SRM Industrial Capabilities Report

to

Congress

Redacted Version

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Office of Under Secretary of Defense
Acquisition, Technology & Logistics
Industrial Policy

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Executive Summary

Solid rocket motors (SRMs) have been important to the Department of Defense (DoD) and other government agencies for many years. SRMs are required for space launch vehicles and DoD strategic missile, missile defense, and tactical missile systems. Maintaining these systems through their operational lives and sustaining the industrial base that supports these systems is essential to meeting national security objectives.

Recent decisions to significantly extend the operational lives of the Minuteman III (MM III) and the Trident II D-5 strategic missile systems prompted Congress to request the Department provide an overall assessment of the SRM industrial base and also evaluate the ability of the industrial base to sustain those strategic systems through their operational lives. The results to the Department's assessment are summarized below.

SRM Industrial Capabilities Assessment

- The SRM industrial base – both prime and subtier suppliers – is capable of meeting most technological and production requirements.

- Continuous production is likely to address immediate D-5 and MM III industrial concerns.

- The production demand for SRMs is declining:

    - The production demand for large SRMs (space launch, strategic missiles, and some missile defense programs) is significantly lower than historic levels primarily due to the completion of the NASA shuttle program, lower strategic requirements, the completion of the MM III Propulsion Replacement Program (PRP) and the expectation of a commercial space launch market that never materialized.
    - The demand for missile defense programs is declining roughly 30 percent over the FYDP.
    - The limited commercial space launch business has strong competition from foreign suppliers.

- Inadequate investments are being made in large and small SRM research and development, reducing the reliability and cost effectiveness of the SRM industrial base. If there are no new development programs, the SRM industry will continue to lose its capability to be able to design and produce new generation SRMs.

- The lack of meaningful production orders and limited development efforts for the next decade is not conducive to the long term well-being of the industry. The SRM industry needs deliberate government research and development (R&D) and production investments with corporate entities willing to invest in internal independent research and development (IRAD) to ensure the continued viability of the industrial base for the Department's current and future systems.

- The tactical and missile defense business segments, which generally use smaller SRMs, are positioned better to maintain their industrial capabilities in the near-term than the strategic and space launch business segments, which generally use large SRMs, because smaller SRMs are supported by multiple programs with more overall funding certainty than larger SRM programs.

- The limited competitive opportunities for SRM activities will make it hard for prime contractors to attract and retain a skilled engineering and manufacturing workforce which in turn will make it difficult to retain the design and engineering expertise necessary to develop and produce our next generation large and small SRMs.

- Delays in the NASA Ares program could have significant negative impact on the large SRM prime contractor industrial base and more significantly on the subtier supplier base, specifically material suppliers.

- While there has been consolidation at the prime contractor level, the low projected demand for large SRMs may result in further consolidation in the industrial base in the form of possibly reducing the number of primes from two to one, or ATK may have to consider rationalizing its large SRM facilities at Promontory and Bacchus to one for more efficient operations. Where possible, government should coordinate its SRM activities to develop strategies that maintain competition.

- For Aerojet and subtier companies, liquid and non-rocket businesses help to keep SRM engineers engaged and absorb overhead costs.

- Foreign military sales (FMS) have had a positive impact on small SRM workload in the industry due to requests for tactical and missile defense weapon systems. However, FMS orders are not predictable and should not be expected to sustain the SRM industrial capabilities.

- Adherence to government environmental regulation, both domestic and foreign, has an adverse impact on the viability of the supplier base.

Ability to Sustain Strategic Systems Through Operational Lives

Minuteman III

- Given an adequate level of operations and support through FY 2030, there are no technical reasons why Minuteman III SRMs could not be maintained at current capabilities through FY 2030. The Air Force aging and surveillance program will not have sufficient data to assess the design and manufacturing changes made during the PRP program and establish new service life expectancy until 2014/2015.

- The Air Force approach is the lower cost for the government but higher risk approach for the industrial base and is dependent on the stability of other programs, such as the Trident D-5, to maintain the large SRM industrial base.

Trident II D-5

- The Navy approach for sustaining the operational life of the D-5 missile is to continue production at a minimal level. The benefits of this approach are:

  - Provides stability in the strategic industrial base
  - Enables future systems development and production capabilities
  - Addresses many of the concerns/issues in the Congressional tasking

- The Navy continuous production approach does not adequately address maintaining the design and development skills required for developing our next generation strategic systems.

- For the D-5, continuous rocket motor production is the most affordable, lowest cost and least risk option for sustaining the sub-launched strategic deterrent through 2042. The Navy is committed to continuing rocket motor production in order to support D-5 deployment through 2042. The current inventory of D-5 rocket motors is insufficient to support a service life of 30 years. This approach still leaves a gap in development skills which degrade over time.

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Introduction

The Department of Defense is providing this report to the congressional defense committees as directed in section 1050 of the National Defense Authorization Act for Fiscal Year 2008, Public Law 110-181, dated January 28, 2008. Section 1050 reads as follows:

“SEC. 1050. REPORT ON SOLID ROCKET MOTOR INDUSTRIAL BASE.

(a) Report.—Not later than 190 days after the date of the enactment of this Act, the Secretary of Defense shall submit to the congressional defense committees a report on the status, capability, viability, and capacity of the solid rocket motor industrial base in the United States.

(b). Content.—The report required under subsection (a) shall include the following:

(1) An assessment of the ability to maintain the Minuteman III intercontinental ballistic missile through its planned operational life.

(2) An assessment of the ability to maintain the Trident II D-5 submarine launched ballistic missile through its planned operational life.

(3) An assessment of the ability to maintain all other space launch, missile defense, and other vehicles with solid rocket motors, through their planned operational lifetimes.

(4) An assessment of the ability to support projected future requirements for vehicles with solid rocket motors to support space launch, missile defense, or any range of ballistic missiles determined to be necessary to meet defense needs or other requirements of the United States Government.

(5) An assessment of the required materials, the supplier base, the production facilities, and the production workforce needed to ensure that current and future requirements could be met.

(6) An assessment of the adequacy of the current and projected industrial base support programs to support the full range of projected future requirements identified in paragraph (4).”

The Department addresses the requirements of this congressionally mandated report with two assessments. The first assessment is an industrial capabilities assessment of the solid rocket motor (SRM) sector, which addresses items 3 – 6 from the congressional report language above. The assessment addresses the Department’s ability to maintain current and future programs with SRMs through their operational lives. The industrial capabilities assessment focuses on three areas:

- The SRM market demand review identifies the Department, other government agencies, and commercial requirements for SRMs
- The SRM prime contractor review evaluates production and engineering capabilities. “Production” includes prime contractor facilities, manufacturing processes, and workforce skills. “Engineering” includes the

ability to maintain design engineering capabilities (both at the primes contractors, subtier suppliers, and science and technology (S&T) level).

- The subtier suppliers assessment determined the ability of the subtier base to develop and produce the products/components/materials needed by the primes to design and produce SRMs for today and tomorrow

The second assessment determined the ability of the Department to maintain its strategic systems—the Minuteman III (MM III) and the Trident D-5—through their planned operational lives. The assessment describes the Air Force and Navy approaches to maintaining the Department's strategic systems for long-term operational lives and identifies the risks associated with their approaches (requirements 1 and 2 of the report language).

