Unique and Complementary Characteristics of the U.S. ICBM and SLBM Weapon Systems

Mitch Bott[1]

Abstract

Given the high level discussions being conducted by the current U.S. administration on the U.S. nuclear posture, it is important to understand the characteristics of the U.S. strategic systems in order to make informed decisions on future nuclear posture requirements. This paper will discuss the background of the current U.S. strategic missile systems, summarize and discuss the important characteristics of each of the missile systems; ICBMs & SLBMs, how the two systems complement each other, and finally address force structure considerations with respect to the START follow-on goals. After examining the two systems, it is shown that the overall technical performance of the two systems is similar. It is also shown that the START follow-on goals can be met without impacting the existing force structure; provided weapon counting rules are reformed to better reflect actual levels. Due to these conclusions, force structure decisions should not be driven by the technical performance of either system.

Introduction

U.S. President Barack Obama and Russian President Dmitry Medvedev reached an agreement in July of 2009 to cut their countries respective nuclear arsenals to 1,500 to 1,675 warheads and 500 to 1,100 strategic delivery vehicles under a replacement for the 1991 Strategic Arms Reduction Treaty (START).[2] These decisions will affect

---

[1] Mitch Bott is a Systems Engineer with Northrop Grumman Aerospace Systems. The views expressed in this paper are the author's and do not represent the views of Northrop Grumman.

[2] "Tensions Persist in U.S. Over START replacement" Global Security Newswire Article, dated September 9th, 2009. <http://www.globalsecuritynewswire.org/gsn/nw_20090909_8670.php>

the nuclear posture of the U.S. It is important to understand the characteristics of the U.S. strategic systems in order to make informed decisions regarding the force structure of the U.S. nuclear deterrent. This paper discusses two of the three legs of the nuclear triad; the Intercontinental Ballistic Missile (ICBM), and Submarine Launched Ballistic Missile (SLBM). The third leg, strategic bombers, are not discussed in detail as the characteristics of this leg, and how it differs from the other two, are better understood than the subtle differences between ICBMs and SLBMs.

Six characteristics of the two strategic missile systems will be examined to show differences and similarities between the two systems. The six characteristics are: availability, reaction time, target coverage, payload, survivability, and cost. These characteristics will also be examined for synergies between the two systems or how the systems complement one another. The characteristics chosen for this study were selected as the characteristics that provide the best indicator of technical performance of the system and overall value of the system to the user.

Background

The U.S. ICBM force is currently comprised of the Minuteman III weapon system. The Minuteman III system consists of 450 missiles that are based in silos spread amongst 3 Missile Wings at Malmstrom AFB, Montana; Minot AFB, North Dakota; and F.E. Warren AFB, Wyoming.[3] The Minuteman III was developed in the 1960's and first fielded in the 1970's. Minuteman III has seen significant upgrades throughout the time it has been deployed. The latest upgrades for the Minuteman III started in the 1990's and are either completed or nearing completion. These include efforts to replace aging guidance system components, solid rocket motors, various ground systems, and an upgrade to the reentry system to allow the missile to carry a single reentry vehicle. [4, 5]

---

[3] Robert S. Norris and Hans M. Kristensen, "U.S. nuclear forces, 2009," *Bulletin of the Atomic Scientists,* March/April 2009, vol. 65, no. 2, 59–69.
[4] "Minuteman Missile History", Strategic-Air-Command.com, <http://www.strategic-air-command.com/missiles/Minuteman/Minuteman_Missile_History.htm> [cited 8 Dec 2009].
[5] Tony Lin, "Development of U.S. Air Force Intercontinental Ballistic Missile Weapon Systems," *Journal of Spacecraft and Rockets*, Vol. 40(4), July-August 2003, 491-509.

The Trident II (D-5) missile is the current SLBM used by the U.S. The Trident II is based in 12 Ohio class submarines (two additional submarines are considered to be in dry dock undergoing an overhaul at any given time).[6] Five of these submarines are based at Kings Bay, Georgia as part of the Atlantic fleet, and seven are based at Bangor, Washington as part of the Pacific fleet.[7] The Trident II missile was initially developed in the 1980's, and first deployed in 1990.[8] The Trident II missile is also currently undergoing a life extension process that expects to extend the life of the missile until 2040.[9]

Availability

Availability is defined as the portion of the missile force that is available for use at any given time. Maintenance actions and scheduled down time can put missiles into a state where they are not available for use should an emergency arise.

