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OPTIONS FOR RETIRED ICBM BOOSTER SYSTEMS BEYOND COMMERCIAL APPLICATIONS

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Summary

The options for post-retirement uses of intercontinental ballistic missiles (ICBMs) are controlled by Title 51, Section 50134, of the U.S. Code. This policy prohibits the transfer of ICBM systems to private industry for commercial space launch purposes. Advocates for change would like to create a low-cost launch service provider whereas opponents to changing the policy argue this would unbalance the commercial launch market and stifle innovation from emerging companies. While much of the debate has centered around these key points, not enough consideration has been made for other applications of ICBM systems after they are retired. This paper presents strategic options other than commercial space launch that would be advantageous to the U.S. government and the overall space industry. For the purposes of this paper, "ICBM" is defined as all components of the system excluding the warhead.

Introduction

The use of ICBM booster systems[a] in the commercial marketplace has been intensely debated for decades; unfortunately, this debate has not fully considered other uses for these systems once they are retired. The fiscal year 2018 (FY18) National Defense Authorization Act (NDAA) requires the Secretary of Defense to "provide a briefing to the congressional defense committees on the range of options and recommendations for modification of the existing policy on the usage of ICBM motors for commercial sales that would support the domestic industrial base."[b,1] Before change options to policy can be presented, the full suite of opportunities for ICBM booster systems must be explored. Injecting a commercial payload into orbit is one of many potential applications for vehicles with such tremendous capabilities. This may be the most intuitive application, but advocates and opponents for policy change should at least expand the scope of their conversations to include other, corollary uses that would not adversely impact the commercial market. These uses range from non-lift applications to technology demonstrators, some of

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[a]For the purposes of this paper, a "booster system" is considered as the casing, propellant, motor, flight controls, software, and any other subsystem required for each stage of ICBM flight operations.
[b]The term "motor" in the NDAA is interpreted as equivalent to, or a subset of, this paper's use of the term "booster system."

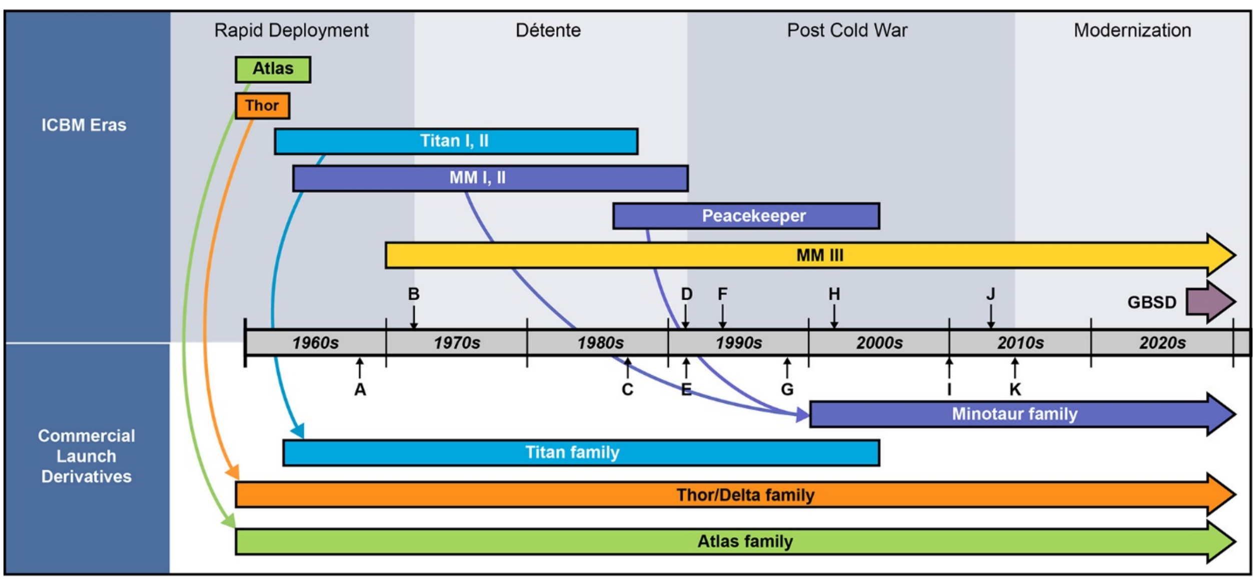
which do not even require a policy change for approval.

