations.

This paper does offer a broad conceptual and operational framework for a reusable satellite system. It begins with a basic description of the SMV system and the command relationships required to maximize the responsiveness of SMV to theater warfighters. Next, it provides the framework for operating the SMV system. It then uses the proposed CONOPS to illustrate notional SMV employment scenarios. Finally, the paper addresses the implications of the SMV employment for the future of space operations.

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[1] The five operational domains are space, sea, land, air, and information. Joint Chiefs of Staff, *Joint Vision 2020*, Washington DC, Jun 2000, 6.

[2] International law does not contain a blanket prohibition on placing or using weapons in space.

SMV SYSTEM

The SMV (Fig. 1) is a reusable, unmanned orbiting vehicle with integral propulsion that completes an on-orbit mission and then re-enters the atmosphere and lands for retasking. The SMV's on-orbit maneuverability allows it to change altitude and execute plane changes allowing access to multiple orbits, thereby greatly increasing its operational flexibility and making it a difficult platform to track and intercept. Based on mission requirements, the SMV system can be employed either as a single asset or in a constellation of several SMVs.

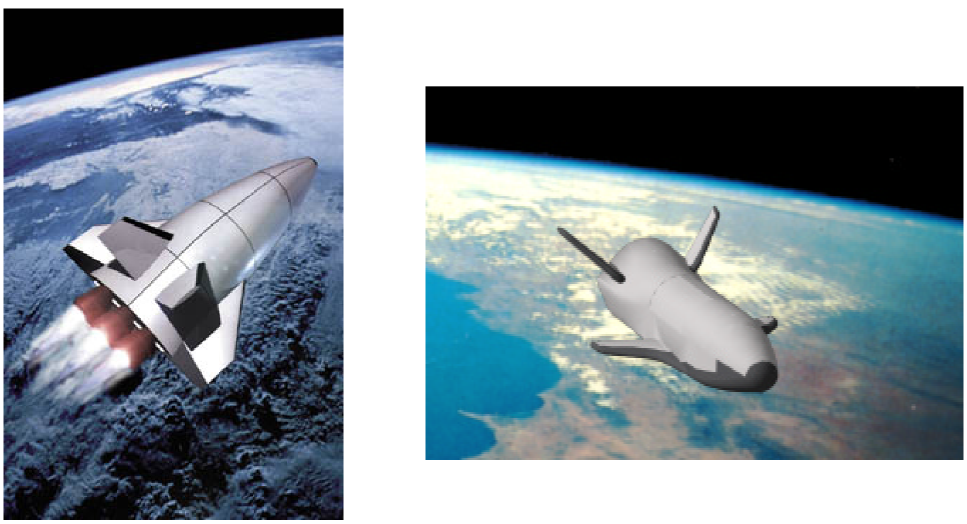

Figure 1. Notional Space Maneuver Vehicles[3]

The SMV can be launched from numerous vehicles to provide operational flexibility independent of future launch system development. Potential launch vehicles include Expendable Launch Vehicles (ELV), AirLaunch[4] and the Space Operations

Vehicle[5] (SOV) (Figure 3). In line with current launch policy, some launches of the SMV may be contracted to commercial launch service providers.

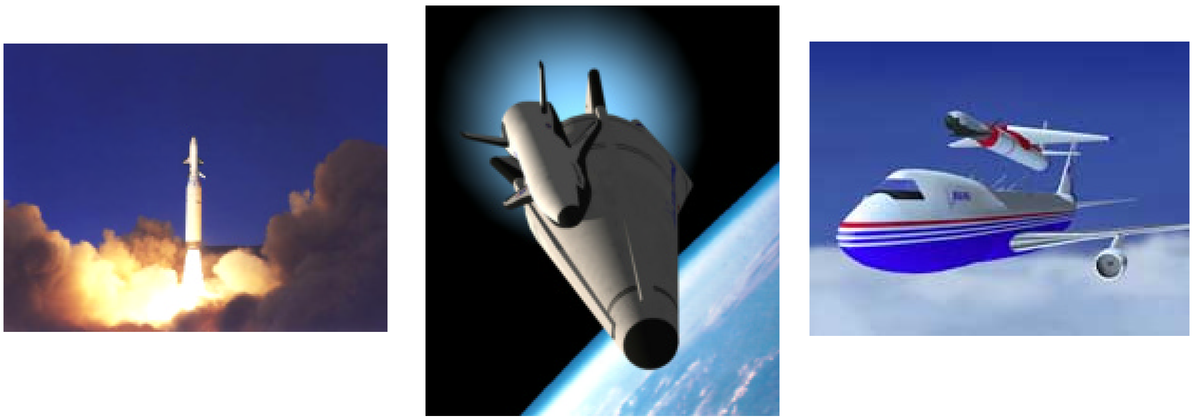

Figure 2. Notional ELV, SOV, and AirLaunch with External SMV Payload[6]

For launch, the SMV would be stacked on top of an expendable vehicle, externally mounted on AirLaunch, or mounted either internally or externally on a sub-orbital SOV. When launched by a sub-orbital SOV or a smaller ELV, the SMV serves as an upper stage and uses its onboard propulsion system to provide the final boost to orbit. This delivery method reduces the amount of fuel available for SMV maneuvering and necessitates missions that do not require extensive on-orbit maneuvering capability, such as a fixed constellation. When launched by a heavy lift ELV, AirLaunch or orbital SOV, the launch system provides all the lift necessary to insert the SMV into orbit and allows a fully fueled system to perform large altitude and plane changes, Geosynchronous Earth Orbit (GEO) flybys, or co-orbital station keeping with satellites in Medium Earth Orbit (MEO) and Low Earth Orbit (LEO)[7].

On orbit, the SMV operates as a system of systems and consists of two primary segments: vehicle segment; and the command and control (C2) segment.

The vehicle segment includes the flight vehicle and the payloads (e.g. ISR sensors, navigation systems, microsats, etc) required for intended missions. Flight vehicle, flight hardware and associated payloads will use standard interfaces to minimize vehicle processing and refurbishment time.

The flight vehicle hardware includes the airframe, propulsion system, payload bay, flight control systems, communication and navigation systems. It is a highly maneuverable, reusable upper stage with integral propulsion which can accommodate a variety of payloads and return them to Earth for refurbishment and reuse.

