7th Responsive Space Conference
RS7-2009-1007

Sea-Launched TacSats for Responsive Space (STaRS)

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7th Responsive Space Conference
April 27–30, 2009
Los Angeles, CA

AIAA-RS7-2009-1007

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ABSTRACT

The Responsive Space community has focused on Responsive Launch as an area of improvement that would help space become more responsive. Unfortunately, developing a Responsive Launch capability is fraught with difficulties. American launch facilities (i.e., Eastern Range, Western Range, Kwajalein, etc.) have numerous logistical and physical limitations that restrict U.S ability to quickly launch a satellite, including: restricted launch fans, prior easements, launch plumes, and safety concerns.

This paper proposes a possible solution that avoids many of the difficulties associated with launch systems used today: a Sea-launched TacSats for Responsive Space (STaRS) system.

A sea-based TacSat launch capability would solve many of the problems associated with limited launch pads at fixed sites, including issues with "possible" launch pad availability due to competing program priorities as opposed to having a definite launch date. Of course, STaRS systems will need to deal with issues that land-based systems do not, such as ocean environments, transportation logistics, and security concerns.

Sea-launched vehicles are a proven technology. The prime example of a highly effective sea-based launch system is Sea Launch. Another example is the ICBM architecture which already exists with Submarine Launched Ballistic Missiles (SLBMs) aboard ballistic missile submarines (SSBNs). Russia has been launching satellites from submarines since at least 1994. For example, in 2006, the Russian Federation successfully launched an 80 kg Compass-2 satellite from a K-84 "Ekaterinburg" submarine.

The least expensive option for a sea-borne STaRS platform would be to convert a used tanker or cargo ship. Command of a STaRS ship would likely be split between the Navy and the Air Force. Cost savings could be realized by utilizing a primarily civilian crew on the STaRS ship with joint Navy and Air Force command, similar to how the Military Sealift Command's Prepositioning Program is crewed. A more expensive option would be to convert and dedicate a SSBN submarine for STaRS missions. STaRS ships/subs could be pre-positioned near the equator or incorporated into a Navy fleet. For larger payloads, the U.S. can develop systems similar to Sea Launch.

A STaRS platform will likely be able to carry at least several launch vehicles on standby, if not several dozen. A STaRS platform will therefore likely have the capacity to quickly launch a constellation of TacSats which would provide more flexibility and responsiveness. The ability to quickly replenish constellations would help deter the use of ASATs by adversaries. In addition, STaRS could launch a Payload Assist Module (PAM) in order to insert a payload beyond LEO.

A STaRS system has the potential to avoid many of the problems associated with land-based launch and provide a real responsive launch capability.

KEYWORDS: Sea Launch; STaRS; submarine; cargo ship; Trident missile; SSBN; TacSat; ICBM; SLBM.

* Disclaimer: "The views presented are those of the authors and do not necessarily represent the views of Department of Defense or its Components."

1. INTRODUCTION

This paper proposes a possible solution that avoids many of the difficulties associated with land-based launch systems used today: a Sea-launched TacSats for Responsive Space (STaRS) system. The use of sea-based launch platforms will further the goals of Operationally Responsive Space (ORS), particularly in the area of responsive launch.

2. ORS PLAN

The Plan for Operationally Responsive Space (the Plan), issued by the DoD on 20 Apr 2007, sets forth the overarching objectives of Responsive Space. The DoD defines Operationally Responsive Space (ORS) broadly as assured space power focused on timely satisfaction of Joint Force Commanders' (JFC) needs. The ORS Plan categorizes space assets into three tiers:

- Tier-1: On-orbit (current assets leveraged and prioritized for warfighter)
- Tier-2: ORS assets in ready reserve; ready for launch or deployment
- Tier-3: New assets rapidly acquired to meet specific COCOM/User need

A STaRS system would launch Tier-2 assets.