Although this paper does briefly acknowledge the respective concerns regarding ICBMs within commercial applications, it is intended to highlight a wider set of alternatives for post-retirement uses to support long-term, strategic planning.

Background

The Debate

As shown in Figure 1, ICBM booster systems have been transferred to the commercial space launch industry, oftentimes even before retirement from military service. During the 1950s and 1960s, the intertwined development of ICBMs and space launch vehicles was widely regarded as a mutually beneficial success. Later, when Cold War tensions eased during arms reductions in the 1970s and, then, when the collapse of the Soviet Union occurred in 1991, many argued that ICBMs should be repurposed for commercial applications. The success of such an idea was proven through the conversions of the Atlas, Delta (formerly Thor), and Titan systems. Opponents to commercial repurposing claimed that saturating the commercial market with government-supplied systems had unfairly suppressed new providers and any proposed innovation. The surges in this debate naturally corresponded to the retirement of ICBM and submarine-launched ballistic missile (SLBM) systems over the years (Polaris and Poseidon in the 1990s, Peacekeeper (PK) in the early 2000s). After the retirement of the space shuttle, NASA emphasized the importance of the commercial sector for its space launch needs, which led to emergent companies disrupting the status quo with new models for business. Along with the debate between the established and emergent companies,[2,3] the Air Force released a Request for Information (RFI) in August 2016 regarding the use of excess ICBM motors for commercial space launches.[4] During a Washington Space Business Roundtable luncheon in January 2018, Secretary of the Air



Milestone Legend

A – Treaty on the Non-Proliferation of Nuclear Weapons (NPT) signed (1968)
B – Strategic Arms Limitation Treaty I (SALT I) signed (1972)
C – Missile Technology Control Regime (MTCR) established (1987)
D – Strategic Arms Reduction Treaty (START) signed (1991)
E – Soviet Union collapses (1991)
F – 1994 National Space Transportation Policy released (1994)
G – Commercial Space Act of 1998 released (1998)
H – Strategic Offensive Reductions Treaty (SORT) signed (2002)
I – New Strategic Arms Limitation Treaty (New START) signed (2010)
J – 2013 National Space Transportation Policy released (2013)
K – Ground Based Strategic Deterrent Request for Information released (2015)

Figure 1: Timeline showing ICBM systems in their respective eras and their commercial launch derivatives.

Force Heather Wilson commented that the Air Force did not intend to change the current policy prohibiting their conversion for commercial use,[5] and an inquiry with a member of her staff in September 2018 confirmed that stance.[6] Nonetheless, the debate will undoubtedly rise again and the strategic options should at least be considered today. The Air Force is modernizing its ICBM fleet to the Ground Based Strategic Deterrent (GBSD) system, which will replace its aging three-stage Minuteman III (MMIII) vehicle. With the deployment of GBSD, several hundred of the MMIII's stage 1, 2, and 3 booster systems will be phased out of military service beginning in the late 2020s.[7] Commercial space launch market forecasts do not typically extend this far in the future;[c,8] however, history should be expected to repeat itself when the MMIII booster systems are retired. Payload operators, whether from the government or commercial sectors, will pressure the Air Force to allow the booster systems to be converted into a low-cost space launch system. Launch service providers will point to a track record of innovation and success with their homegrown systems that would be jeopardized if the Air Force enabled a market disruptor. Understanding and balancing the interests of both launch service providers and payload operators is critical in developing alternative uses for ICBM booster systems.

Legislation

The prohibition of ICBMs in the commercial space launch sector began with the 1994 National Space Transportation Policy and was further codified by the Commercial Space Act of 1998. Today, the policy is stated in Title 51 of the U.S. Code, "National and Commercial Space Programs," and specifically Section 50134, "Use of excess intercontinental ballistic missiles." The statute says that the federal government shall not convert or transfer ownership of any excess former ICBMs into a space transportation vehicle configuration, unless (1) it can certify that doing so would result in cost savings to the government compared to commercial providers, (2) all mission requirements could be met, (3) international obligations are upheld, and (4) the Secretary of Defense (or a designee) approves.[9] This policy was reiterated in the 2013 National Space Transportation Policy.[10] The international obligations referred to are the Missile Technology Control Regime (MTCR), the Treaty on the Non-Proliferation of Nuclear Weapons, the New Strategic Arms Reduction Treaty (New START), and the Intermediate Nuclear Forces Treaty, as shown in Figure 2. In each of these partnerships, the essential goals are the stabilization of the geopolitical environment and the non-proliferation of technology that could be used to create and deliver nuclear weapons.