The Minuteman III system is characterized by having a very high availability. The alert rate, the ratio of the force that is available for launch to the total force, is greater than 90%[10] and is near 100%.[11] This alert rate puts the Minuteman III availability at somewhere between 405 to 450 missiles. This high alert rate is facilitated by the remove and replace repair concept utilized with Minuteman III, and a minimal amount of scheduled maintenance. Launch crews work 24 hour alert shifts, being ready at any time to launch if required.

---

[6] Robert S. Norris and Hans M. Kristensen, "U.S. nuclear forces, 2009," *Bulletin of the Atomic Scientists,* March/April 2009, vol. 65, no. 2, 59–69.
[7] Amy F. Woolf, "U.S. Strategic Nuclear Forces: Background, Developments, and Issues," *CRS Report for Congress,* RL33640, July 14, 2009.
[8] "Trident II D-5 Fleet Ballistic Missile", Federation of American Scientists, <http://www.fas.org/nuke/guide/usa/slbm/d-5.htm> [cited 8 Dec 2009].
[9] "Navy Awards Lockheed Martin $248 Million Contract for Trident II D5 Missile Production and D5 Service Life Extension", Lockheed Martin Press release dated January 29th, 2002, <http://www.lockheedmartin.com/news/press_releases/2002/NavyAwardsLockheedMartin248MillionC.html>
[10] William M. Arkin and Robert S. Norris, "Nuclear Alert After the Cold War," *Natural Resources Defense Council*, NWD 93-4, October 18, 1993.
[11] Airmen 1st Class Ross Tweten, "Minot's Rough Riders shatter alert rate record," Minot Air Force Base Public Affairs, February 5, 2006, <http://www.missilenews.com/space-command-news/minots-rough-riders-shatt.shtml>

The Trident II force's availability is characterized by having a portion of the force on "hard alert" meaning that its missiles are available for immediate use. This is largely driven by the concept of operations of the SSBN force. Of the 14 total submarines, 2 are in dry dock undergoing a 12 month refurbishment, 3-4 are docked undergoing maintenance and replenishment that lasts roughly 25 days, 8-9 are at sea performing deterrence patrols which last 60-90 days, and of the 8-9 that are on patrol, 4 are on continual hard alert.[12, 13] The portion of the force that is on hard alert provides 86-96 missiles that are available for immediate use, assuming a 90%-100% alert rate similar to Minuteman III. Another 86-120 missiles are also available in the submarines that are on patrol, but would require some additional reaction time as discussed below.

Reaction Time

Reaction time for the two missile systems is defined as the time required for a missile to execute a mission, i.e. time from receipt of launch command until the target is reached. This consists of two parts: how long it takes a launch crew and the system to launch after receipt of a valid launch command and how long it takes for the missile to reach its target.

The name of the Minuteman missile refers to the ability to launch the missile within minutes after receipt of a valid launch order.[14,15] After launch, it would take roughly 30 minutes for the Minuteman III to deliver its warhead to target.[16] This time will vary somewhat depending on the distance between the launch point and the target.

---

[12] Hans Kristensen, "U.S Strategic Submarine Patrols Continue at Near Cold War Tempo," FAS Strategic Security Blog, March 16th, 2009, <http://www.fas.org/blog/ssp/2009/03/usssbn.php>
[13] "SSBN-726 Ohio-Class FBM Submarines", Federation of American Scientists, <http://www.fas.org/programs/ssp/man/uswpns/navy/submarines/ssbn726_ohio.html> [cited 8 Dec 2009]
[14]"LGM-30 Minuteman", Absolute Astronomy, <http://www.absoluteastronomy.com/topics/LGM-30_Minuteman>
[15] John Morgan, "Peacekeeper's last month", trib.com, August 3rd, 2005 <http://trib.com/news/state-and-regional/article_63f543ad-e9bc-54ab-b9b3-4fd537c7533a.html>
[16] Ibid.

Improvements in communications systems have allowed SLBMs to be able to have times from receipt of a valid launch order to launch similar to that of ICBMs.[17] From this, one can infer that the time required to validate a launch command and launch a Trident II missile is on the order of minutes, similar to that of the Minuteman III system. The 4 to 5 submarines that are on patrol would also be able launch if a valid command was received; however, it is expected that there will be additional time required to ready missiles for launch over the missiles that are on hard alert. Although an estimate on how long this would take was not able to be found during a literature search, it is estimated to be in the tens of minutes range based on knowledge of inertial navigation startup requirements, with additional time likely to be required for the submarine to get into a firing position/location depending on where the submarine is. After launch, it would take approximately 15-25 minutes for the Trident II to reach its target depending on the distance between the launch site and the target. [18,19]

Target Coverage

Target coverage is a measure of how well a system is able to hold targets at risk. For the ballistic missiles discussed in this paper, this is largely dependent on accuracy and range of the system. Basing modes and number of available assets also play a part in defining how many targets a given system can hold at risk of an attack.