3. STaRS

Space Operations planners from the commercial sector to military applications desire responsive satellite systems that are multi-mission capable, easily and inexpensively produced, smoothly integrated, and rapidly launched. This emphasis demands shifting the launch paradigm to one that truly enables access to space, providing tactical deployment on demand and the capability to put current payload technology into orbit, versus several years by today's standards, by which time the technology is already obsolete. Today's launch paradigm overly constricts the opportunity window to meet commercial sector needs and military demands; however, a STaRS system would solve many of the problems associated with limited launch pads at fixed sites, including issues with "possible" launch pad availability due to competing program priorities as opposed to having a definite launch date. Of course, Sea-based launch capability will need to deal with issues that land-based systems do not, such as ocean environments, transportation logistics, and security concerns.

Consider land-based weather challenges, including annual hurricane season and that Florida's Cape Canaveral faces annual risk of destruction. According to the National Weather Service, from 1899 to 2002 Florida has been hit with 60 hurricanes ranging from 1 to 5 on the Saffir/Simpson category number. Landfall frequency is 0.57 storms per year, with a return period of 1.7 years.[1] So far, the Eastern Launch Range has survived, but gambling on maintaining space access from this fixed site is not prudent, especially if the Cape Canaveral Spaceport Leaders 50-Year Master Plan, unveiled in 2002, moves forward on its goal to increase launches to 251 per year by 2075, which is significantly up from about 21 per year.[2] Other pervasive weather factors provide ongoing challenges to scheduled launches. An average of "80 days of thunderstorms strike Florida's Atlantic coast each year" and rainfall amounts to about 50 inches per year. Another challenge is the formation of 100 to 350 tornadoes across the state every month.[3]

Besides threat of natural disaster, planned satellite launches must compete for the Eastern Launch Range's finite launch processing capability and few pads in comparison to launch needs. For example, most U.S. commercial launch pad availability resides at the Air Force run Cape Canaveral, and "[p]rivate companies say using those facilities is expensive and hampered by security issues and burdensome regulations."[4] A total of seven launch pads are used at Cape Canaveral[5], and five launch pads at Vandenberg[6] to support both military and commercial launches; however, launches from the Western Range are best suited for polar or retrograde orbits. The U.S. Army's Reagan Test Site (RTS) located at the Kwajalein Atoll, which can accommodate small launch vehicles, is also available.[7] SpaceX has a launch facility on Omelek Island in the Atoll. Assured access to space must provide launches on demand, awaiting the next payload to successfully deploy, rather than payloads queuing for the next available ride in a scheduling hierarchy.

If current launch methodology is not optimal for assured access to space, then what other possible approaches are viable? The authors believe that a sea-based launch approach provides a more optimal solution for Responsive Space. ORS should begin development of Sea-launched TacSats for Responsive Space (STaRS) systems.

Sea Launch has already shown the feasibility of sea-based launches.[8] Figure 1 shows the Sea Launch system and Figure 2 shows a rocket launched by Sea Launch. However, the converted oil rig and associated command ship process only one launch vehicle at a time and suffers from some of the same latencies associated with land launches. The concept certainly provides a worthwhile option, especially with optimal positioning along the equator to take advantage of Earth's angular momentum in order to launch larger payloads than possible at other latitudes. A launch can be planned to meet a desired launch window based on the required payload mission profile. If weather appears to be an issue, the Sea Launch can reposition.

Figure 1: Sea Launch Assembly and Command Ship (ACS) and Odyssey Launch Platform in port
(source: fcc.gov)

Figure 2: Equatorial Launch by Sea Launch
(source: fcc.gov)

The authors propose the following mass categories for sea launch systems:

Category 1: Micro-satellites, which are 10 to 100 kg (22–220 lb). These small payloads could be launched by submarines or small cargo ships.

Category 2: Mini-satellites, which are 100 to 500 kg (220–1100 lb). Currently, American TacSats are sized in this range (e.g., TacSat-1 is about 110 kg, TacSat-4 is about 450 kg). These satellites would have to be launched from a large cargo ship or a platform similar to that used by Sea Launch.