Overall, the policy dictates that excess ICBMs could be retained only for government use or must be destroyed. This paper is not intended to make an argument for or against any policy changes, but is merely intended to present alternative applications that could inform the options for change.

Trade Space Exploration

The law prohibits using ICBM booster systems for commercial launches but *does* allow using them for government missions under specific criteria. Many of the launch vehicles within the Minotaur series offered by Northrop Grumman—Innovation Systems (formerly Orbital ATK) use government-furnished PK and Minuteman II (MMII) booster systems converted to space launch purposes, and have shown a 100 percent success rate through 26 orbital or suborbital launches as of August 2017.[11] These vehicles are restricted to government missions,[12] and although they were originally designed for the ICBM mission, the success rate verifies their versatility. In the upcoming years, that

[c]The Federal Aviation Administration's Annual Compendium of Commercial Space Transportation: 2018 does not extend its market forecast beyond 2027. It does show a launch demand forecast in the mid-2020s higher than experienced in the mid-2010s, but with a peak in the 2018–2020 time frame. GBSD begins deployment in the late-2020s, but the Air Force has not released a projected completion date. The Air Force would not likely declare MMIII end of service until after that completion date; hence, it is a better indication of when the MMIII booster systems would potentially be available for conversion.

Figure 2: Clockwise from top left: (1) Signing of the Treaty on the Non-Proliferation of Nuclear Weapons, (2) Signing of the Intermediate Nuclear Forces treaty, (3) 2017 Plenary Meeting of the Missile Technology Control Regime, and (4) Signing of the New START treaty. (Photos courtesy of [1] U.S. Department of State, Office of the Historian; [2] Ronald Reagan Presidential Library and Museum; [3] Ireland Department of Foreign Affairs and Trade; and [4] U.S. Department of State, AP Image)

versatility within ICBM-derived launch vehicles will be required to support all opportunities within the trade space. Some of these opportunities are within the full scope of the law:

- Government satellite launches
- Reentry technological demonstrators
- Ballistic missile defense targets
- Propellant recycling

However, if the policy were expanded to allow payloads that clearly support national interests but may not directly support government missions, then other opportunities emerge:

- Industry internal research and development (IRAD)
- Academic research
- Science, technology, engineering, and mathematics (STEM) education

Not included above are opportunities that do not require the ICBM to be converted to a space transportation vehicle but could require a transfer of ownership. Examples of these opportunities are:

- Support equipment checkout
- Process verification and training
- Public display

Alone, these opportunities could not likely consume the entirety of the 186 PK booster systems and 537 MMII booster systems in possession by the Air Force's Space and Missile Systems Center,[13] nor the 400 deployed MMIII booster systems that will be inherited by the Air Force's Global Strike Command as GBSD is deployed.[14] Plus, the cost of each opportunity will influence its attractiveness and affordability to the government. These opportunities are not presented from a position of advocacy, but merely for exploring the trade space. For the purposes of this paper, the cost of using ICBM booster systems is assumed to be acceptable to the federal government.

Government Satellite Launches

Launching government satellites and placing them on orbit is the purpose of the Minotaur I and Minotaur IV vehicles. These launches support the Department of Defense, NASA, and the Intelligence Community and use converted ICBM booster systems to launch payloads up to 1,270 lbs. and 3,520 lbs. to low Earth orbit, respectively.[15] Some perceive this model as giving an unfair advantage to the Minotaur supplier, which is one of three companies on the Air Force's Orbital/Suborbital Program-3 (OSP-3) contract. The expiration of the OSP-3 contract in November 2019[16] and the pending retirement of MMIII booster systems may be an opportunity to refresh the acquisition strategy to reflect a more equitable model. Protecting ICBM components from security and non-proliferation risks is of vital importance, but lessons from the Minotaur model could be expanded upon to enable more market entrants that otherwise could not afford significant upfront capital expenses. This expansion would inevitably lead to innovations that maximize the efficiency of launching assets into space, some as simple as standardizing the size constraints of small satellites.[17] If these innovations could be separated from the ICBM-derived launch vehicles, then they could be spun off into the industry without any further need for government sponsorship.