The information, analysis, and conclusions contained in this report address the SRM industrial base: its impact on the Department's ability to maintain current weapon systems through their operational lives and the ability to meet future national security requirements. The report does not address other missile subsystem areas such as reentry vehicles, guidance and navigation, or warheads.

Assessment #1: Industrial Capabilities Assessment Solid Rocket Motors

SRMs are required for space launch, strategic, missile defense, and tactical missile systems. SRMs are propulsion systems consisting of a casing filled with a mixture of solid compounds which, when ignited, burn at a high rate expelling hot gases from a nozzle to produce thrust. A short introduction on how an SRM works is necessary to help understand the basic principles of SRM design and the complexity and hazards of production. At first glance, the basic principles of SRM design seem simple because individuals can design and build their own model rockets fairly inexpensively. However, at the other extreme, they are so complicated that there are very few countries that have mastered space launch. The production and integration of SRM components for weapon systems and space launch platforms is hazardous, technically challenging and requires complex and unique industrial capabilities to include facilities, manufacturing processes, engineering, and workforce.

Producing SRMs is Hazardous

There are inherent hazards in producing SRMs due to the explosive nature of energetics. In 2003, Pratt & Whitney's Chemical Systems Division (CSD) suffered two separate explosions. The first explosion occurred in August 2003 and destroyed a mixing facility. The second explosion occurred one month later and killed a worker. Pratt & Whitney decided to close the CSD facility which reduced the number of SRM prime contractors from 3 to 2. The CSD workload ended up being split between the remaining two primes, ATK and Aerojet.

Mishaps, while infrequent, appear to be part of the business. ATK suffered a mishap at its Promontory facility in February 2005 that resulted in two injuries; one fatal. Aerojet experienced a mishap in September 2008 at its Camden, AR, facility that also resulted in a fatality.

A 2005 DoD SRM Safety Assessment observed that training, qualifications, and experience are key elements to maintaining safe work conditions. The assessment also noted that large SRM production is significantly declining which affects the ability to maintain minimal sustaining rates at the large SRM production facilities.

The simple part of SRM design is the premise behind Newton's third law of motion, "to every action there is an equal and opposite reaction." A simple diagram of an SRM is shown in Figure 1 below. In SRMs, the propellant is poured into a high pressure vessel or case with special tooling installed inside the chamber to provide the required propellant contour, which most commonly will have a center bore. The motor case acts as the combustion chamber. The igniter, at one end of the case, lights the propellant creating a flame front on the exposed surface of the propellant. The combustion produces exhaust gas at high temperature and pressure. The amount of exhaust gas that is produced is a result of the propellant surface area ignited. SRM designers, by proper use of tooling, create a variety of different shapes in the propellant design to control the required amount of thrust generated.

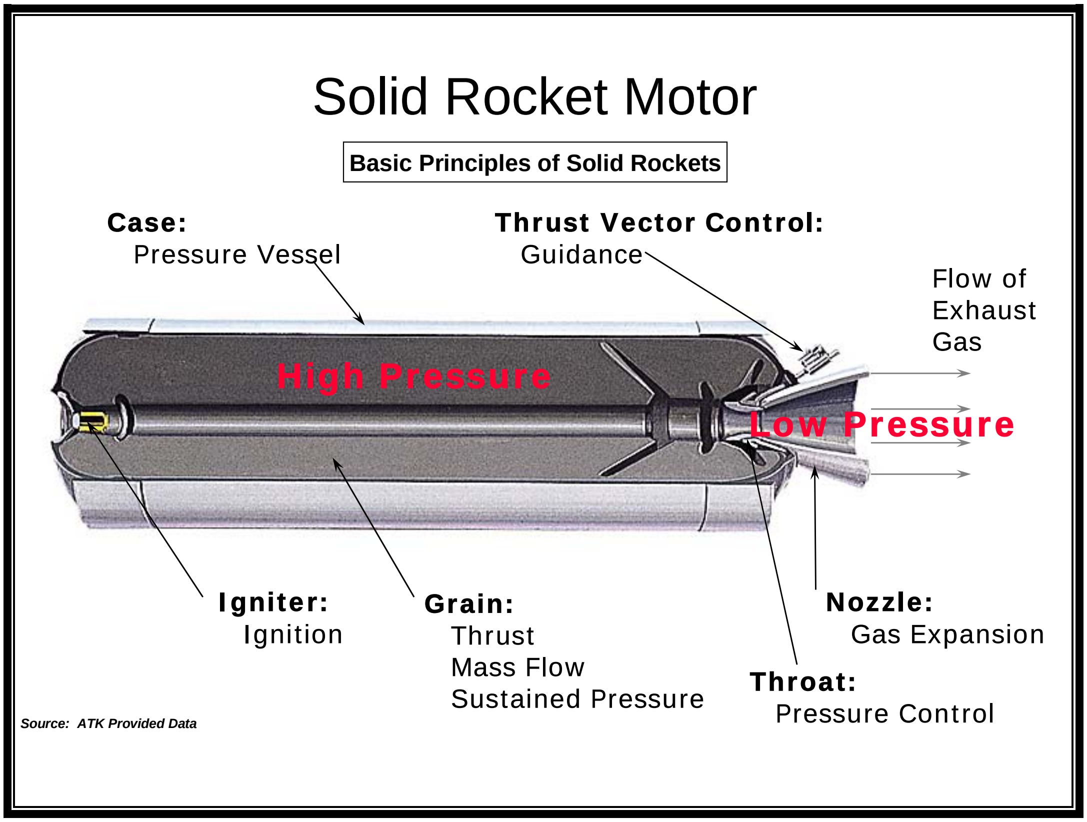


Figure 1

Taxonomy

The taxonomy for the SRM system can be broken down into 5 major areas; propellant, igniter, motor casing, electronics, and the nozzle. Each area can be further defined as depicted in Figure 2 on the following page.