Category 3: "Regular" satellites, which mass 500kg and up. The Minotaur I payload to LEO is 580kg. A Delta IV or Atlas V can boost up to ~25,000 kg to LEO. This class of satellite would have to be launched from a stable platform such as the one used by Sea Launch.

Certain submarines are equipped to be roving launch platforms, ready to provide tactical launches upon command. The key point here is more than one launch is possible in a matter of minutes. This approach has more than military applications. Russia has already begun pioneering sea-based launch for commercial practices,[9] and "in May 2006, Russia successfully launched the Compass-2 micro-satellite, designed to monitor natural and man-caused disasters, from the Yekaterinburg submarine in the Barents Sea using a Shtil booster rocket."[10] The Russian launches were from the Barents sea because of range issues. Conceivably, they could probably launch a 100kg satellite using a Shtil launched by a submarine from an equatorial area.

Although submarine launches of satellites are possible, this method begs the question of just how much cost is involved. If it is just as expensive as the historical average of "$10,000 per pound of payload placed in orbit," then there's no need for further consideration. [11] The "Novomoskovsk K-407, a 667BDRM Delta-IV-class or Delfin-class submarine of the Russian Northern Fleet's 3rd Flotilla" launched two German satellites into orbits ranging from 250 to 500 miles above the Earth.[12] Both were nanosatellites, one weighing eighteen pounds and the other seven pounds, and the "Northern fleet reportedly was paid $111,000 for the launch."[12]

Russia has continued refining its submarine launched satellite concept. The Volna, a liquid two-stage rocket, is "based on the R-29R submarine-launched ballistic missile—NATO designator SS-N-18/Stingray—has a length of 46 feet long and a diameter of 6 feet."[13] Delta III or IV class submarines are used as the platform, and the Volna has the capability to place 115 kg into LEO from an equatorial launch site with a maximum volume of 1.3 cubic meters. A collaborative effort between two groups, Makeyev Design Bureau and American investors, occurred in 1993 to look at the potential for a follow on vehicle, called Surf, and was going to "be launched in a floating condition on the surface of the sea and would provide a LEO payload capacity of 2.4 metric tons."[13]

Most commercial and military payloads would require satellites of considerably larger size than Category 1 (10 to 100 kg). Although payload size on a single sea-based launch vehicle would not likely achieve the heavy class [Category 3 (500kg plus)] in modern satellites, small to medium payloads [Categories 1 and 2 (100-500kg)] will likely be perfect for sea launches.

Borrowing from existing submarine missile launch technology and adapting it to STaRS is plausible. The Trident II used in the Navy's boomers is 44 feet tall with a diameter of 6 feet and 2 inches.[16] For comparison, the Delta II, used to launch GPS satellites, is 125 feet 9 inches in height with a core diameter of 8 feet, and a fairing diameter of 9.5 feet.[17] Tridents could be retrofitted to lift payloads of less than 100kg. Figure 3 is an illustration of rockets being launched from a submarine.

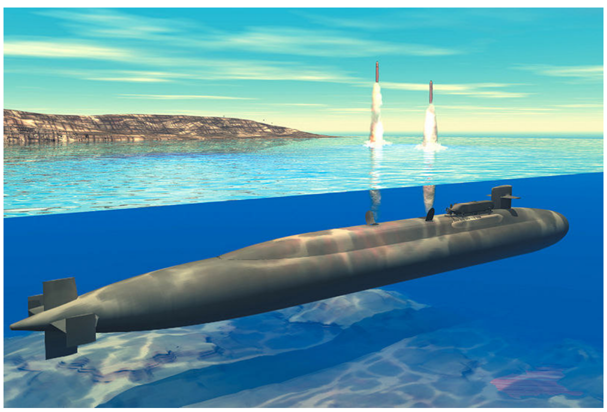

Figure 3: Artist conception of a SSGN Tactical Trident outfitted to launch Tomahawks, UUVs, UAVs (U.S. Navy image)

A converted oil tanker (or equivalent class) could be used for sea-based launch by blending the concept of submarine lift with payload sizing consideration. A mid-size oil tanker can measure 967 feet long and 166 feet wide.[14] By comparison, a ballistic missile submarine can measure 560 feet long,[15] coming in at about sixty percent the length of a mid-size oil tanker. Borrowing from existing submarine technology, a converted ship would have the capacity to use a silo approach on a larger scale than a submarine. The silos would provide a shield against the environment, and could even extend above the top deck, presuming proper ballast exists below the water line for stability. These silos could be sized larger than possible on a submarine, allowing for larger boosters.