Reentry Technology Demonstrators

In February 2018, the Air Force released an RFI related to the Mk-21A Reentry Vehicle Program Technology Maturation and Risk Reduction.[18] The Mk-21A carries a nuclear warhead and is intended for deployment on the GBSD weapon system under a similar concept of operations as every other ICBM system. With GBSD deployment not projected to begin until the late 2020s, the Mk-21A reentry vehicle will need another booster system for its own test and evaluation. Using MMIII stages as a demonstrator booster system not only provides a very similar environment, but it also provides a hedge in case GBSD is delayed. The reentry trajectory could also aid hypersonics research, given the aerothermal environments that are generated. This area has burgeoned over the past few years and continued growth should be expected.

Beyond military applications, other suborbital or reentry experiments could benefit as well. The emerging space tourism industry will hopefully introduce new, enhanced safety features that increase mission assurance. Mars missions, despite becoming seemingly routine, are as complex as ever, particularly during descent and landing. ICBM booster systems provide a means to increase the number of tests available to these programs with greater operational realism versus simulators or ground tests.

Ballistic Missile Defense Targets

Aside from reporting on the use of surplus ICBM motors, the FY18 NDAA also requires the Director of the Missile Defense Agency (MDA) to submit a report that "assesses the options for acquisition strategies that could lead to more affordable, threat-representative, and reliable targets."[19] The MDA's ground-based midcourse defense requires targets replicative of adversarial ICBM systems for their kinetic interceptor tests. Historically, these tests have exceeded $200 million each.[20] The targets alone were $30–40 million for two tests in 2013.[21] From 2000 to 2016, the MDA consumed a total of 173 targets (including non-ICBM types),[22] and the FY18 NDAA predicts an increasing pace of intercept tests. These tests, of course, have high costs—partially because they require two missile systems to be built: the interceptor and the target. Since the target is an ICBM system, using retired ICBM booster systems seems a logical fit, and the Minotaur II variants flown from 2000–2008 were just that. However, target systems are not developed with the same set of requirements as fielded systems, and thus the cost to develop and manufacture a new system from scratch may be less than the cost to retrofit and repurpose an ICBM booster system. From a technical perspective, the goal of the interceptor is to shoot down ICBMs fielded by our adversaries, which operate differently from U.S. systems. Whether these differences are subtle or substantial depends on the case scenario of each individual test. Nonetheless, just as expanding the Minotaur model should be reconsidered for government satellite launches, it should also be reconsidered for ballistic missile targets.

Propellant Recycling

Ammonium perchlorate is a key ingredient in solid rocket fuel, yet only one domestic provider exists. This issue is the rationale for the FY18 NDAA requirement for the Secretary of Defense to assess the cost of utilizing a new supplier and conducting a business case analysis for the options to ensure a robust domestic industrial base.[23] However, ammonium perchlorate can be reclaimed for future use, as demonstrated through the United Launch Alliance Delta IV GEM-60 motor. Even if no alternative uses were employed for other booster components, the propellant within the MMII, PK, and MMIII booster systems could be reclaimed, re-casted, and repurposed for government or commercial use. This recycling process neither converts the ICBM into a space transportation vehicle nor requires a transfer of ownership and, thus, is not subject to the same legal and regulatory constraints.

Industry IRAD

Because state-of-the-art technology is often developed using IRAD funds rather than through government-sponsored work, supplying industry with retired ICBM booster systems purely for IRAD would enable them to flourish with new ideas and innovations. The notion of a profit-driven marketplace encouraging the industry to innovate is an underlying reason for the push to commercialize the space launch sector. Under appropriate clauses and conditions, private companies could be provided with ICBM booster systems for research purposes in a manner of their choosing. In this case, the government would likely have to transfer ownership, but could still apply oversight on the grounds of treaty compliance. Challenges to this use would determine a manner of fairly and equitably distributing the booster systems among the industry and the required change in policy, if a private company sought to convert the booster system to a space transportation system. But, because the ultimate consumer of IRAD is the government, justifying the use of ICBM boosters for these launches may not be as controversial as compared to commercial satellite launches.