SMV Payloads (Fig. 3) will utilize a standardized interface that will simplify

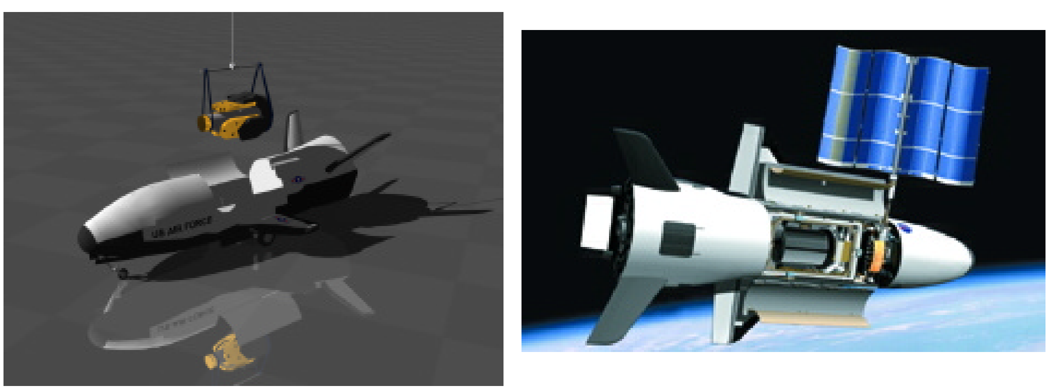

Figure 3. Containerized Payload During Emplacement and On-Orbit[8]

loading and checkout. Ideally, all payloads will use a containerized system to allow "plug and play" capabilities that will maximize operations tempo and rapid reconfiguration. Additionally, containerized payloads allow for the rapid introduction of new technological advances in the payload with little or no impact on SMV design. Most SMV payloads are envisioned as mission suites that are operated in the SMV or on small free flying satellites (microsats and picosats[9]) deployed from the SMV. Of course, the SMV will maintain the ability to support payloads with non-standard interfaces, however, use of these payloads will result in a significant increase in launch integration and preparation time. Because the SMV will operate primarily as a tactical system, extended on-orbit checkout of the payload is not envisioned. Additionally, SMV payloads will be designed to directly support the warfighter by direct downlinking data to theater CINCs, as required, using current/existing theater hardware.

Because of the need to reduce the cost of space operations, the SMV must have designed-in reliability and maintainability that is capable of high tempo, high sortie rate operations. Increased reliability will provide assured return of the vehicle for retasking. Low loss rates originate in the SMV's ability to abort and safely recover from any portion of its flight envelope after release from the launch vehicle[10]. On-board health monitoring, redundant systems, line replaceable units, and engines designed for long life and rapid replacement will provide significant improvements in maintainability compared to other space systems. Moreover, he SMV will incorporate automation during flight preparations and flight operations to minimize the number of flight line personnel and time required for mission readiness. The flight line preparations for preflight, ground servicing, repairs and post flight should be analogous to the processes used to support and maintain military aircraft. Robust maintenance teams, combined with designed-in maintainability, will allow rapid mission turns for on-demand launches and surge operations in support of required military operations. Flight critical subsystem failures shall be detectable to allow back-up systems to safely abort and recover the vehicle or continue the mission.

SMV availability will be maximized by performing all payload processing off-line. Payloads will be fully checked out and fueled prior to mating with the SMV. After payload integration the only an automated test and interface checkout should be required prior to launch.

The SMV's C2 segment consists of the flight and ground systems necessary for operators to control the SMV. Flight control includes the onboard flight control system (autonomous or remotely piloted) as well as the SMV Mission Control Center (MCC). The MCC manages and monitors all aspects of the SMV, including flight operations. The MCC will have the capability to transmit and receive commands, monitor environmental conditions that affect space and ground segments and monitor launch and recovery conditions. Ground control will contain all data-gathering systems and network processors necessary to integrate individual SMVs and payload components into a cohesive system. The existing Air Force Satellite Control Network (AFSCN) would support the SMV by providing global communication resources to support on-orbit operations, anomaly resolution, and both nominal and contingency missions.

The C2 segment will be responsive and reactive enough to meet operational timelines while remaining reasonably secure from jamming or disruption. A key characteristic of the SMV's C2 system is its compatibility with current/existing battle management, command, control and communications (BMC3) systems. While the SMV would primarily rely on fixed C2 nodes, mobile C2 resources could deploy worldwide, augmenting fixed nodes and space-based relay assets. Another key feature of the SMS's C2 structure is the presence of an onboard, autonomous back-up system to take control of the vehicle if commands to the SMV are being jammed. Additionally, the SMV may use crosslinking for C2 when employed in a constellation either as a routine operation or to defeat C2 jamming of a specific SMV uplink.

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[3] Lockheed Martin Astronautics Operations, RSTS Gallery, "Space Maneuver Vehicle", <www.ast.lmco.com/gallery/glry_rsts.shtml>, accessed 9 Mar 2002.

Boeing Corporation, Phantom Works, "Experimental vehicles continue to push new frontiers of flight", <www.boeing.com/phantom/xplanesdt.html>, accessed 7 Nov 2001.

[4] AirLaunch is a Boeing Aerospace concept that would launch the SMV from a converted Boeing 747 with the help of a small expendable rocket motor. For more information see www.boeing.com/phantom/als.html.

[5] SOV is the current name for the MS-1A Multi-Mission Military Spaceplane. Like the Space Transportation System, it is a Reusable Launch Vehicle. However, the SOV is capable of rapid reuse in order to perform responsive military missions.

[6] Lockheed Martin Astronautics Operations, RSTS Gallery.

Boeing Corporation, Phantom Works, "AirLaunch System (ALS)", <http://www.boeing.com/phantom/als.html>, accessed 9 Nov 2001.

[7] Orbits are generally categorized by their altitude. Low Earth Orbits (LEO) from 100-300 miles, Medium Earth Orbits (MEO) from 300-22,300 miles and Geosynchronous Earth Orbit at 22,300 miles and above. At 22,300 the orbital period of the satellite matches the rotation speed of the earth and the satellite remains constantly over a fixed area on earth at the equator.

[8] Boeing Corporation, Phantom Works, <www.boeing.com/phantom/xplanesdt.html>, accessed 7 Nov 2001.

[9] Microsats are satellites that weigh 10 to 100 kilograms while picosats weigh less than 10 kilograms. Traditional satellites weigh 1000 kilograms or more.

[10] Unlike traditional space systems, SMVs launched using reusable launch vehicles may operate in proximity to populated areas. Given this possibility, the SMV will be capable of safely aborting a mission following the failure of a critical system, and preferably should be able to complete, rather than abort the mission given the same failure.

COMMAND RELATIONSHIPS

The SMV as a "system of systems", will dramatically increase the capabilities and effectiveness of theater warfighters at all levels of war and across the range of military operations. However, as with any system, operators must resolve questions regarding who will command and control the SMV system and how it will be done. Clearly, the key to C2 is the ability to effectively command and control an asset. In today's joint environment, command and control is much more than the than the transmission of orders. At the most basic level C2 is about the command relationships that specify who owns, who tasks, and who operates the SMV system. The following section provides a proposed framework for how the Air Force should design command relationships for the SMV.