In order to balance real estate with payload lift capacity on a mid-size oil tanker class (or larger) for STaRS, then a new launch vehicle could be sized between Trident II and Delta II dimensions. Another approach would be to use existing Delta II launch vehicles, and position the STaRS launch tubes down the center line of the ship. Figure 4 is an artist's conception of how a cargo ship might look if retrofitted to launch rockets.

Figure 4: Artist Conception of a Cargo Ship Launching a Small Launch Vehicle
(Image credit: Christopher Doray)

Launching to LEO would not be a limiting factor if satellite missions require another orbit. By first inserting a payload to LEO, coupled with near simultaneous launch of a payload assist module—docking on orbit of this follow on module could provide the taxi ride to final insertion. Payload assist module technology already exists, and was designed to transfer payloads to geosynchronous orbit. Successful use of this concept has been done for both Space Shuttle missions and Delta class launches.[18]

A tactical sea-based launch capability could provide a niche to augment military applications, especially for communications and intelligence gathering as demands surge during conflicts. These dynamic, real world events will not wait for traditional launch processing cycles. Short lived satellites with a mean mission duration of six months to a year could quickly augment space-based resources. In the near future, sea-based launch could also handle routine, smaller payloads to include launch profiles that are otherwise too restricted on land due to the need for avoiding dropping expended stages on the population. A payload assist module could be launched separately in order to boost a given payload to its final insertion point—sea-based launch could provide these complementary launches within a short time. In addition, sea-based launch could help free up precious land-based pads for medium to heavy class launches.

Considering concept of operations, STaRS potentially has significant military application as a submarine-based asset. It is possible that the ability to rapidly replenish a satellite constellation may provide deterrence to the use of Anti-Satellite (ASAT) systems by adversaries. For example, an Ohio-class submarine with 24 GPS-like small satellites could ensure the U.S. continues to have essential space-based navigation capabilities over very limited latitudes. Since 24 satellites is the minimum goal for an operational GPS constellation,[19] then STaRS could posture for rapid replenishment, effectively countering ASAT denial. Normal replenishment could occur periodically from STaRS in order to maintain mission proficiency, make use of the existing GPS-like payloads, then reload with upgraded GPS-like satellites.

Rapid replenishment of a communications satellite constellation is also feasible. Orbcomm satellites are 142kg and a constellation of 29 Orbcomm satellites covers most of the earth. Theoretically, a submarine with 24 silos that has the capability of launching 150kg payloads to orbits of approximately 900km could possibly repopulate most of an Orbcomm-like communications constellation if ASATs were to destroy them.

The notion of countering an ASAT threat should be taken seriously. Hundreds of commercial and military satellites are in orbits less than 1000 km above the earth, an orbital region known as LEO. Many of these satellites provide critical services during peacetime and combat operations. ASAT capability is not new and "[t]he USA demonstrated a practical system as early as 1959, while the Soviets reportedly tested their first weapon in 1968."[20] ASAT technology has proliferated and a "simple, direct-ascent ASAT based on a ballistic missile or scientific sounding rocket is now well within the grasp of a determined developing state."[20]

Another area of great utility is communications. During combat operations, STaRS platforms could rapidly augment space-based communications satellites. This action would provide a surge capability to increase available resources for increased, high-demand bandwidth loading in direct support of combat operations.

Given the potential military applications for STaRS, an existing submarine may be suitable. Ohio-class ballistic missile submarines (SSBN), each armed with 24 Trident II Submarine Launched Ballistic Missiles (SLBMs), could be used as a STaRS asset.[21] Conceptually, a mix of payloads might be used across the available Ohio-class SSBNs—16 tubes could be dedicated to the nuclear mission, with the other 8 devoted to military satellite payloads. Or one or two Ohio-class submarines might be entirely dedicated as STaRS platforms.