Academic Research

Universities have also had a key role in advancing the state of the art, but typically tackle the basic research challenges involving much less mature technologies. University projects, though, do not receive nearly the amount of funding as projects funded through a private company's IRAD budget. Government-sponsored programs, such as NASA's CubeSat Launch Initiative, help these small-budget programs and can be expanded upon by allowing access to retired ICBM booster systems. The nature of basic research, however, is that a return on investment can be years or decades in the future. In fact, many research projects end with a conclusion that certain ideas are not feasible. This type of lesson can be very valuable but is difficult to assign a dollar figure. Therefore, using retired ICBM booster systems for academic research would require a change in policy because it would require a conversion to a space transportation system that would not result in cost savings to the government. Although Title 51 does pertain to commercial space programs, the intent is interpreted to include all forms of use for ICBM vehicles.

STEM Education

Conducting basic research is just a secondary benefit from partnering with academia. The nation's need for STEM professionals requires educational opportunities at every grade level. In recognition of this need, the previously mentioned CubeSat Launch Initiative program from NASA has launched projects all the way down to the elementary school level.[24] At that level, the scientific value is undoubtedly trumped by educational value, but this use still supports national interests and justifies it as a very worthy endeavor. These types of educational launches have occurred on probably every class of launch vehicle, including ICBM derivatives. The first launch of the Minotaur family hosted the Joint Air Force—Weber State University Satellite (JAWSAT)—shown in Figure 3. This was a multi-payload adaptor that included projects from Stanford University and Arizona State University.[25] University projects are often chosen for launches that are seemingly higher risk, but more opportunities could be created by allowing access to retired ICBM booster systems under the appropriate oversight.

Support Equipment Checkout

With many heavy and super heavy launch vehicles in a design and development phase,[d] ICBM booster systems could be repurposed for applications as simple as checkout of support equipment. Although this application may not have a high demand, it would be a non-lift application and, therefore, would not require conversion to a space transportation vehicle.

Early prototypes and engineering models typically have higher costs compared to assets coming off a production line, and the livelihood of many companies depends on their effective use. For example, an oversight as simple as an undersized fastener or a miscalibrated thermocouple could lead to the loss of a prototype without any information gained. ICBM booster systems are uniquely able to replicate the loads and environments these vehicles will experience, thereby providing a cost-effective way to validate many types of support equipment such as test stands, handling equipment, or

Figure 3: The JAWSAT multi-payload adaptor integrated into the Minotaur I vehicle. (Photo courtesy of L'Garde and eoPortal Directory)

[d]Examples include Blue Origin's New Glenn, Orbital-ATK's Omega, SpaceX's Falcon Heavy, SpaceX's BFR, ULA's Vulcan, and NASA's Space Launch System.

instrumentation. The booster systems could even be ignited to evaluate items such as launch pad gantry configurations, static fire test-stand structural worthiness, or advanced-sensor checkout. Allowing private industry to use retired ICBM booster systems as substitutes for the new, costly vehicle prototypes would require either a transfer of ownership or supplying them as consumable government-furnished equipment (GFE), just as in the case of a satellite launch provider.

Process Verification and Training

Ensuring human error is mitigated as much as possible means verifying processes are correctly documented and maintainers, operators, logisticians, and all other personnel understand how they should be followed. This task is just as critical as ensuring the equipment is satisfactory. Transportation and handling methods, emergency operations procedures, and refurbishment best practices could all be rehearsed on retired, inert ICBM booster systems prior to applying them on new prototype vehicles.[e] Although the retired systems will be in different configurations from the new models, the relationship is analogous to having a newly hired trainee practice engine work on a rusted junkyard heap well before a customer drives in with an expensive sports car needing a tune-up. Again, either transferring ownership or supplying the booster systems as GFE would be required, as would security and non-proliferation protocols.