Title 10 US Code, Section 164, assigns the Commander-in-Chief, United States Space Command (USCINCSPACE) Combatant Command (COCOM)[11] over space forces in support of the other Unified Commanders-in-Chief (CINCs) (Figure 5). USCINCSPACE will retain COCOM of the SMV system at all times and will normally delegate operational control (OPCON) to the Commander, United States Air Force Component to United States Space Command (COMSPACEAF). COMSPACEAF is "dual hatted" as Commander, Fourteenth Air Force (14 AF/CC) a subordinate Numbered Air Force (NAF) to Air Force Space Command (AFSPC). The 14 AF/CC, through AFSPC, will organize, train, and equip SMV forces as directed by the Secretary of the Air Force and Headquarters United States Air Force (HQ USAF).

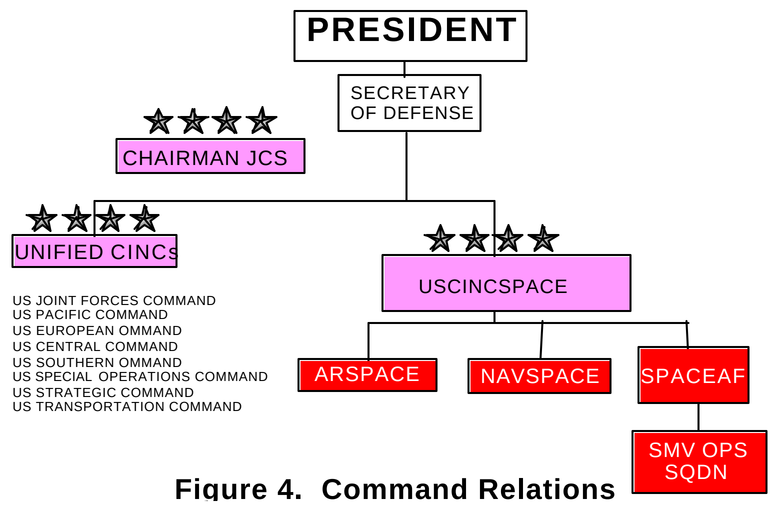

Figure 4. Command Relations

USCINCSPACE, with SECDEF approval, may delegate Tactical (TACON) or Operational Control (OPCON) of SMV sensor and data flow to Joint Task Force (JTF) Commanders in support of assigned missions. The JTF Commander will normally further delegate control of the SMV to the Joint Force Air Component Commander (JFACC) regardless of service affiliation. Therefore, the JFACC and the Joint Air Operations Center (JAOC) staff should possess the ability to prioritize and integrate SMV operations and execution into theater operations. At the point in the future when space operations becomes coequal with air, maritime and land operations or simply begin to overtask the JAOC staff, the CJCS should create a “Joint Forces Space Component Commander” (JFSCC). The JFSCC would control, task and apportion theater space assets in support of the theater CINC.

Regardless of global or theater focus, USCINCSPACE will be responsible for coordinating SMV missions directly with the Secretary of Defense, the CJCS, Theater CINCs, and other agencies. United States Space Command (USSPACECOM) will integrate all requests for SMV operations. The SPACEAF AOC will then perform operational/campaign planning to include building Space Objectives incorporating SMV operations into the Space Tasking Order (STO). Upon recommendations from SPACEAF, USSPACECOM will perform functional-level planning and task other USSPACECOM components through mission type orders (Operations Orders, Fragmentary Orders, Special Instructions). SPACEAF will manage the SMV systems and execute through their planning and execution cycle. USCINCSPACE will develop and provide to SPACEAF standing rules of engagement for the SMV missions and coordinate support for other CINCs' SMV requirements.

The preferred method for providing SMV support to theater is via general support.[12] USCINCSPACE will authorize the dedicated use of the SMV system under pre-programmed options to support theater contingencies. Under this principle, USCINCSPACE directs forces, in this case SPACEAF's SMV forces, to support the operational requirements of the theater CINCs. For the SMV system, these forces would be the vehicles and payloads that could provide coverage as their orbits bring them over the identified area of operation.

During crises action planning, SPACEAF will provide recommended courses of action (COAs) to USSPACECOM. SPACEAF will execute mission type orders as directed by USCINCSPACE and will coordinate with other USSPACECOM components prior to performing detailed mission planning. SPACEAF will control SMV forces and report, as directed, to USSPACECOM. When command of SMV forces is transferred to theater, SPACEAF will provide similar support to the designated CINC. Regardless of whether SMV OPCON is with SPACEAF or the theater, USCINCSPACE and the theater CINC must establish a Direct Liaison Authorized (DIRLAUTH) relationship between the SPACEAF AOC and the theater JAOC--the organization responsible for tasking assets supporting the theater in executing its campaign plan

Timely and responsive support to theater forces will be a top SMV priority. The DIRLAUTH relationship between COMSPACEAF and the theater components will be the first step in providing a useful conduit for reachback to identify operational support requirements. The space element in the JAOC must identify requirements and integrate SMV support into theater operations. The space element must interact frequently with the SPACEAF AOC to ensure integral SMV support. In addition, the space cell must insure JFACC is aware of SMV capabilities and can effectively integrate SMV operations into the theater campaign plan.

Day to day, the theater CINC or any customer--including national agencies--will provide their requirements/mission objectives to USCINCSPACE. The priority of support for these requirements will be based on guidance from CJCS and the Secretary of Defense. USCINCSPACE will integrate the requirements and provide direction for support in the form of mission type orders (operations orders (OPORDs)/fragmentary orders (FRAGOs)) to COMSPACEAF. COMSPACEAF will then task the SMV operations squadron, using the Space Tasking Order, to perform the detailed mission planning and execute the tasking. During time-urgent situations and when the effects from the SMV mission will be localized to the engaged region, USCINCSPACE will normally authorize COMSPACEAF to respond directly to the Theater commander's requests and transfer (OPCON) of an SMV unit (squadron, flight, etc.) to the Theater commander. In this case, the squadron would respond to direct tasking from the theater. Strike assessment and battle damage assessment (BDA) will normally be provided to USSPACECOM. However, when under theater command these reports will to be provided directly to the Theater Commander as required.

[11] See glossary for JCS, Joint Pub 1-02, "Department of Defense Dictionary of Military and Associated Terms" definitions of COCOM, OPCON, and TACON.

[12] According to JCS, Joint Pub 3-0, "Doctrine for Joint Operations", 10 September 2001, II-9, General support is the action that is given to the supported force as a whole rather than to a particular subdivision thereof.