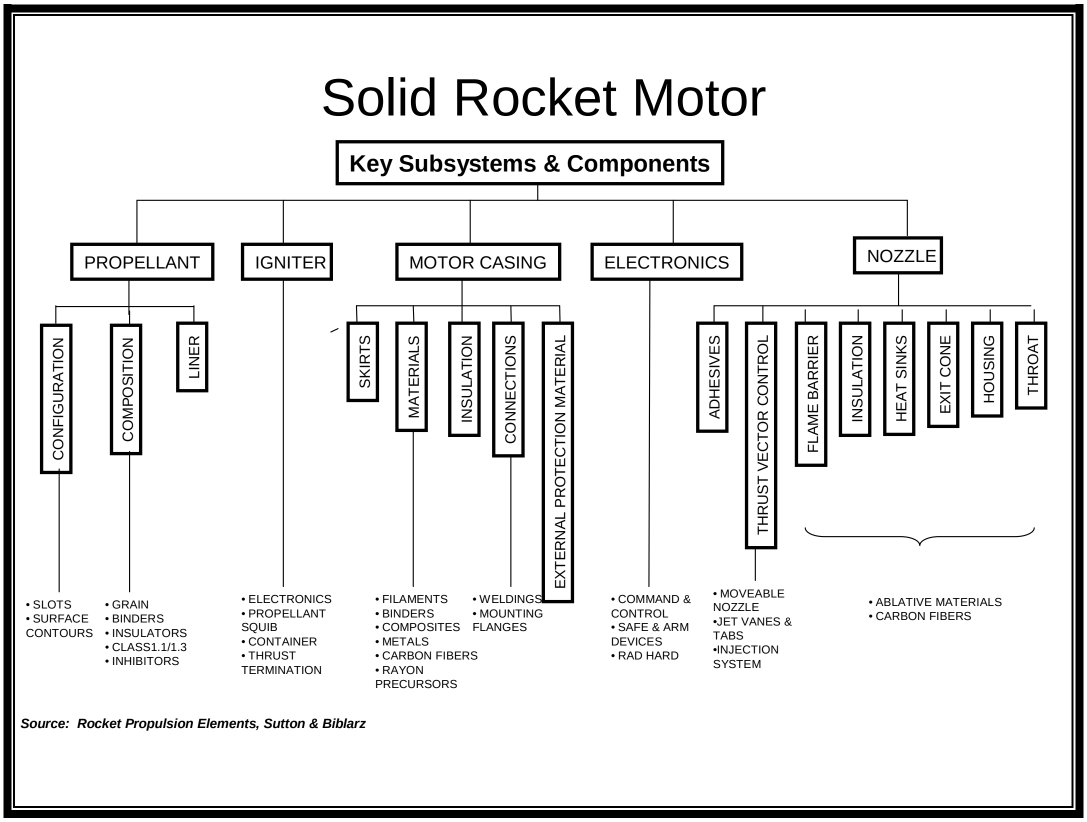


Figure 2

Solid propellant is used in defense missile applications because it is stable at ordinary temperatures and easily storable compared to liquid fuels. SRM propellant comes in two families: homogeneous and composite. Homogeneous propellants are either single base or double base. A single base propellant consists of a single compound, usually nitrocellulose. Double base propellants usually consist of nitrocellulose and nitroglycerine. Composite propellants are physical mixtures of fuel and oxidizer materials held together by a binder system. Typically aluminum powder is used as fuel and a crystallized or finely ground mineral salt such as ammonium perchlorate is used as an oxidizer. The propellant is held together by a polymeric binder, usually polyurethane or polymers (hydroxyl terminated polybutadeine). Depending on the requirements, other compounds may be added to help increase burn rate, or to make the propellant easier to manufacture. The final product is a substance with the consistency of a hard rubber eraser.

The igniter in an SRM provides the means to induce combustion. It consists of a container of material like a metal-oxidizer mixture that is more easily and quickly ignited than the propellant. It is ignited using an electric squib or other externally energized means. The igniter case is designed to be sealed until it is needed to start SRM combustion. Most ignition systems include some kind of “arming” feature that prevents ignition by unintended stimuli.

The SRM casing serves both as the propellant storage tank and the combustion chamber. The casing is usually designed in a manner to protect the casing from overheating with insulation and to promote adhesion between propellant and insulation with liners. The use of insulation prevents the casing from reaching temperatures that endanger its structural integrity. Casings generally are made from metals and composites.

The nozzle is a specially-shaped tube, or duct, that is connected to the combustion chamber of the SRM in which the gases produced in the chamber are accelerated to super sonic velocities, thereby converting the pressure of the exhaust into thrust. Like the combustion chamber, the nozzle gets extremely hot and the materials used to make them must withstand the high temperatures. Recently new materials have become available, including ceramics and composites that can withstand these high temperatures (i.e., there are materials being developed to replace the North American Rayon Corporation (NARC) stockpiled rayon that is the traditional ablative material for large SRMs).

The electronics for SRMs are mostly associated with command and control or thrust vector control components and the safe and arm devices. These components may require radiation hardened (radhard) components for some missile applications, such as strategic systems.

Past SRM Studies

SRMs have been an important industrial sector to the Department of Defense and other government agencies for many years. Maintaining strategic systems through their operational lives and sustaining the industrial base that supports these systems is essential to meeting national security objectives. All SRM users are concerned with the health of this sector. The Department has been closely monitoring and studying SRMs for the last decade to ensure the SRM industrial capabilities remain sufficient to meet our needs. Most of these studies have focused on large SRMs.

In 1994, the Department's Strategic Advisory Group (SAG) initiated several industrial base studies and supported new programs to address various aspects of strategic missile industrial capabilities. Some of those programs included the Guidance Application Program, the Reentry Systems Application Program and the Propulsion Application Program (PAP) to specifically sustain the unique engineering skills needed for strategic systems. In 1996, the Department performed an industrial capabilities assessment for SRMs and determined that DoD, civil, and commercial demand for SRMs should ensure that no industrial capability would be lost through 2005. The assessment did raise concerns with maintaining an adequate engineering and design base.

In 2000, the SRM Interagency Working Group (IWG) analyzed the SRM industry. The IWG determined that the SRM demand appeared likely to be sufficient to sustain at least two SRM prime contractors to meet DoD needs; but the industrial capabilities are not efficiently split. In other words, the SRM demand may not be sufficient to support two primes with equal industrial capabilities to compete for SRM programs across all four business segments – space launch, strategic missiles, tactical missiles, and missile defense. The IWG developed 5 "triggers" that if met would require the SRM industry to be reassessed. These triggers were:

- Changes in the Space Shuttle reusable solid rocket motor (RSRM) production levels,
- Failure to fund the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) program at the current levels,
- Failure to fund PAP critical engineering skill/technology program at the current levels,
- Reduction in the number of SRM producers to less than 3,
- Disruption of the subtier supplier base.

Following the two explosions at Pratt & Whitney's Chemical Systems Division (CSD) in 2003, DoD initiated an additional assessment of the SRM industrial base. The study team determined that some IWG triggers had occurred.

- Since the National Aeronautics and Space Administration (NASA) shuttle Columbia disaster on February 1, 2003, shuttle booster production levels dropped to very low levels.
- The Department funding for the PAP program dropped significantly.
- The number of SRM producers dropped to two after the CSD explosion.
- There had been disruption in the subtier supplier base with some providers operating at minimum sustainable levels, some materials and components having only one qualified source, and the lack of demand forcing some companies out of business.

This study concluded that there was significant overcapacity within the industry with many of the production lines running at minimum utilization rates to maintain equipment operational status and to preserve the intellectual capital of the overall production capability. Any further decrease in demand requirements would require shutting production lines down, retooling/re-machining equipment, or restructuring the entire process to accommodate lower demand levels. The bottom line, "the SRM industry is in decline and in the long run, the SRM industry is not sustainable and supportable at its current funding levels."

In 2006, the Department decided to reassess the SRM industrial base. The earlier 2004 study focused its assessment mostly on large SRMs and did not include the NASA shuttle and NASA's follow-on space launch system, the Ares I and V, in part because NASA had not determined whether the new launch system would use all liquid engines or a combination of liquid and solid similar to the shuttle. By 2006, NASA had decided that the new launch system would use SRMs. The new Ares I platform will have a single booster with 5 segments similar to the 4 segment boosters of the shuttle.

The study team concluded that it was necessary to include the NASA requirements in its industrial capabilities assessment due to the impact NASA demand has on the industry both at the SRM prime and subtier level. Table 1 lists examples that give an indication of the magnitude of NASA's significant influence on the SRM market. For a more complete list, see Appendix C.