Public Display

Perhaps the simplest application for retired ICBM systems is to put them on display at museums and parks around the nation, as demonstrated in Figure 4. Even though other military systems are frequent items of display, the public seems to have mixed receptiveness to nuclear weapons due to the magnitude of lethality. Although showcasing safe and inert ICBM booster systems does not generate economic gain, the cultural value is inarguable. For those opposed to the country's possession of nuclear weapons, the displays would serve as a centerpiece for dialogue in line with other war memorials. Some ICBM booster systems already exist in museums today, and this option would merely be an extrapolation of that concept.

Non-Practical Applications

For the sake of completeness, other applications were briefly considered before being deemed non-practical. For example, scavenging the retired booster systems for salvage, either as a whole or for components, would likely require a considerable amount of effort and would only recoup antiquated technology. Also, transferring ownership to partner nations, even those under the U.S. nuclear umbrella or within the Missile Technology Control Regime (MTCR), would pose unacceptable risks to geopolitical stability and non-proliferation efforts. Finally, retaining the booster systems indefinitely as a latent hedge in a configuration that complies with

Figure 4: From left to right, the Peacekeeper, Minuteman III, and Minuteman I ICBMs on display at the entrance to F.E. Warren Air Force Base. (Photo courtesy of F.E. Warren Air Force Base)

[e]The cost and difficulty associated with rendering an ICBM inert is dependent on technical specifications, which is outside the scope of this paper.

New START limitations should not be considered because of the potential ramifications to future arms limitations agreements, cost of storage, cost to prevent degradation, and lack of usefulness given the successor system has been or will have been deployed.

Future Study

In order to respond to the previously mentioned congressional request to brief on ICBM booster systems' post-retirement options, the Secretary of Defense should consider requesting an additional study to follow up on an August 2017 report from the Government Accountability Office (GAO) on the breakeven cost to transfer ICBM-related assets to industry. This report estimated the cost of storing, testing, refurbishing, and disposing surplus MMII and PK motors and calculated a breakeven price for which they could be sold to the industry. The report acknowledged that the calculated breakeven price was based on a specific model of transferring the booster systems to the private sector and would fluctuate if the model changed. The Secretary of Defense should consider requesting a study that expands upon the GAO report with the following objectives:

- Present the breakeven prices for the PK and MMII booster systems under the range of cost assumptions used rather than the average.[f]
- Include consideration for the projected breakeven price for the MMIII booster system.
- Present alternative models for transferring the booster systems to the private sector and, if possible, the associated breakeven costs.
- Calculate the cost of repurposing the booster systems into each of the alternative options presented in this paper, either by individual stages or by sets of stages.
- Estimate a fair market value for each of the options presented in this paper which would be affordable and acceptable to recipients of the booster systems.
- Assess the net gain or loss for the government if the cost of transferring the booster systems is not equal to the estimated fair market value.
- Recommend a distribution plan for the 186 PK, 537 MMII, and 400 MMIII booster systems, taking into consideration the options presented in this paper.
- Calculate the total net loss or gain for the government once all booster systems have been distributed and assess that amount against any non-tangible benefits.
- Provide a range of options and recommendations to modify the existing policy on the usage of ICBM booster systems for commercial sales that would support the domestic industrial base, in support of the FY18 NDAA requirement levied upon the Secretary of Defense.

Participants in this study should include those with experience in ICBM sustainment, commercial launch services, payload operator needs, cost estimation, and strategic planning. Because specifics regarding the capabilities and performance of ICBMs may be required, the study should be conducted at the appropriate security classification level.

[f]The GAO report concludes that the cost of a PK-derived launch system would be $46M and the cost of a MMII-derived launch system would be $40M based on assumptions received from the Air Force's Rocket Systems Launch Program. However, the report also discloses that one of the respondents to the Air Force's August 2016 RFI suggested a sale price much lower than the GAO's calculated breakeven price. This suggested sale price would reduce the cost of a PK-derived launch system to $12.5M. The validity of either assumption is unknown, but the range between the two estimates warrants follow-up analyses.

Conclusion

The fate of retired ICBM booster systems has been and will continue to be debated. The discussion, however, should not be limited to considering commercial space launch as the only viable use. This paper presents alternate options, some of which do not require changes to current policy. The goal for presenting these options is to fully explore the trade space such that retired ICBM booster systems can be distributed via a long-term, enterprise plan. This plan must promote national interests in a manner that balances security with economics for both the public and private sectors.

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