The Minuteman III missile has accuracy on the order of about 400 feet circular error probable (CEP).[20] CEP is defined as a circle with a specified radius, in the case of Minuteman III this radius is 400 feet, centered about the target point whose boundary is expected to include 50% of the warheads aimed at the target point. Minuteman III has a range around 8,000 miles, which will vary with warhead

---

[17] Craig C. Whitehead, "Operational improvements to the U.S. submarine launched ballistic missile enable this leg of the strategic triad to assume the role of the U.S. intercontinental ballistic missile," Naval War College, 13 February 1992.
[18] Brito, Mesquita, and Intriligator, "The Case for Submarine Launched Non-Nuclear Ballistic Missiles," January 2002.
[19] "Undersea Global Strike", March 13th, 2006, <https://www.sott.net/articles/show/111948-Undersea-Global-Strike>
[20] "Minuteman III", Missile Threat, <http://www.missilethreat.com/missilesoftheworld/id.79/missile_detail.asp> [cited 9 Dec 2009]

loading.[21] Minuteman III is launched from fixed silos which affect its target coverage several ways. While Minuteman III's range does not offer the ability to target any spot on the globe, it does allow targeting of all major regions of interest. Launching from a fixed point also allows potential adversaries to plan for an attack as the direction the missile will attack from is known ahead of time. Having a fixed launch site also causes concerns about flying over U.S. and potentially, territories of other nations. Spent stages are likely to fall in sparsely populated areas and there are few countries that would have the technology to detect if a Minuteman were flying over their territory, but there are potential political ramifications that may need to be addressed regarding these issues. With the availability discussed previously, Minuteman III is able to hold between 405 and 450 target regions at risk.

The Trident II missile has accuracy of the order of 400 feet CEP.[22] The range of the Trident II varies with warhead loading between 4,600 miles with a full warhead load and up to 6,900 miles with a reduced warhead load.[23] The mobile launch platform provided by the submarine provides some benefits for target coverage. While the range of a Trident II missile is not sufficient to reach anywhere on the globe from a given launch point, the launch point can be moved, which allows the Trident II to be able to target any spot on the globe. The mobile launch site also allows the Trident II to attack a target from almost any direction, which can complicate enemy defenses. The mobile launch site may be able to alleviate the over-flight concerns mentioned above for the Minuteman III, but only if the target location, launch location, and time constraints to move the launch location, if required, allow it. Overall, the Trident II system is able to constantly hold 86-96 target regions at risk, with the ability to hold another 86-120 target regions at risk with the submarines that are on patrol given additional reaction time as discussed previously.

---

[21] Ibid.

[22] "Trident II Fleet Ballistic Missile: Specifications," Global Security, <http://www.globalsecurity.org/wmd/systems/d-5-specs.htm> [Cited 9 Dec 2009]

[23] Bob Aldridge, "U.S. Trident Submarine & Missile System: The Ultimate First-Strike Weapon," Pacific Life Research Center, PLRC-022227D, 16 November, 2002.

Payload

Payload is defined as what the missile can carry. The payload for the ICBM and SLBM weapon systems are reentry vehicles, also known as reentry bodies on SLBMs. These reentry vehicles, which are part of the weapon system, house the warheads, and travel from the point they are released from the missile, outside of the atmosphere, through the rigors of atmospheric reentry, and finally, to the target.

Minuteman III has a payload capability of 1 to 3 warheads per missile.[24] With approximately 550 warheads deployed on the Minuteman III force, the Minuteman III force is primarily equipped with single warheads.[25] The Minuteman III is capable of attacking either a single target, or 2 to 3 targets within its Multiple Independent Reentry Vehicle (MIRV) footprint limitations. The MIRV footprint is defined as the maximum distance between warhead impact points that a MIRV missile can achieve. The MIRV footprint for Minuteman III is believed to be greater than that of the Trident II, as the Minuteman III employs a more efficient liquid-fueled post boost vehicle to deploy each reentry vehicle where Trident II uses a solid-fueled post boost vehicle.[26] Minuteman III missiles, with a single reentry vehicle, have the capability of carrying out limited strike missions (attacking a single target) and missions to isolated targets, where these type of missions are either not possible or inefficient for MIRV equipped missiles.