COMPARING SPACE SHUTTLE RSRM TO OTHER SRMS		
Missile Program	Pounds of Propellant	Equivalent # of SRMS to Equal One Space Shuttle RSRM
Space Shuttle RSRM	1,106,059	1
Trident II D-5	110,200	10
Minuteman III (MM III)	66,642	17
Ground Missile Defense (GMD)	43,469	25
Kinetic Energy Interceptor (KEI)	20,026	55
Patriot Advanced Capability-3 (PAC-3)	350	3,160
Guided Multiple Launch Rocket System (GMLRS)	216	5,121
Advanced Medium-Range Air-to-Air Missile (AMRAAM)	113	9,788
Hellfire	20	55,303
Javelin	3	368,686

Table 1

The 2006 study team obtained data from NASA with projections for Ares booster segments. The new data indicated that there would not be a significant production gap in producing large SRMs. The study team also identified booster requirements for the Evolved Expendable Launch Vehicle (EELV) program that were not included in the 2004 study. The 2006 study concluded that the production gap and weakness in the SRM market envisioned in 2004 were not as severe as originally thought due to the clearer demand picture from NASA and the EELV. The study team also concluded the tactical market, while smaller, played a key role in sustaining the subtier supplier base.

SRM Industry Trends: 1990 - Present

The solid rocket motor manufacturing output of the United States has been declining for nearly two decades. This trend is reflected in Figure 3 as it shows four programs that utilize large SRMs: the NASA Space Shuttle and Ares program, launch vehicles, the MM III, and the Trident II (D-5).

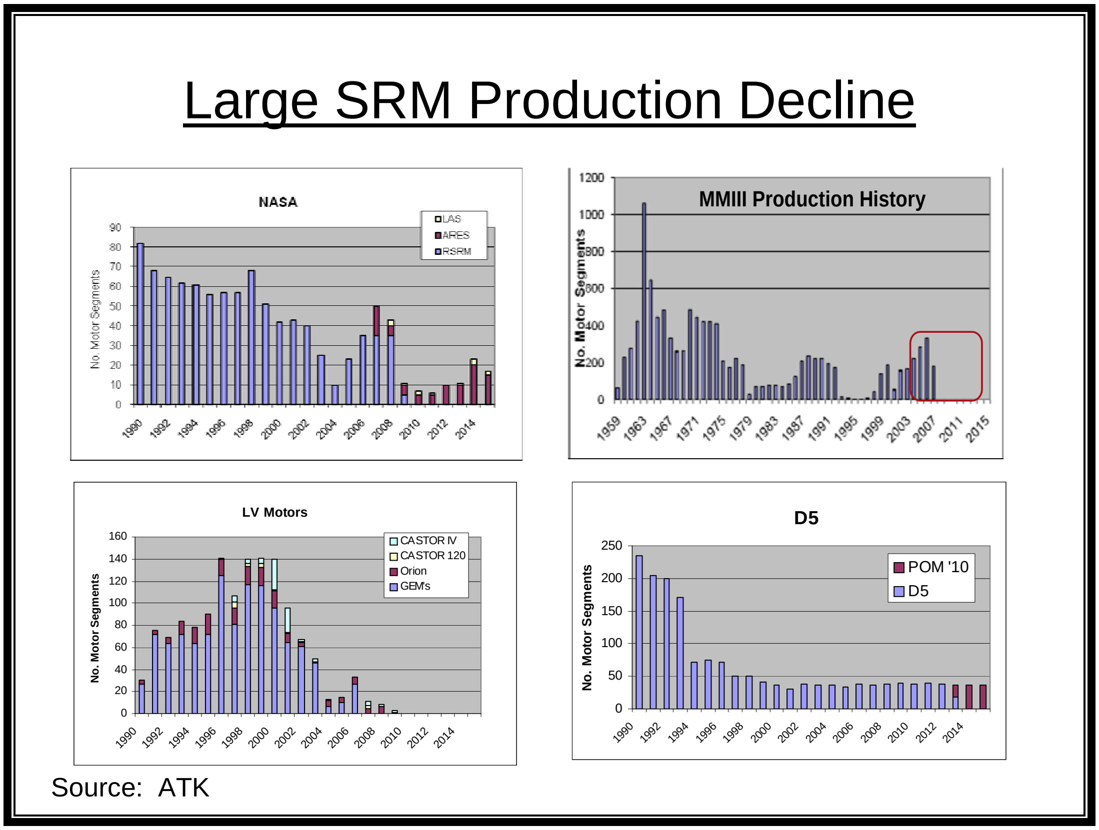


Figure 3

The significant drawdown of defense budgets during the 1990s and the collapse of the demand for commercial launch capabilities during the late 1990s and early 2000s resulted in significant SRM industry consolidation, a "lean" industrial base, and under utilized production facilities. This consolidation—as shown in Figure 4—reduced the number of prime contractors in the SRM industrial sector from five to two (Alliant Techsystems (ATK) and Aerojet). ATK, which was not in the SRM business, acquired Hercules in 1995. The Department of Defense anticipates further decline in demand in the SRM market as many of the large scale current production programs are ending.