This approach provides unique challenges compared to land-based launches. A home port must be established to provide logistical transfer of rocket bodies and their payloads. Security must be maintained at the appropriate level for the payloads. Transit time to and from port is a consideration for launch cycles, and would therefore drive a recommendation for a minimum of two sea-launched TacSats for Responsive Space (STaRS) platforms. While one STaRS ship is in port either for maintenance or receiving new launch vehicles and accompanying payloads, the other STaRS ship can be at sea.

Down-range tracking and communication issues arise with the use of sea-based systems. Sea Launch has an Assembly and Command Ship (ACS) that provides for mission control of the converted oil-drilling platform used for launch. STaRS systems would likewise require a similar down-range ship or platform to provide for mission control and range safety. Significantly, the U.S. could leverage the use of Unmanned Aerial Vehicles to provide range services. Another consideration will be developing appropriate flight termination systems, which could be evolved from current systems for missiles.

4. FUTURE ROLE OF STaRS IN ORS

STaRS systems could enable on-orbit assembly of satellites by allowing more frequent launches and flexibility in reaching various orbits. In the long run, satellites could be designed as modules, similar to plug-and-play devices already produced with computers. A master module containing some fuel, thrusters, docking sensors, universal docking, and on-board computing could be launched along with modules necessary to assemble and play on orbit. The master module would maneuver to dock with its other modules, to include items such as a fuel module, sensor suite, communications package, on-board mission processors, and solar arrays. The master module would boot up the on orbit assembled payload package and run through diagnostics. If a module did not pass, then that module would be disconnected and allowed to be disposed of through burn up on reentry. The master module would await a replacement piece and STaRS could provide the responsive replacement launch. Once the new piece is inserted into orbit with the master module, the new piece can be assembled for play on orbit.

After successful checkout, a payload assist module launched from STaRS would insert the satellite into its final position—multiple payload assist modules could be docked in a staging arrangement to allow insertion into any desired orbit. Note that assemble and play on orbit opens up the possibilities of payload sizes even larger than today's heavy class satellites. The final on orbit assembled designs would not be limited to faring sizes—the construction itself need only survive the space environment.

5. JOINT OPERATIONS FOR STaRS

Although, the Air Force is the Executive Agent for space, sea-based operations are out of the realm of normal Air Force operations. A Joint mission is required for STaRS. STaRS ships/subs could be pre-positioned near the equator or incorporated into a Navy fleet. The Navy could run ship operations, or include a mix of contractor personnel. The Air Force would conduct launch operations and could do so in collaboration with the Navy.

The use of military crew aboard STaRS ships would provide for security, especially for missions involving national significance. For submarine-based STaRS, an entirely Navy crew should be able to handle the mission—when a STaRS launch occurs, operational mission control is transferred to the Air Force after the launch vehicle clears the ocean surface.

6. SUMMARY AND RECOMMENDATION

In 2006 U.S. Representative Terry Everett (R-Ala.), chairman of the House Armed Services strategic forces subcommittee, stated and was noted in a Government Accountability Office (GAO) audit, "[Defense Department] Needs a Department Wide Strategy for Pursuing Low-Cost Tactical Space Capabilities."[22] STaRS has high potential to meet the need for low-cost, tactical space capabilities.

Responsive spacelift may become as important as nuclear deterrence. A STaRS system, especially one based on a hard to find submarine equipped for satellite launches could discourage adversaries from attacking satellites. A STaRS system could have the mission to quickly replenish friendly space power, thereby reducing the utility of an ASAT. If there was an effective, responsive system to quickly replenish friendly space power, then any space attack would be reduced to a gesture that may harass, but not deny friendly presence in space.

There are great possibilities to generate ORS capability using sea-based assets and adapting submarine launch technology. The authors highly recommend development of this concept to determine the optimum approach in terms of end-to-end fielding and system operations of a STaRS system.

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