SMV CONCEPT OF OPERATIONS

The SMV system will provide total global access and can be employed in one of two ways: 1) As an individually controlled platform where only one SMV is needed or the mission requires direct operator control; 2) As multiple SMVs that make up a constellation and are controlled as a group by a single operator team.

The individual mission profile (Figure 5) is used when a high degree of interaction is required between the operator team and the vehicle. Missions such as on-orbit servicing, refueling and missions that may require multiple orbital maneuvers will use the individual mission profile.

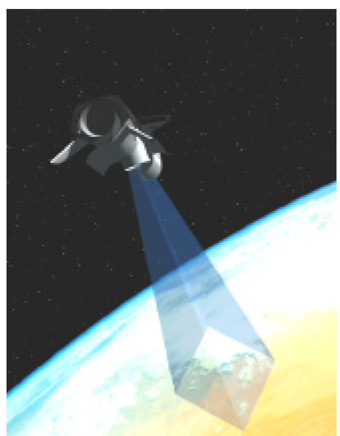

Figure 5. Individual Mission Profile

The constellation profile (Figure 6) takes advantage of the orbital similarities of the mission and allows one operator team to manage multiple SMVs at the same time. This profile is used when the majority of the mission can be automated and operators only manage anomalies. Should the need arise, the constellation can be modified to cover an emerging area of interest. Missions such as communication or ISR augmentation can be achieved without having to "fly" each satellite as an individual platform.

Figure 6. Constellation Profile

The SMV will support a wide range of operational missions, from performing reconnaissance and space control missions to on-orbit servicing of other satellites. The responsiveness and affordability of the launch systems used will enhance the overall effectiveness and efficiency of the SMV system. Just as the airplane's military role began solely as a reconnaissance platform and evolved to perform many types of missions based on different payloads, the SMV represents the next step in the evolution of space systems by providing an orbital vehicle capable of performing multiple missions.

The SMV will complement DoD warfighting assets. Its primary attributes are reusability, affordable cost, global coverage, responsive orbital agility, orbital endurance for as long as 12 months, and relative invulnerability to enemy defenses. These characteristics will allow the SMV to enhance and expand space operations, protect existing space assets, and enable new missions that are beyond the capability of current systems.

Taken together, the reusability and maneuverability of the SMV will be critical to protecting United States (US) military, civil and commercial space assets and providing the National Command Authorities (NCA) and Joint Force Commander (JFC) the required flexible and survivable capabilities needed for dynamic crisis and battle management.

The SMV can fill vital needs in space control[13] which current systems are unable to meet. By providing a highly maneuverable space platform for both offensive and defensive Counterspace, Space Superiority can be achieved. Protection of valuable military, civil and commercial space assets from potential adversaries and denying the use of adversarial space assets will assure our access to space and meet the objectives of Space Control.

Once deployed by the launch vehicle, an SMV's payload can perform Defensive Counterspace missions by electronic jamming or temporarily blocking hostile space systems. As our commercial and military systems evolve to rely more heavily on space-based systems, Defensive Counterspace activities must expand and evolve to provide enhanced on-orbit resource protection.

Because US and foreign military space systems are predominantly information systems, achieving Space Superiority will involve offensive and defensive information operations (IO). SMV and its payloads have great potential to contribute to IO in space. An SMV payload could deny, influence, degrade, or destroy the information an adversary derives from its space systems by jamming communication links, or spoofing ground/space-based sensors.

SMV's space-based multi-mission capabilities could play a key role in establishing and maintaining future National Missile Defense (NMD) and Theater Missile Defense (TMD) systems. Small elements of a missile defense system could be delivered, deployed, repositioned or recovered by the SMV. SMVs could service permanent elements of an missile defense system through on-orbit refueling or repair. Onboard payloads, or payloads deployed from the SMV, could provide short notice gap-filler capability for an missile defense system until it is restored to full capability and the SMV can then recover the temporary asset for refurbishment and reuse.

By performing surveillance and reconnaissance of space, sensors deployed from the SMV or operated as an onboard suite can complement and enhance existing ground-based systems for tracking satellites and identifying their capabilities. Through its ability to perform fly-bys of other satellites, the SMV will markedly improve our Space Object Identification (SOI) capability to catalog other nations' space forces. The SMV can complement and enhance existing ground-based systems through its ability to perform autonomous proximity operations to deliver very high-resolution SOI data. This space surveillance capability will also provide increased coverage and resolution for space debris detection and warning for friendly assets.

Enhancing Operations consist of those operations conducted from space with the objective of enabling or supporting terrestrial-based forces[14]. Navigation, communications, reconnaissance, surveillance and environmental sensing help reduce uncertainty and friction at all levels of war.

The SMV will be capable of using onboard surveillance and reconnaissance suites during overflight of an area of interest to help provide crucial intelligence information essential to the "transparency" envisioned in Joint Vision 2020 for use in battle planning and strategy development. When fielded as a part of the SOV System, the SMV gives theater Commanders-in-Chiefs (CINCs) a major advantage early in a conflict before other platforms arrive. Major assistance to the theater will be possible through the ability to deliver and deploy a large number of surveillance and reconnaissance configured SMVs to low Earth orbit. These SMVs can be flown to create an independent Intelligence, Surveillance and Reconnaissance (ISR) constellation or they could augment existing ISR constellations to improve coverage over particular areas of interest. Additionally, the SMV can deploy payloads to augment communications in areas where coverage is degraded or missing due to a comm system failure. The SMV's rapid on orbit retasking capability, along with its standoff and real-time downlink ability, make it well suited for ad hoc taskings that meet the challenge of a rapidly changing battlefield situation. Employment of the

SMV will provide a quantum leap in maneuvering flexibility for ISR payloads above and beyond that found in orbital systems today. Unlike current space systems, which are severely limited in their ability to change orbits, SMVs with onboard ISR payloads can respond to emerging requirements and threats by performing critical orbit inclination changes. This enables multiple target overflight opportunities at unpredictable times, decreased revisit times (omnipresence) and quick response to retaskings. In essence, the SMV will be capable of complementing or replacing traditional airborne ISR platforms with a continuous, on-demand theater-wide system that is more flexible, more responsive and more survivable.

Supporting Space Forces is critical to ensure space superiority. The SMV will be the first space vehicle designed to support on-orbit servicing of military space-based assets, such as the Space-Based Laser and small satellites. The SMV can perform the necessary on-orbit maneuvers to rendezvous, refuel, upgrade, repair, reposition and possibly recover space assets. This will include the capability to co-orbit with and assess damage to friendly space-based platforms, thereby providing support for anomaly resolution.