The Trident II missile has a maximum payload capacity of 12 warheads, but is limited to a maximum of 8 warheads under the current START treaty.[27] Currently it is estimated that there are 1,152 warheads allocated to the Trident II force for an average of 4 warheads per missile.[28] This allows each Trident II missile to attack 4 targets within its MIRV footprint limitations. This capability makes Trident II best suited to attack targets that are grouped in close vicinity of each other. If single warhead capability were desired for the Trident II, there is no technical limitation of

---

[24] "Minuteman III", Missile Threat,
<http://www.missilethreat.com/missilesoftheworld/id.79/missile_detail.asp> [cited 9 Dec 2009]
[25] Robert S. Norris and Hans M. Kristensen, "U.S. nuclear forces, 2009," *Bulletin of the Atomic Scientists,* March/April 2009, vol. 65, no. 2, 59–69.
[26] "Trident II Fleet Ballistic Missile," Global Security,
<http://www.globalsecurity.org/wmd/systems/d-5-features.htm> [Cited 9 Dec 2009]
[27] "Trident D-5," Missile Threat,
<http://www.missilethreat.com/missilesoftheworld/id.174/missile_detail.asp> [Cited 9 Dec 2009]
[28] Robert S. Norris and Hans M. Kristensen, "U.S. nuclear forces, 2009," *Bulletin of the Atomic Scientists,* March/April 2009, vol. 65, no. 2, 59–69.

the system that would prevent this as it could easily be accomplished by adding ballast in the place of warheads. It is believed that Britain has Trident II missiles with single warheads.[29]

Survivability

Survivability is defined as the ability of a weapon system to survive attack. This attack could be nuclear or non-nuclear. In order to be survivable, the ICBM and SLBM weapon systems have adopted different methodologies as discussed below.

Each Minuteman III missile is based in a single silo.[30] These silos are geographically separated such that any nuclear attack on a silo will not damage another silo. These silos are also hardened against nuclear environments such as overpressure and electromagnetic pulses (EMP), which enhance the ability of a silo to withstand nearby nuclear detonations.[31] Each group of 10 missiles is controlled by a Launch Control Center (LCC), which are also hardened against nuclear environments. These LCCs have redundant command and control in that any LCC in a squadron (50 missiles) can assume command and control over the missiles controlled by another LCC in the event that the LCC is lost. This command and control is made further redundant through the use of the Airborne Launch Control System (ALCS), in which a military airplane is able to assume command and control over missiles on the ground.[32] These survivability features are primarily for defense against nuclear attack, but would also apply to the unlikely scenario that the missiles are attacked conventionally. The Minuteman III force is essentially invulnerable to attack with the exception of a large nuclear exchange. Even in this scenario, an adversary would likely be forced to use at least a 2 on 1 targeting scheme to ensure destruction of each missile due to accuracy limitations. This would require an adversary to have a minimum of 900 weapons, which makes Russia the only real threat to the ICBM force. Even if the above scenario is 95% successful, around 20

---

[29] Robert S. Norris and Hans M. Kristensen, "British Nuclear Forces, 2005," *Bulletin of the Atomic Scientists,* November/December 2005, Vol. 61, No. 6, 77-79.
[30] "LGM-30 Minuteman III," Federation of American Scientists, <http://www.fas.org/nuke/guide/usa/icbm/lgm-30_3.htm> [Cited 9 Dec 2009]
[31] "The Minuteman III ICBM," Nuclear Weapon Archive, October 7th, 1997. <http://nuclearweaponarchive.org/Usa/Weapons/Mmiii.html>
[32] Ibid.

missiles would still be able to retaliate. The above example shows how costly it is, in terms of an adversary's warheads and resources, to engage the ICBM force. With most of the ICBM force having only a single warhead, each silo is a low value target, making the above scenario even less attractive to a potential adversary in that they would have to commit 2 of their warheads to destroy a single ICBM warhead. This characteristic gives the ICBM force a high deterrence value and make them highly stabilizing.[33]