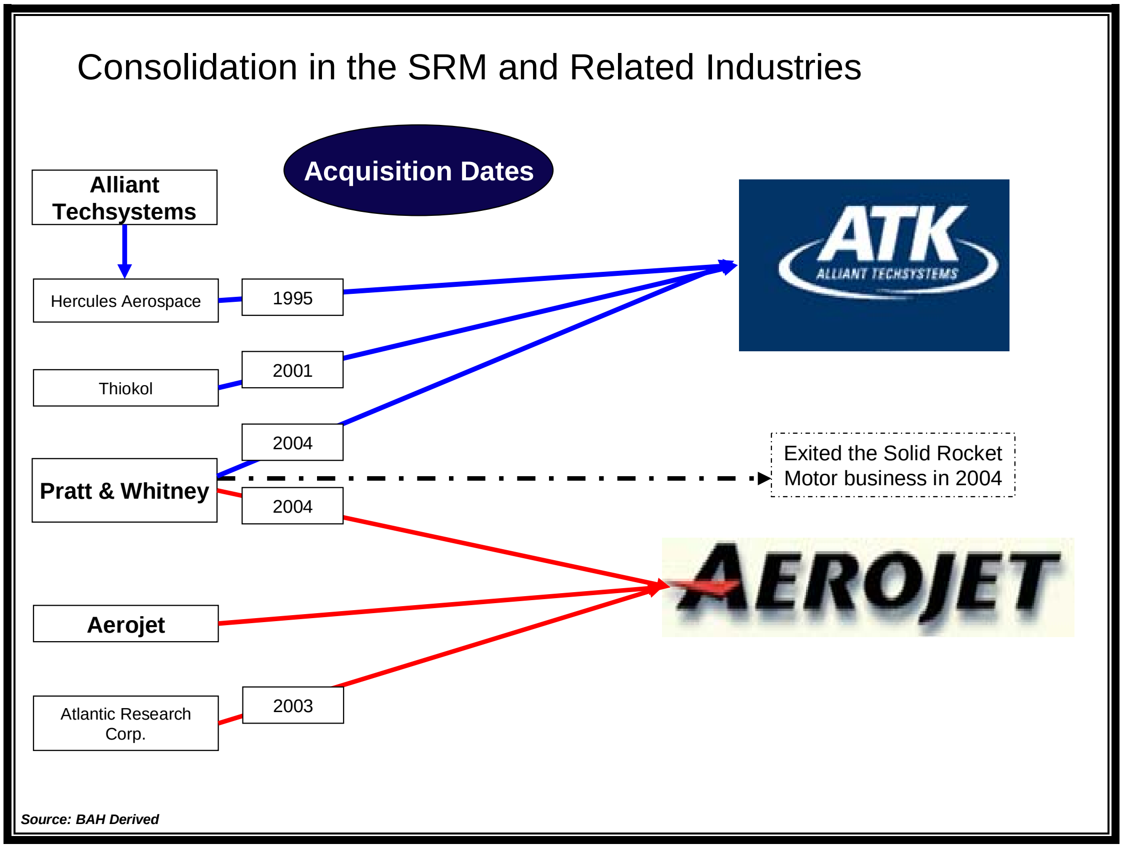


Figure 4

SRM Business Segments

The Department considers the SRM industry to be composed of four business segments: strategic, space launch, missile defense, and tactical as shown in Figure 5 on the following page. For the most part, these business segments fall into two broad industrial capabilities categories: large and small. The diameter of the SRM distinguishes between large and small SRMs. While the chemistry of the SRMs may be similar, size plays a significant role in determining the size of the facilities and equipment and the requisite design and engineering skills. The space launch, strategic and some missile defense business segments include the large SRM boosters – larger than 40 inches in diameter. The space launch upper stages, missile defense, and tactical systems encompass the smaller boosters – 2.75 to 40 inches in diameter.

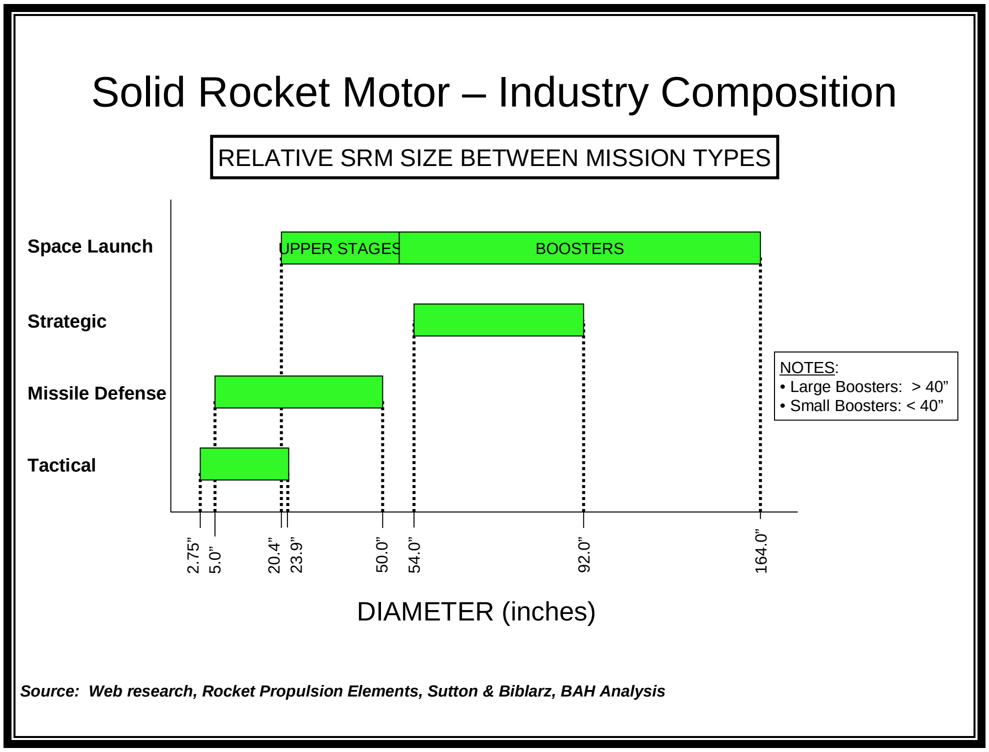


Figure 5

The industry for large and small SRMs exists primarily to serve the needs of government for vital defense, communication and space exploration applications. Defense and space exploration dominate the demand for SRMs. There is a small market for SRMs in commercial space launch. Aerojet and ATK have the industrial capabilities to design and produce both large and small SRMs and provide SRMs for all four business segments.

SRM Demand/Requirements

The demand for SRMs comes from DoD, NASA, foreign military sales (FMS), and space launch. This report identifies demand for both production and research and development (R&D). The funding provided in the charts, tables, and appendices of this report include total DoD missile programs funding from the FY 2009 President's Budget, dated February 2008, except where documented differently. Most of the monies for missile programs do not go to the SRM industry, but are used for other missile subsystems such as flight controls, electronics, navigation & guidance, and warheads. The SRM generally accounts for 3-30 percent of missile unit cost. The percentage of cost is affected by the relative size of the SRM, the complexity of the SRM – multi-stage or dual pulse – and the complexity of the other missile systems – guidance, navigation, and warhead. Table 2 provides some missile program examples for SRM cost as a percentage of missile unit cost.

Missile Segment	Program	% SRM cost to Unit Cost
Tactical	AMRAAM	3
Tactical	GMLRS	13
Tactical	AMRAAM	3
Tactical	Hellfire II	3.8
Tactical	Hellfire Longbow	2.5
Tactical	NLOS PAM est.	3.3
Missile Defense	SM-6	20
Missile Defense	SM-3	8
Missile Defense	PAC -3	3
Strategic	MM III	29
Strategic	Trident II D5	21
Strategic	Peacekeeper	33
Strategic	SICBM	32

Table 2

Note: D-5 unit costs are based on the Selected Acquisition Report (SAR)

Procurement

The procurement demand for defense missile programs is summarized in Figure 6 on the next page. DoD program procurement specific funding can be found in Appendix B. The figure portrays the defense budget for missiles by mission category – space launch, strategic, missile defense (MD) and tactical systems. Figure 7 breaks the same funding out by the SRM prime contractor who won the production contract.