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[13] According to United States Air Force, "Air Force Doctrine Document (AFDD) 2-2", *Space Operations*, GPO: Washington DC, 23 Aug 1998, 8, "Space control is the means by which space superiority is gained and maintained to assure friendly forces can use the space environment while denying its use to the enemy."

[14] USAF, AFDD 2-2, 11.

SMV EMPLOYMENT SCENARIOS

The following scenarios are designed to illustrate employment of an SMV architecture. They are notional and intended to be examples of potential SMV operations.

Enhancing Operations. An adversary has developed the capability to forecast the overflight of US surveillance satellites. It is also believed this nation is producing weapons of mass destruction with a missile delivery system. With their knowledge of the overflight times of our assets, they are able to deny us knowledge of the movement of personnel and weapons systems from their production facilities. Due to the adversary's geographic location, the use of standoff or overflight airborne surveillance and reconnaissance is not possible. A series of SMV launches are accomplished from the continental United States (CONUS) Main Operating Base with SMVs carrying surveillance and reconnaissance sensors. A temporary surveillance and reconnaissance constellation is established using recoverable SMVs, which provide a high degree of on-orbit maneuverability and long on-orbit duration. When employed in sufficient numbers (approximately 36 SMVs) with orbits selected to maximize revisit frequency over the area of interest, the SMV's increased coverage can achieve an overflight omnipresence that would negate the adversary's cover, concealment and deception and allow the collection of crucial intelligence data. Smaller constellations (12-24 SMVs), with less frequent revisit rates, will provide near omnipresence with re-visit rates between 30 and 11 minutes (reference, based on modeling using STK). In situations in which we can exploit an adversary's limited satellite tracking capability, fewer SMVs (less than 12) are required because we can use the SMV's maneuverability to create a highly dynamic constellation that will make overflight times unpredictable. Should events dictate a shift in emphasis from one area of interest to another, the existing SMV constellation on-orbit can be quickly tailored to provide coverage of the emerging area of interest.

Space Control. An adversary is massing troops in an attack posture near the border of a US allied country and prolonged diplomatic efforts have failed to resolve the situation. The US has been monitoring their activities through space-based surveillance and reconnaissance assets. This activity reveals that the adversary has recently deployed several new satellites to GEO. These satellites are of an unfamiliar design and their mission is unknown. Due to their positions on the geostationary belt, radar resources cannot be employed to gather SOI, and the distances involved preclude adequate optical imagery from earth-based sensors. An SMV is launched on demand into a GEO transfer orbit (GTO) with a suite of on board sensors to perform flyby reconnaissance of the GEO satellites. The Mission Payload Assessment based on the SMV data indicates the adversary has deployed a co-orbital anti-satellite (ASAT) system which threatens our ISR assets and space-based theater missile warning satellites. In response, An SMV, carrying the appropriate number of microsats, launches into a GTO and deploys microsats. The microsats use attached propulsion modules to co-orbit with the threatened satellites in order to block the potential ASAT attack. Scenario Option: Co-orbit an SMV or SMV-deployed microsat with the adversary ASAT to jam command and control links or temporarily degrade, deny, disrupt, destroy, exploit or neutralize its ASAT capability. The same capability could be used to degrade, deny, disrupt, destroy, exploit or neutralize other known adversary space capabilities such as communications, ISR, navigation, etc.

Supporting Space Forces. Situation: The US is engaged in a major theater conflict against a regional power in Asia. The enemy possesses a large number of chemical, and biological weapons. In addition, the enemy has “weaponized” the chemical and biological agents in warheads deliverable via short and medium range mobile theater missiles and several long-range mobile missiles capable of striking portions of the US. At the onset of hostilities a large, in-theater ballistic missile attack took place against deployed coalition forces, key airfields and ports using conventional warheads. During the conflict the newest National Reconnaissance Office (NRO) imagery intelligence (IMINT) satellite ceases to function. The remaining NRO satellites providing IMINT support are older and have limited fuel onboard. Because of the IMINT satellites low fuel levels they are limited in their ability to maneuver in order to provide the IMINT coverage necessary to target the chemical and biological weapons and the missile delivery systems. The limited IMINT coverage and has put US and allied personnel and assets at risk to follow-on chemical and biological missile attacks. SMV Employment: SMV has the capability to carry and replenish the IMINT satellites onboard fuel. Similar to air-to-air refueling, an SMV could dock with an IMINT satellite, refuel it and autonomously return to earth. Key Scenario Options: SMV refuelers could be pre-propositioned in the IMINT satellites orbital plane prior to hostilities. As satellites maneuver in order to cover required collection tasks and expend fuel, the SMV, using minimal thrust for in-plane maneuvering, could carry the fuel required refuel multiple NRO satellites.

IMPLICATIONS FOR FUTURE SPACE OPERATIONS

Since the first military satellite went into orbit, space has been changing the face of warfare in all mediums; air, land, sea, space and information. We have reached the point where space capabilities are no longer a novelty, but rather a utility. Like electricity from the power company, space is an assumed capability required for day-to-day operations. The SMV represents the next step in the evolution of space power and will allow US forces to better control and exploit the space medium while maintaining current utilities space already provides. This next step is possible because the SMV possesses four key enablers not present in current space systems (Table 1). Each enabler increases current capabilities and facilitates new ones.

SMV Key Enablers
Reusability
Maneuver
Proximity Operations
Responsiveness

Table 1

Reusability

The SMV's most unique feature is the ability to reuse the vehicle after the completion of a mission. Current design requires discarding a satellite if it loses redundancy on a critical subsystem or when it possess only enough fuel for an end of mission disposal maneuver. Because the SMV can return to Earth when the mission is complete, it will be possible to refurbish and refuel satellite systems allowing for significant cost savings. The ability to interchange mission payloads for subsequent sorties allows for the spiral development and employment of improved capabilities and requirements not recognized during initial systems design. In addition, because the major satellite systems (C2, airframe, propulsion, flight control, communication and navigation) and associated development costs are borne by the SMV it will now be practical to develop highly specialized or limited use payloads that previously did not merit development of a entire satellite system. For example, because the limited current threat to U.S. satellites, it is difficult to justify the costs to develop a dedicated space control platform. Because the SMV contains the major satellite subsystems and acts as a carrier, the marginal cost to develop a mission payload to conduct space control is greatly diminished and the development of the capability may now be justified.

Reusability also allows for reductions in the number of redundant satellite subsystems. Current satellite systems often have quadruple redundancy of critical subsystems to ensure continued operation once on orbit. While the SMV will have backup systems for autonomous recovery, the mission payloads do not require redundant subsystems because the SMV can be recovered in case of a payload failure. The removal of multiple redundant subsystems reduces the time required to "turn on" the mission payload from weeks to hours by shortening the on-orbit activation and testing procedures currently used to ensure the early identification and correction of anomalies. In addition, the removal of the redundant subsystems allows for increased payload capabilities or results in room for additional SMV fuel to increase the SMV's ability to maneuver on orbit.