Each Ohio-class submarine is equipped with 24 Trident II missiles.[34] This creates a very high value target in the submarine, holding 96 warheads in one place. The main source of survivability for the submarines is their stealth that they have when at sea. This complicates the ability of an adversary to attack the submarines as their location is unknown. The vast open areas of the world's oceans make it very difficult to search for these submarines as well. Communications between the National Command Authority (NCA) and the submarines is accomplished via four independent methods: Very Low Frequency (VLF), Low Frequency (LF), Extra Low Frequency (ELF), and aircraft borne communication links.[35] Current submarine tracking capabilities are effective in finding submarines known to be near a given location, but wide area surveillance is limited.[36] The Ohio ballistic missile submarine force at sea is essentially invulnerable, with the exception of a break-through in submarine tracking capability. As long as the submarines remain undetected, they will be survivable to attack. The 4-5 submarines that are at port at any given time would be vulnerable to an attack due to being in a fixed, known location. The submarine force can also be engaged via conventional weapons at sea. The Ohio-class submarine has some armament to defend itself against conventional attack and may also be escorted by other submarines while at sea.[37] A conventional attack on an Ohio-class submarine does not necessarily have the same ramifications on the

---

[33] Conrad, et al., "The Long Pole of the Nuclear Umbrella," Senate ICBM Coalition, November 4th, 2009.
[34] "SSBN-726 Ohio-Class FBM Submarines", Federation of American Scientists, <http://www.fas.org/programs/ssp/man/uswpns/navy/submarines/ssbn726_ohio.html> [cited 9 Dec 2009]
[35] Craig C. Whitehead, "Operational improvements to the U.S. submarine launched ballistic missile enable this leg of the strategic triad to assume the role of the U.S. intercontinental ballistic missile," Naval War College, 13 February 1992.
[36] G.G. Wren and D. May, "Detection of Submerged Vessels Using Remote Sensing Techniques," *Australian Defence Force Journal,* No. 127, 9-15, November/December 1997.
[37] SSBN-726 Ohio-Class FBM Submarines", Federation of American Scientists, <http://www.fas.org/programs/ssp/man/uswpns/navy/submarines/ssbn726_ohio.html> [cited 9 Dec 2009]

aggressor as does an attack on the ICBM force, as attacking the ICBM force is a direct attack on sovereign U.S. territory. The overall deterrence and survivability value of the SLBM is directly tied to its ability to remain undetected.

Cost

The cost of the two missile systems was examined both in terms of year to year recurring costs and estimated future costs to maintain each system to 2050, which will take both systems through a replacement of major components. All costs presented below have been normalized to Fiscal Year (FY) 2010 dollars using the "Green Book."[38] The operations and support cost encompasses all costs required to sustain the system in any given year. The major acquisition costs are the costs of procuring new and/or upgraded systems as the existing systems age out.

Minuteman III has a year to year operations and support cost of approximately $1.3B.[39, 40] When examined on a per-warhead basis, assuming 550 deployed warheads,[41] the Minuteman III costs $2.36M per deployed warhead. The current Minuteman III force is expected to remain in service until 2030,[42] at which point either a replacement or major upgrade would be required. This replacement has an estimated procurement cost of $53M per missile with a $16B Research, Development, Test, and Evaluation (RDT&E) effort to develop the system.[43] Assuming force levels remain at 450 and that 550 missiles are procured allowing 100 spare missiles/test assets, the total cost of the ICBM system to get from 2010 to 2050 would be $97B as outlined in Table 1. Assuming warhead levels remain at 550 deployed warheads, the ICBM system cost is $176M per deployed warhead.

---

[38] "National Defense Budget Estimates for FY 2010 (Green Book)," United States Department of Defense, June 2009, <http://www.defenselink.mil/comptroller/Budget2010.html.>
[39] "Comparative Funding for B-52H, B-2, Minuteman ICBMs, and Trident Submarines and Missiles," Congressional Research Service, May 19, 2009.
[40] "The START Treaty and Beyond," Congressional Budget Office (CBO), Washington, D.C., 1991.
[41] Robert S. Norris and Hans M. Kristensen, "U.S. nuclear forces, 2009," *Bulletin of the Atomic Scientists,* March/April 2009, vol. 65, no. 2, 59–69.
[42] Michael C. Sirak, "Many More Minutes," *Air Force Magazine*, November 17t, 2009.
[43] Steven M. Kosiak, "Spending on US Strategic Forces: Plans and Options for the 21st Century," Center for Strategic and Budgetary Assessments (CSBA), Washington, D.C., 2006.