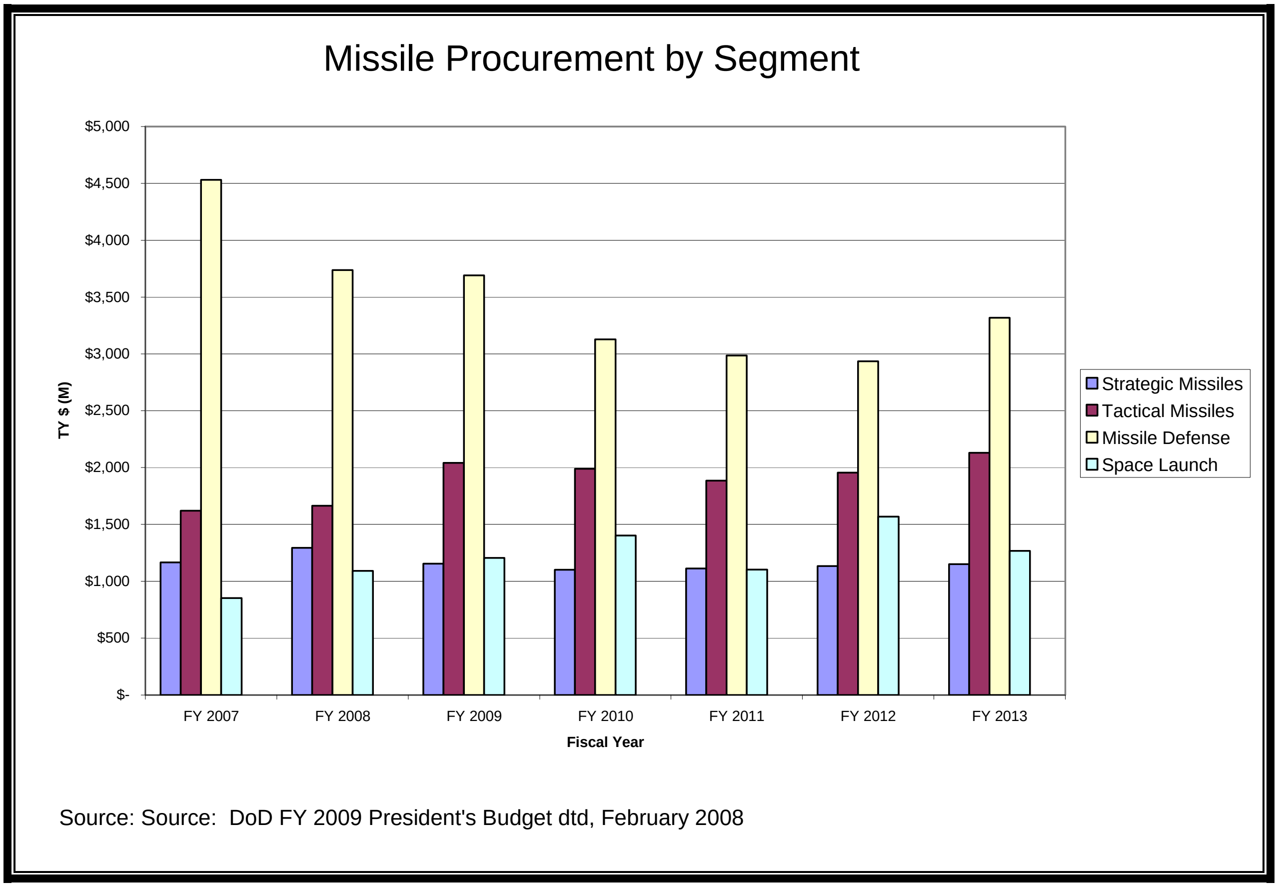
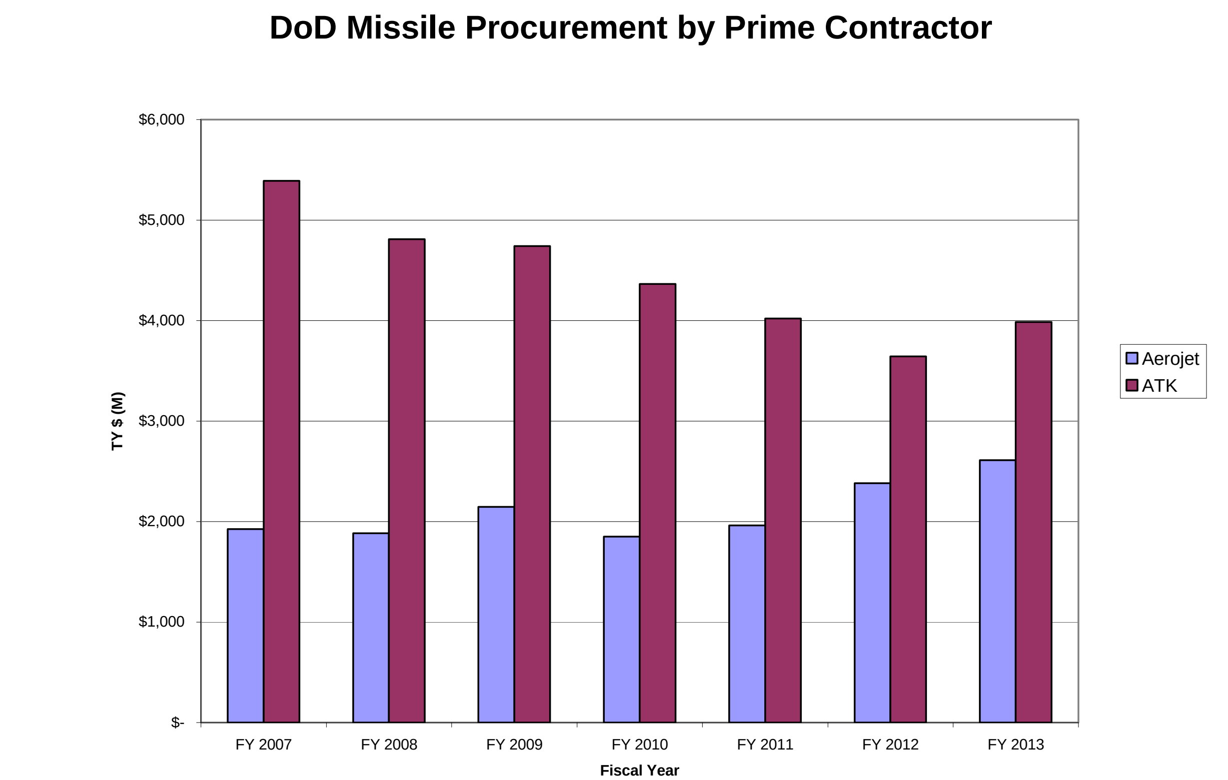


Figure 6

The budget for tactical missiles is stable through FY 2013. Strategic missiles funding appears stable, but the only remaining program is the D-5 with the MM III Propulsion Replacement Program (PRP) concluding in FY 2009. Space launch is stable through FY 2013 but the number of launches is down considerably from past experience as can be seen from the NASA and Launch Vehicles graphs in Figure 3 on page 9. The DoD portion of the space launch business segment consists of the EELV program which includes both the Delta IV and Atlas V launch vehicles. While the chart reflects total EELV program funding, all EELV platforms do not include SRMs. The Delta IV includes the ATK GEM strap-on SRM and the Atlas V includes the Aerojet SRB strap-on when the payload requires additional boost capacity. The missile defense program has the highest funding levels but declines 30-35 percent by FY 2010 through FY 2013 as a result of declines in the Kinetic Energy Interceptor (KEI) and Ground-based Missile Defense (GMD) programs. The funding for systems that use large SRMs (space launch, strategic systems, and GMD from missile defense) is in a steep decline of 50 percent from FY 2007 to FY 2013. The GMD program is included with the large SRMs because the Orion motors that are used on the GMD have a 50 inch diameter. This is in addition to the decline in the 1990s and early 2000s referenced earlier in Figure 4. The funding for systems that use small SRMs (all tactical and missile defense less GMD) is increasing by roughly thirty percent from FY 2007 to FY 2013.