In essence, the Line of Communication (LOC) for every satellite we launch today is automatically severed upon launch. The SMV provides ability to reestablish the broken LOCs and therefore, the SMV's reusability allows for greater flexibility.

Maneuver

The SMV's second key enabler is a direct result from the first. Maneuverability is a key element of the SMVs flexibility and is derived primarily from the ability to reuse the SMV. Whereas reusability primarily affects the design of the SMV and it's payload, the resulting maneuverability changes the way the SMV is employed.

Traditionally, each satellite maneuver reduces the satellite's operational life[15]. Maneuvering for reasons other than maintaining the current orbit are therefore only accomplished when absolutely necessary to accomplish the mission. This is fuel limitation is more pronounced for satellites that are either very expensive, operationally unique or in LEO where atmospheric drag necessitates more frequent station keeping maneuvers. This creates a cost benefit analysis for most satellite maneuvers--is the value of the maneuver worth the corresponding reduction in satellite fuel? The ability to recover the SMV instead of discarding or destroying it at end of mission reduces the cost variable of the cost benefit relationship and allows for increased on-orbit maneuver. Additionally, because you can recover the system in case of a payload failure, the number of multiple redundant systems is greatly reduced. Using the resulting weight savings for additional fuel increases the SMV's mass fraction resulting in an increased Delta V [16].

The SMV's increased Delta V capability allows for increased on-orbit maneuver and increases SMV's flexibility. Specifically, the increased ability to maneuver allows the SMV to frequently modify its orbit. Therefore, the SMV can perform multiple missions on a single sortie and, significantly negates an adversary's ability to determine SMV over-flight times. This over flight uncertainty has a deterrent effect, as adversaries could never be certain if they are vulnerable at a given time and place.

The SMV also possesses ability to transfer this increased maneuver to other satellites. First, the SMV could deploy entire constellations of microsats from its payload bay. Each microsat would reach its assigned orbit fully fueled, thereby gaining maneuverability from the SMV. Second, the SMV can act as a space tanker and refuel high-value satellites. Because the ability to refuel would alter the existing cost benefit equation, high-value satellites could improve their mission effectiveness by maneuvering more frequently without decreasing operational life. This would also have the added effect of complicating the adversary's SOI efforts while making over flight times more difficult to predict. Considering the $1B unit cost[17] (excluding launch and operating costs) of some satellites, the ability to refuel satellites has tremendous potential. A third option is to use the SMV as a space tug. The SMV could pull non-reusable satellites into the desired orbit. Of course, using the SMV as a space tanker or tug would require changes in satellite design. Whereas the space tug modification (essentially an attachment point) would be simpler, its effect would limited to the amount of time the SMV remained attached to the target satellite.

Proximity Operations

In a new environment where the SMV embraces rather that avoids maneuvering, the ability to conduct on-orbit operations in close proximity to other spacecraft engenders the SMVs third key enabler. Once in a similar orbit, the SMV has the ability, using on-board systems, to autonomously execute very precise orbit changes in order to maintain a constant position relative to a target satellite. This unique ability to conduct proximity operations is essential to execute new and improve existing space missions such as the satellite refueling/repositioning, and counterspace operations previously discussed.

Current counterspace doctrine focuses on passive defensive measures like encryption, hardening and frequency hopping[18] intended primarily to protect the satellite link. Active defense measures are more limited: maneuvering and possibly the use of decoys. However, as adversary SOI evolves, these limited active defense measures may not be enough. The SMV, because of its ability to co-orbit in very close proximity to high-value friendly satellites, would significantly improve DCS by intercepting or blocking hostile ground or space-based attacks.

SMV proximity operations offers Offensive Counterspace (OCS) options as well by blocking, jamming, spoofing or incapacitating hostile spacecraft. Current USAF OCS capabilities are limited to direct attack against ground stations or associated infrastructure using air or land or air forces[19]. While ground-based OCS is technologically feasible today and clearly more cost-effective, the SMV's ability to conduct proximity operations allows it to carry out both lethal and persistent non-lethal operations in space. SMVs will be able to close on an adversary's satellite and employ a range of techniques to degrade, deny, disrupt, destroy or negate the adversary's capabilities. The SMV on-orbit effects are more persistent because they are not limited by the length of time the satellite remains in view of a particular ground station. In addition, the co-orbiting SMV could constantly track the target, preventing it from maneuvering away from a non-lethal effect.

Perhaps most importantly, proximity operations allow the SMV to conduct on-orbit SOI. While we can conduct SOI today, the ability to execute the mission on-orbit rather than from the ground provides the opportunity for increased resolution and supports detailed targeting and weaponeering solutions. In addition, because some payloads operate intermittently, the ability to conduct continuous on-orbit surveillance results in an increased capability to conduct MPA.

Responsiveness

The final key enabler contributing to the SMVs improved operational utility is its ability to dramatically increase responsiveness. In addition to the reduced checkout times enabled by the absence of redundant subsystems, the SMV will increase the responsiveness of space systems by embracing changes that will enable aircraft-like operations.

Current satellites require several months for launch vehicle integration. While efforts with the Evolved Expendable Launch Vehicle (EELV) are working to reduce total integration time down to 30 days with only six to eight of those days required for launch pad integration[20]. The SMV's use of a standard interface, along with the utilization of containerized payloads, will reduce the both satellite and launch pad integration time down to less than 72 hours[21].

In addition to the responsiveness gained in preflight operations, the SMV will also simplify postflight operations. Unlike the space shuttle, the SMV will use non-cryogenic, non-hypergolic fuels (JP-8 and hydrogen peroxide)[22]. Removing hypergolic and cryogenic fuels from flight operations will significantly reduce the complexity and require infrastructure of ground operations. Two important steps to achieving aircraft-like operations.

However, simplifying SMV ground operations is only half of the battle. In order to

SMV Launch Segment Comparison

	ELV	**AirLaunch**	**Sub-Orbital SOV**	**Orbital SOV**
Sortie Cost	High	Med	Low	Low
Orbits	LEO[1]	LEO	LEO, MEO	LEO, MEO, HEO, GEO
Responsiveness	Low	Med	High	High
Available	Currently	Near-Term	Mid-Term	Long-Term

Table 2

be a truly responsive space system the launch segment must be responsive as well. As depicted in Table 2, current and near-term launch systems are less responsive and more expensive. While this would appear to be a problem, it has the potential to facilitate the gradual development of reusable space systems. The ELV, while expensive and less responsive could provide important launch opportunities that would support the research and development of SMV hardware and the concept of operations. The AirLauch concept could provide the same research and development opportunities while also providing an initial operational capability. The SOV would provide the full operational capability rapidly providing SMVs to all operationally useful orbits.