Table 1: Minuteman III Costs 2010-2050 ($FY10)

Item	Cost	Total cost from 2010-2050
Yearly operations and support	$1.3B ($2.36M/warhead)	$52B
Minuteman Replacement in 2030 (550 missiles)	$53M/missile	$29B
Minuteman Replacement RDT&E	$16B	$16B
Total	**N/A**	**$97B ($176M/warhead)**

The Trident II system, including submarine, has a year to year operations and support cost of $3.0B[44]. Assuming approximately 1,152 deployed warheads,[45] the operations and support cost is $2.60M per deployed warhead, which is comparable to the Minuteman III per warhead operations and support cost. The Ohio-class submarines are anticipated to require replacement in 2029.[46] It is estimated that each new submarine will cost $6.4B with an additional $6.4B being required for RDT&E efforts.[47] The Trident II missiles are currently expected to last until about 2040.[48] The replacement Trident missile is expected to cost $106M/missile with an additional $21.5B required for RDT&E.[49] Assuming force levels identical to today, with 14 new submarines each carrying 24 missiles and 388 total missiles procured, 100 of these for spares and test assets, the total cost from 2010 to 2050 for the SLBM force is $279B as shown in Table 2. Assuming warhead levels remain at 1,152, the total system cost is $242M per deployed warhead.

---

[44] "Comparative Funding for B-52H, B-2, Minuteman ICBMs, and Trident Submarines and Missiles," Congressional Research Service, May 19, 2009.
[45] Robert S. Norris and Hans M. Kristensen, "U.S. nuclear forces, 2009," *Bulletin of the Atomic Scientists,* March/April 2009, vol. 65, no. 2, 59–69.
[46] "SSBN-X Future Follow-on Submarine," Global Security, <http://www.globalsecurity.org/wmd/systems/ssbn-x.htm> [cited 9 Dec 2009]
[47] Steven M. Kosiak, "Spending on US Strategic Forces: Plans and Options for the 21st Century," Center for Strategic and Budgetary Assessments (CSBA), Washington, D.C., 2006.
[48] "Navy Awards Lockheed Martin $248 Million Contract for Trident II D5 Missile Production and D5 Service Life Extension", Lockheed Martin Press release dated January 29th, 2002, <http://www.lockheedmartin.com/news/press_releases/2002/NavyAwardsLockheedMartin248MillionC.html>
[49] Steven M. Kosiak, "Spending on US Strategic Forces: Plans and Options for the 21st Century," Center for Strategic and Budgetary Assessments (CSBA), Washington, D.C., 2006.

Table 2: Trident II Costs 2010-2050 ($FY10)

Item	Cost	Total cost from 2010-2050
Yearly operations and support	$3.0B ($2.6M/warhead)	$120B
Ohio Replacement in 2029 (14 submarines)	$6.4B/submarine	$90B
Ohio Replacement RDT&E	$6.4B	$6.4B
Trident II Replacement in 2040 (388 missiles)	$106M/missile	$41B
Trident II Replacement RDT&E	$21.5B	$21.5B
Total	**N/A**	**$279B ($242M/warhead)**

Complementary Characteristics

It is important to understand not only the individual characteristics of the ICBM and SLBM weapon systems, but how they complement one another and, together, provide characteristics that are not inherent to either system. If one ever contemplated eliminating either system, one must consider the risk in losing some of the synergies provided by the two systems together. Each of these characteristics, derived by the synergy of the two systems, is discussed below.

The risk of losing both systems is much lower than the risk of losing one. As discussed in the survivability section, the ICBM and SLBM systems have different vulnerabilities. This makes it impossible for an adversary to disarm both systems with a single strike. It also greatly complicates a potential adversary's strategy to defeat both systems simultaneously by mounting a large scale nuclear strike on the ICBM silos, and finding then attacking each of the Ohio-class submarines. This also does not allow an adversary to focus their resources on defeating only one system.

Having both systems also forces potential adversaries to account for the two types of different threats coming from the ICBM and SLBM force. There would potentially be a large number of missiles coming from a known location, and a smaller number of MIRV equipped missiles coming from an unknown location to consider. This greatly complicates how to defend against these threats as missile defense is best suited to defending against a small number of missiles coming from a known location.

The Minuteman III and Trident II systems are different, were developed independent of one another, and thus a technical problem with one system will not likely affect the other. This greatly reduces the risk of a "single point of failure" scenario. This also allows one system to continue to function if there is a technical problem with the other system avoiding a potentially dangerous gap in deterrence.