Source: Source: DoD FY 2009 President's Budget dtd, February 2008

Figure 7

Figure 7 shows a significant decline in procurement for ATK – roughly 35 percent from its high in FY 2007 to its low in FY 2012. The average decline is approximately 30 percent from the high to the average for FY 2011 through FY 2013. The procurement decline for ATK is mostly due to ending the MM III PRP and the reduction in the GMD – both large SRM programs. ATK's tactical missile procurement remains stable. Procurement for Aerojet remains stable through FY 2011 and then increases by 20 percent in FY 2012 and then increases an additional 10 percent in FY 2013. The increase for Aerojet is due to their work in tactical (GMLRS) and missile defense missiles (Patriot Medium Extended Air Defense System/Missile Segment Enhancement (MEADS/MSE) and Standard Missile). The procurement funding for programs produced at Aerojet's Sacramento facility, its large SRM production site, are declining. Currently, the THAAD program – a missile defense program – and the throttling divert and attitude control system (TDACS) for the SM-3 are the only DoD production programs at Sacramento. THAAD program funding declines 70 percent from FY 2007 to FY 2013.

NASA Requirements

NASA programs play a significant role in sustaining the industrial capabilities for the SRM industry. As shown earlier in Table 1 on page 7, it takes many DoD missile programs to equal just one Shuttle RSRM booster and it will take more to equal the SRM booster for the new Ares I and Ares V launch vehicles that are part of NASA's Constellation Program. The Ares I SRM is a 5 segment booster very similar to the 4 segment Shuttle booster. The Ares V has 10 segments. The segments for the Shuttle and Ares are the same size. Constellation Program SRMs are shown in Table 3. The table also includes the size of the SRM, identifies the prime SRM contractor, and indicates the number needed for each Ares I flight.

NASA Constellation Program SRMs			
SRM	**SRM Prime Contractor**	**Propellant Weight Estimate**	**Number per Ares I Flight**
Ares I RSRMV Segment	ATK	250,000	5
Abort Motor	ATK	4,750	1
Jettison Motor	Aerojet	366	1
Attitude Control Motor	ATK	638	1
Ullage Setting Motor	TBD	90	8
Booster Tumbling Motor	ATK	77	2
Booster Deceleration Motor	ATK	77	8
Booster Separation Motor	ATK	77	16 (Ares V)

Table 3

While NASA's Ares I first launch is still years away, NASA plans to build SRM flight sets for test and evaluation and to qualify the safety of the Ares launch vehicle for man-rated systems. Figure 8 summarizes the schedule for procuring SRMs for the Constellation Program. As can be seen, NASA plans to procure SRMs for one Ares I fight set in FY 2009 and FY 2010 and then increase to two flight sets beginning in FY 2011. NASA plans to begin procuring an SRM flight set for Ares V beginning in FY 2013 and increasing to two sets in FY 2017. The procurement of NASA's launch vehicles support the SRM industry but they do not come close to the number of systems that NASA procured during the heyday of the Shuttle program where they produced roughly 60 segments per year from 1990 through 1998 as shown earlier in Figure 3 on page 9.

NASA SRM Forecast

NASA Solid Motor Forecast													
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Constellation Program													
Ares I First Stage (segments/year)		5	5	10	10	10	10	10	10	10	10	10	10
Ares V Booster (segments per year)						5	5	5	10	20	20	20	20
Launch Abort System (LAS) (#/yr)	6	3	6	2	2	2	2	2	2	2	2	2	2
Abort Motor	1	1	2	2	2	2	2	2	2	2	2	2	2
Jettison Motor	2	1	2	2	2	2	2	2	2	2	2	2	2
Attitde Control Motor	3	1	2	2	2	2	2	2	2	2	2	2	2
Booster Deceleration Motor (BDM) (#/yr)		5	1	1	8	16	16	16	16	16	16	16	16
Booster Tumbling Motor (BTM) (#/yr)		5	1	1	4	4	4	4	4	4	4	4	4
Ullage Settling Motor (USM) (#/yr)	2	3	8	8	16	16	16	16	16	32	32	32	32
Booster Separation Motor (BSM) #/yr								5	5	32	32	32	32
NASA Launch Services Program													
Atlas 5	2	1	0	2									
Delta II	4	3	2	1									
Delta IV	1	1	0										
Taurus	1	1	0										
Pegasus	1	0	0										
Small class (unassigned)				1 to 2	1	1	1						
Medium class (unassigned)						0	2						
EELV class (unassigned)				1	1	3	1						
Commercial Orbital Transportation Services (COTS)													
Castor 30 - Taurus II				3	3	3	3	3					

Source: NASA

Figure 8

Figure 8 also shows the declining number of space launches NASA plans in the future for their Launch Services Program. NASA has nine launches using various launch platforms in 2008, declining to only four by 2014. NASA does plan to use Orbital's Taurus II for three launches per year from 2011 to 2015. The Taurus II uses ATK's Castor 30 SRM.

Foreign Military Sales (FMS)

In the aftermath of the terrorist strikes on the United States on September 11, 2001, many foreign countries have asked to buy several DoD missile systems under the Foreign Military Sales (FMS) program. These sales exercise SRM prime contractor and their subtier supplier production bases including the workforce and the SRM industrial facilities. Figure 9 shows an erratic increase in FMS buys from 2002 to 2008. However erratic the increase has been, the magnitude has increased from roughly $813 million in 2002 to $2.0 billion in 2008.