Multi-Mission

While many operational satellites do have secondary and sometimes tertiary missions, the satellite's primary mission has always been very specific. As with aircraft, there is increased operational utility and flexibility in designing systems that accomplish a variety of missions.

While primarily a result of the SMV's reusability and maneuverability, the four Key Enablers, in concert, give the SMV the ability to be the first true multi-mission satellite (Table 3). In addition to having the physical ability to perform multiple missions, reduced mission costs allow the SMV to accomplish a variety of missions that are too expensive to justify development of a dedicated platform.

SMV Missions		
Space Support	**Space Control**	**Enhancing Operations**
Satellite Reposition Satellite Refuel On-Orbit Servicing Satellite Recovery	Offensive Counterspace Defensive Counterspace Block, Jam, Spoof, Escort High definition On-Orbit SOI	Navigation Augmentation Comm Augmentation ISR Augmentation

Table 3 [23]

The ability to execute multiple missions also increases the deterrent value of the SMV to countries capable of SOI. While they could identify the platform, they will not know the mission it is performing.

The SMV's ability to accomplish multiple missions using containerized payloads has the potential to change the composition and concept of operations for existing satellite constellations[24]. Instead of needing large constellations of satellites to always be on orbit, the SMV would allow the day-to-day use of smaller constellations. When the situation dictates, SMVs could augment the existing satellite constellation to fill the gaps. This two-tier architecture has the potential to reduce the costs of launching, operating and maintaining "permanent" satellite constellations. In addition, this approach provides an inherent ability to rapidly replenish satellite constellations in case of loss through an attack or failure.

The potential for multi-mission is limited only by our current thinking about space operations. While there is certainly room for advances in multi-mission planning, we can be sure that the SMV will influence Air Force and joint operations in the future.

SMV's Impact on Theater Operations

One of the most profound contributions the SMV can make will come in the realm of theater operations. Currently, USSPACECOM acts as the single conduit for space support requests because of the limited understanding, high cost and high demand for space systems. In this role, USSPACECOM prioritizes requests and determines the impact of requested space operations and then directs specific steps for proper execution. This is contrary to the concept of centralized control, decentralized execution and results in the inefficient employment of space power. By centralizing control of all military space within USSPACECOM, theater commanders are repeatedly required to get approval to task and use space assets. Because the theater can not be sure USSPACECOM will approve future requests, they are reluctant to pursue courses of action that dependent on specific space support--If theater forces can't plan to control an asset, they are much less likely to use it.

The SMV will correct this problem. First, because the SMV is reusable, USSPACECOM is more likely to delegate OPCON of the system. Currently, USSPACECOM is reluctant to give theaters OPCON of space forces out of their legitimate concern that theater-based decisions could adversely affect higher priority national objectives (i.e. maneuvering to meet theater requests depletes a satellites fuel rendering it non-operational). This would not be an issue with the SMV. In the event the theater directs significant satellite repositioning and depletes the SMV's fuel, the SMV can be recovered and a replacement placed into orbit with no long-term loss of space capability. Additionally, when the SMV is dedicated to a specific theater's operations, USSPACECOM control is not required to deconflict and prioritize multiple requests for that specific satellite. Since the theater would "own" the SMV, they could count on continuous SMV support throughout the conflict. This continuous support would remove the uncertainty that exists and allow more flexibility in integrating space operations into theater plans. This does not prevent employing the SMV to meet non-theater operational requirements when it is available. In this case, USSPACECOM would request any desired support from the theater through SPACEAF.

A robust SMV system would also provide theater commanders new operational concepts using existing technologies. The SMV platform brings space's unique abilities to the theater fight. The SMV, like traditional satellites, enjoys freedom of overflight over the entire globe, long effective dwell times when employed in constellations and relative invulnerability to ground defenses. Coupling these attributes with existing technologies like Moving Target Indicator (E-8 Joint STARS), Electronic Warfare (EA-6B Prowler), real time on-scene intelligence collection (RC-135 Rivet Joint) could provide the theater CINC with additional capability. While the SMV's increased operating altitude and reduced payload would result in a reduced capability as compared to the air-based systems, the SMV could be on-scene in hours, stay for months and overfly areas denied to air-based platforms. The SMV would not replace the air-based systems, rather it would use the inherent benefits of space to provide a layered capability that improves the theater CINC's ability to understand and shape the battlespace.

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[15] Theresa Foley, "Space 20 Years Out", Air Force Magazine, Feb 2000, <www.afa.org/magazine/0200space.html>, accessed 29 Dec 2001.

[16] Delta V is literally a change in velocity. Because velocity determines the orbit, Delta V is a measure of maneuverability. See Glossary for a complete definition of Delta V.

[17] John C. Anselmo, "House, Senate at Odds over Intel Smallsats", Aviation Week and Space Technology, November 13, 1995, 24-25.

[18] USAF, AFDD 2-2, 10.

[19] USAF, AFDD 2-2, 8.

[20] Department of the Air Force Office of the Assistant Secretary for Acquistion, "Request for Proposal (RFP) F04701-95-R-0009, Evolved Expendable Launch Vehicle (EELV) SPD Annex C," 17 May 1995, <http://www.fas.org/spp/military/program/launch/eelvrfp2/>, accessed 24 Oct 2001.

[21] USAF, Air Force Research Laboratory, "Space Maneuver Vehicle Fact Sheet", <http://www.vs.afrl.af.mil/Factsheets/smv.html>, accessed 24 Oct 2001.

[22] Stephen Clark, "Peroxide Engine Being Developed for Spaceplane", Spaceflight Now, 14 May 01, < http://spaceflightnow.com/news/n0105/14smv/>, accessed 24 Oct 2001.

[23] USAF, AFDD 2-2.

[24] Given the existence of a highly responsive and low-cost launch capability.

CONCLUSIONS

Joint Vision 2020 envisions the transformation of the military in order to create a force "dominant across the full spectrum of conflict--persuasive in peace, decisive in war, preeminent in any form of conflict."[25] Our current space systems, while impressive in their own right, have significant deficiencies in the ability to control space and lack operational responsiveness. The Space Maneuver Vehicle facilitates the transformation envisioned in Joint Vision 2020.