Force Structure Considerations – START follow-on goals

The START treaty follow-on goals, as mentioned in the introduction, are 500-1,100 strategic delivery vehicles, and 1,500-1,675 warheads. Current force levels are shown below in Table 3 for both START counting rules and the best estimate of actual levels for both the U.S. and Russia. It can be seen that actual levels for both countries are somewhat below the levels per START counting rules, and in the case of the U.S. they are significantly lower. This is due to the START treaty counting rules assuming that each launcher is loaded, and each vehicle is loaded with its full MIRV warhead compliment. The U.S. has been downloading warheads on both the ICBM and SLBM systems, and because of this downloading, the START counting rules result in a vast overestimation of the number of warheads deployed on strategic delivery systems.

Table 3: Current Force Levels per START Counting Rules and Estimate of Actual Levels

	USA (START)[50]	**USA(est)[51]**	**Russia (START)[52]**	**Russia (est)[53]**
Delivery Vehicles	1,188	798	809	685
Warheads	5,916	2,202	3,897	3,313

[50] "START Aggregate Numbers of Strategic Offensive Arms," Bureau of Verification, Compliance, and Implementation, U.S. Department of State, October 1, 2009, <http://www.state.gov/t/vci/rls/130149.htm>
[51] Robert S. Norris and Hans M. Kristensen, "U.S. nuclear forces, 2009," *Bulletin of the Atomic Scientists,* March/April 2009, vol. 65, no. 2, 59–69.
[52] "START Aggregate Numbers of Strategic Offensive Arms," Bureau of Verification, Compliance, and Implementation, U.S. Department of State, October 1, 2009, <http://www.state.gov/t/vci/rls/130149.htm>
[53] Robert S. Norris and Hans M. Kristensen, "Russian Nuclear Forces, 2008," *Bulletin of Atomic Scientists,* Vol. 64, No. 2, pp. 54-57, 62.

As of the date this paper is being written, details of the START follow-on treaty have not yet been released. As can be seen above, treaty counting rules could play a very important part in what force structure will be required to meet the START follow-on goals. If one assumes that the counting rules remain the same, a cut of roughly 60% of the force is required to meet the follow on goals for number of warheads, and the number of delivery vehicles will fall below the minimum of 500. This estimate also assumes that systems no longer in use will no longer be counted, e.g. Peacekeeper, Trident I, and B-1. Also, under START rules, the launchers and delivery vehicles associated with the reduction will either need to be destroyed or modified such that they can no longer be used for the nuclear mission. Table 4 shows the reduction in terms of START countable assets and an estimate of actual force levels. Reductions of this magnitude may increase the risk of being able to efficiently and economically sustain the ICBM and/or SLBM systems. As force levels drop, it may become more difficult to procure specialized parts and to recruit and retain talented individuals to perform system sustainment.

Table 4: Force levels to meet START follow-on goals assuming START I counting rules

Vehicle	**Current Delivery Vehicles (START[54]/est.[55])**	**Delivery Vehicles to meet START follow-on goals (START/est.)**	**Current Warheads (START/est.)**	**Warheads to meet START follow-on goals (START/est.)**
B-2	18/16	6/6	18/150	6/56[56]
B-52 Gravity Bomb	47/15[57]	6/6	47/117	6/47
B-52 ALCM	94/29	10/10	940/233	100/80
Minuteman III	500/450	200/200	1,200/550	600/244
Trident II	336/288	120/120	2,688/1,152	960/480
Totals	**995/798**	**342/342**	**4,893/2,202**	**1,672/907**

[54] "START Aggregate Numbers of Strategic Offensive Arms," Bureau of Verification, Compliance, and Implementation, U.S. Department of State, October 1, 2009, <http://www.state.gov/t/vci/rls/130149.htm>

[55] Robert S. Norris and Hans M. Kristensen, "U.S. nuclear forces, 200,"

[56] The reductions on warheads allocated to bombers were made by keeping the ratio of warheads to bombers the same as is currently is in Norris and Kristensen.

[57] The ratio of gravity bomb to ALCM B-52 bombers is not mentioned in Norris and Kristensen. It is assumed that this ratio is 1:2, the same as the ratio as in the START count.

It is also possible that the START follow-on treaty will be able to resolve the over-counting issue with the START treaty. In this case, the force impact to meet the START follow-on goals will be minimized. In fact, the goal for number of delivery vehicles is already met with the current estimate force levels. The goal for number of warheads can be met by downloading the remaining MIRV loaded Minuteman III missiles to a single warhead, and downloading Trident II to carry between 2 and 3 warheads on each missile. It is also possible to keep warhead loading levels the same as they currently are and reduce forces by 25% to meet warhead goals. These two options represent the two ends of the spectrum of possibilities on how to meet START follow-on goals, as some mixture of these two options could also be used to meet the goals. Table 5 illustrates these two options and what force levels result.

Table 5: Two options to meet START follow-on goals assuming new counting rules more accurately reflect force levels showing current and future force levels

Vehicle	**Delivery Vehicles Download only option (Current[58]/ Future)**	**Warheads Download only option (Current/ Future)**	**Delivery Vehicles 25% Force reduction option (Current/ Future)**	**Warheads 25% Force reduction option (Current/ Future)**
B-2	16/16	150/150	16/12	150/113
B-52 Gravity Bomb	15[59]/15	117/117	15/11	117/86
B-52 ALCM	29/29	233/233	29/21	233/169
Minuteman III	450/450	550/450	450/350	550/420
Trident II	288/288	1,152/(576-725)	288/216	1,152/864
Totals	**798/798**	**2,202/(1,526-1,675)**	**798/610**	**2,202/,1652**

[58] Robert S. Norris and Hans M. Kristensen, "U.S. nuclear forces, 2009," *Bulletin of the Atomic Scientists,* March/April 2009, vol. 65, no. 2, 59–69.
[59] The ratio of gravity bomb to ALCM B-52 bombers is not mentioned in Norris and Kristensen. It is assumed that this ratio is 1:2, the same as the ratio as in the START count.

Conclusions

Table 6 summarizes the conclusions drawn from the review of the 6 unique characteristics of the ICBM (MMIII) and SLBM (D-5) systems. Overall, technical performance of the two systems is very similar. Both systems provide a large number of missiles that are available for use at any given time. The reaction time of the two systems is comparable and varies somewhat depending on distance to target. Both systems can hold large target sets at constant risk. Both systems are highly survivable although they derive their survivability through different means. Due to the differences is payload between the two systems, Minuteman III is better suited to single strike missions and attacking widely dispersed targets while Trident II is best suited to attacking grouped targets. The yearly operations and support cost is lower for Minuteman III, but when examined on a per warhead basis, it is similar between the two systems. When examining costs to get to 2050 Minuteman III is less costly both in terms of total cost and per warhead cost.

Table 6: Summary of comparison between Minuteman III and Trident II

	Availability	**Reaction Time**	**Target Coverage**	**Payload**	**Survivability**	**Cost**
MM III	>90%	Launch within minutes, ~30 minutes to target	Constantly hold 405-450 targets groups at risk	1 to 3 warheads	Large number of dispersed, hardened silos	$1.3B/ year $97B to 2050
D-5	65% on patrol 30% on alert	Launch within minutes, 15-30 minutes to target	Can hold any target at risk. Constantly holding 86-96 target groups at risk	Currently ~ 4 warheads	Stealth and vast ocean area	$3.0B/ year $279B to 2050
Conc.	MM III provides 405-450 missiles on hard alert, D-5 provides 86-96 missiles on hard alert and an additional 86-120 on patrol	Both systems have comparable time from receipt of order to target	D-5 offers global coverage, MM III provides near global coverage of dispersed targets	MM III provides single strike, D-5 provides for greater MIRV capability	The systems have different vulnerabilities	Year to year warhead cost is similar. MM III less costly to 2050

Also of importance, it has been shown that the two systems complement one another. Because of differences in the basing mode, development, and the concept of operations in each system, they are independent of one another, and thus each system hedges against the vulnerability of the other. The two systems together thus provide the U.S. with a stronger deterrent than it could have by relying solely on only one system.

Due to the conclusions drawn above, pending decisions regarding the force structure of the U.S. should not be driven by the technical performance of either the ICBM or SLBM system as they are similar, but should be primarily driven by the following items: the risks associated with each system's survivability mode and how force levels affect this risk, budget constraints, the required mission options vs. the mission options provided by each system and the combined systems, and deterrence requirements to both deter the adversaries of the U.S. and assure the allies of the U.S.

It has been shown that START follow-on goals can be met with no impact to existing force levels by downloading warheads only, provided that the new treaty counting rules are revised to better reflect actual force levels. While force reduction also provides a path to reach the START follow-on goals, reductions in force levels can increase risks in the ability to sustain a force that meets the deterrence requirements of the U.S. These potential risks along with the inherent strategic stability of single warhead missiles[60] should be weighed for any potential force reductions.

[60] Thomas Powers, "Call it Suigenocide," *The New York Times, Sunday Book Review,* September 13, 1981.