The SMV's key enablers of reusability, maneuver, proximity operations, and responsiveness provide a space system that allows US forces to achieve and maintain space superiority critical to our national security. [26] Working in concert, the key enablers allow the SMV to perform variety of new missions. From on-orbit servicing and repair to extend the life of other satellites through the ability to integrate, operate, and recover for reuse a mix of ISR payloads to the use of a combination of onboard or deployed payloads to identify and potentially negate adversarial satellites, the SMV will provide operational flexibility unattainable with traditional satellites. Additionally the, the unique multi-mission capability of the SMV will enable a variety of missions previously not possible with traditional satellites.

The SMV's operational flexibility provides the theater commander a variety of options across the spectrum of conflict. Foremost, the SMV provides an opportunity to push control of space systems to the theater CINC, thereby allowing true integration of space into theater operations. Another opportunity the SMV provides is the ability to layer theater capabilities such as moving target indicator, electronic warfare and real time intelligence. With the SMV providing the rapid, persistent coverage to the most difficult areas and the air-based systems providing the improved fidelity, the theater CINC will enjoy improved situational awareness for operational decision making.

This responsive and reusable space system, designed for high sortie rates and extensive on-orbit maneuverability, will allow adaptive space mission planning and the means to freely operate in space. Combined with existing air, ground, and naval forces, the SMV enhances and enables national security through control of the space medium. With the SMV's ability to rapidly establish US space presence and leverage off extant capabilities, the "Joint Vision 2020" goal of Full Spectrum Dominance becomes attainable.

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[25] JCS, Joint Vision 2020, 1.

[26] According to the Report of the Commission to assess United States National Security Space Management and Organization, 11 Jan 01, "We know from history that every medium--air, land, and sea--as seen conflict. Reality indicates the space will be no different. Given this virtual certainty, the U.S. must develop the means both to deter and to defend against hostile acts in and from space. This will require superior space capabilities"

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GLOSSARY OF TERMS

Combatant Command (COCOM). Nontransferable command authority established by title 10 ("Armed Forces"), United States Code, section 164, exercised only by commanders of unified or specified combatant commands unless otherwise directed by the President or the Secretary of Defense. Combatant command (command authority) cannot be delegated and is the authority of a combatant commander to perform those functions of command over assigned forces involving organizing and employing commands and forces, assigning tasks, designating objectives, and giving authoritative direction over all aspects of military operations, joint training, and logistics necessary to accomplish the missions assigned to the command. Operational control is inherent in COCOM.

Combatant Commander. A commander in chief of one of the unified or specified commands established by the President.

Counterspace. Those offensive and defensive operations conducted by air, land, sea, space, special operations, and information forces with the objective of gaining and maintaining control of activities conducted in or through the space environment.

Delta V (? V). Change in velocity, especially referring to spacecraft; designates the velocity change required to transfer a spacecraft from one orbit to another.

Defensive Counterspace (DCS). DCS operations consist of active and passive actions to protect our space-related capabilities from enemy attack or interference.**Information Operations (IO).** Those actions taken to affect adversary information and information systems while defending one's own information and information systems.

Offensive Counterspace (OCS). OCS operations destroy or neutralize an adversary's space systems or the information they provide at a time and place of our choosing through attacks on the space, terrestrial, or link elements of space systems.

Operational Control (OPCON). Command authority that may be exercised by commanders at any echelon at or below the level of combatant command. Operational control is inherent in combatant command (command authority) and may be delegated within the command. Operational control is the authority to perform those functions of command over subordinate forces involving organizing and employing commands and forces, assigning tasks, designating objectives, and giving authoritative direction necessary to accomplish the mission. Operational control normally provides full authority to organize commands and forces and to employ those forces as the commander in operational control considers necessary to accomplish assigned missions; it does not, in and of itself, include authoritative direction for logistics or matters of administration, discipline, internal organization, or unit training.

Pop-Up. Sub-orbital, exo-atmospheric, high Mach-number launch trajectory capable of placing satellites into Low Earth Orbit.

Reusable Launch Vehicle (RLV). A fully reusable vehicle, capable of aircraft-like operations (in terms of sortie rate, maintainability, logistics, take-off and landing field requirements, etc.).

Sortie. In Space Maneuver Vehicle operations, an operational flight by one vehicle.

Space Control. Operations to assure the friendly use of the space environment while denying its use to the enemy. Achieved through offensive and defensive counterspace carried out to gain and maintain control of activities conducted in or through the space environment.

Space Maneuver Vehicle. A Space Maneuver Vehicle is a small, reusable orbital vehicle deployed from a launch vehicle. It carries small payloads to orbit, has an onboard propulsion system with a large ΔV maneuver capability, and can stay in orbit for an extended period before deploying its payload, de-orbiting and recovering for reuse.

Space Operations Vehicle. A military system which will have a high sortie rate and operate in, through, and from space to perform military missions.

Space Power. The capability to exploit space forces to support national security strategy and achieve national security objectives.

Spacelift. Spacelift provides the Air Force the ability to project power by delivering satellites, payloads, and material into or through space.

Sub-Orbital. An exo-atmospheric, ballistic trajectory that does not achieve orbit.

Tactical Control (TACON). Command authority over assigned or attached forces or commands, or military capability or forces made available for tasking, that is limited to the detailed direction and control of movements or maneuvers within the operational area necessary to accomplish missions or tasks assigned. Tactical control is inherent in operational control. Tactical control provides sufficient authority for controlling and directing the application of force or tactical use of combat support assets within the assigned mission or task.

ACRONYM LIST

ABL	Airborne Laser
AF	Air Force
ASAT	Anti-Satellite
BDA	Battle Damage Assessment
CINC	Commander-in-Chief
CJCS	Chairman, Joint Chiefs of Staff
COCOM	Combatant Command
COMAFFOR	Commander, Air Force Forces
COMSPACEAF	Commander, Air Force Space Component
CONUS	Continental United States
C2	Command and Control
DIRLAUTH	Direct Liaison Authorized
DoD	Department of Defense
ELV	Expendable Launch Vehicle
FEBA	Forward Edge of the Battle Area
GEO	Geosynchronous Earth Orbit
GTO	Geosynchronous Transfer Orbit
IO	Information Operations
ISR	Intelligence, Surveillance and Reconnaissance
JAOC	Joint Air Operations Center
JCS	Joint Chiefs of Staff
JFACC	Joint Force Air Component Commander
JFC	Joint Force Commander
JTF	Joint Task Force
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
MPA	Mission Payload Assessment

OPCON	Operational Control
OPORD	Operations Order
SBL	Space-Based Laser
SECDEF	Secretary of Defense
SMV	Space Maneuver Vehicle
SOI	Space Object Identification
SOV	Space Operations Vehicle
TACON	Tactical Control
USCINCSPACE	Commander-in-Chief, United States Space Command
USSPACECOM	United States Space Command