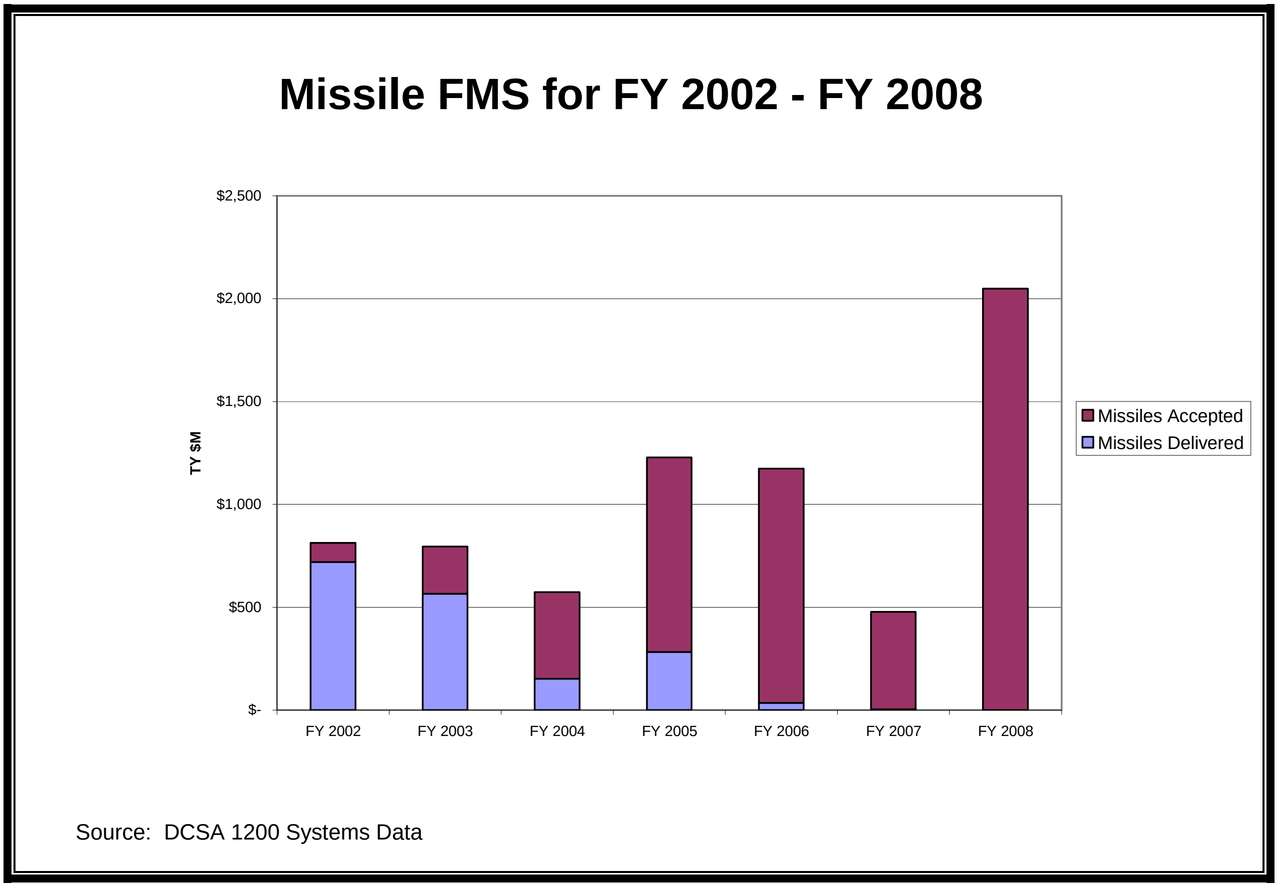


Figure 9

The positive impact of FMS on the SRM industrial base is not evenly spread across all business segments. Figure 10 documents that the majority of the FMS buys have come in the tactical and missile defense business segments with the British D-5 strategic missile buys supporting the strategic business segment. Therefore the positive impact mostly has been noticed at the small SRM level; and to a lesser extent with the British D-5 supporting the large SRM sector.

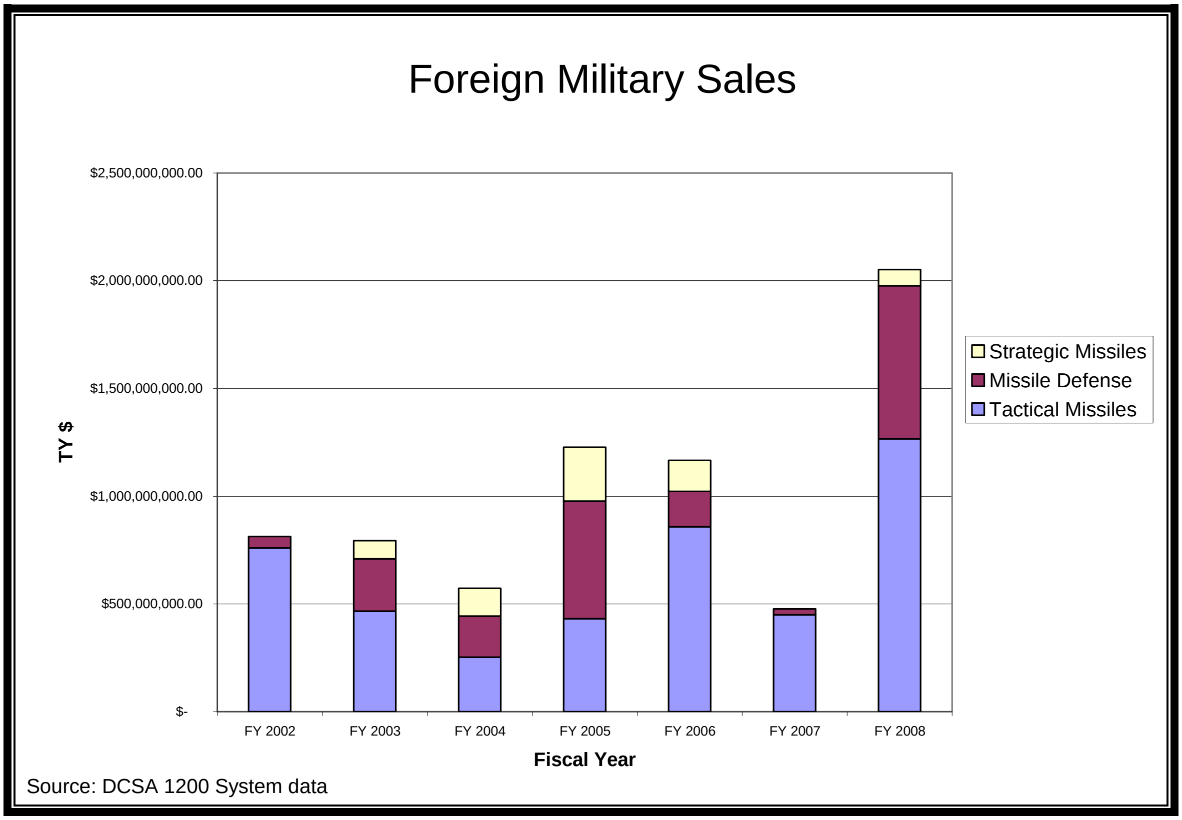


Figure 10

Space Launch

During the mid to late 1990s, the demand for launching commercial communications satellites was forecast to increase dramatically through the beginning of the 21st century. The Department expected this commercial demand for launch vehicles to sustain the large SRM industry and maintain reasonable costs for its launch vehicles – the Atlas V and Delta IV. Unfortunately, this market did not materialize and there has been a significant decline in commercial space launch requirements. Figure 11 shows the level of launch activity for the DoD EELV program (Atlas V and Delta IV) from CY 2003 through CY 2013. Launch activity does not always equate to new production builds. Of the 30 GEM-60 boosters listed for ATK during this timeframe, only 12 reflect new builds.

Military EELV (Delta IV & Atlas V) Solid Rocket Booster Procurement
Calendar Year History & Forecast

Name	Supplier	Booster Details	2003	04	05	06	07	08	09	10	*11*	*12*	*13*
GEM-60 (Delta IV)	ATK	60 in dia HTPB	6		2	2	2	6	2	2	*6*	*2*	*0*
SRB (Atlas V)	AeroJet	61in dia HTPB	2	4			7	9	5	5	*5*	*9*	*0*
	Unassigned								7	2	*4*	*3*	*10*
Number of *Boosters*			**8**	**4**	**2**	**2**	**9**	**15**	**14**	**9**	***15***	***14***	***10***

Notes: CY 2003 – 2008 based on actual orders
CY 2009 – 2013 based on requirements estimated on CY order dates
Numbers represent year of launch service order, not production
ATK numbers reflect 12 actual pours and 18 pulled from inventory
Aerojet numbers are build on need, not our of inventory

Source: Based on the FY09 President's Budget manifest schedule

Figure 11

Figure 12 summarizes the projected commercial Atlas V and Delta IV SRM procurements through 2014. The numbers reflect basically one launch per year per system. This is a result of the small commercial launch market and an increase in foreign competition. For years, the United States and Russia maintained the only capabilities to launch satellites into space. Today, there are competitors from Europe, Japan, Israel, India, Russia, and China. U.S. launch providers' biggest competitors are in Europe and Japan. Europe uses SRMs produced by EADS and Avio. Japan uses SRMs produced by IHI Aerospace and Mitsubishi Heavy Industries. Most Russian and Chinese launches use liquid rocket engines. For the most part, U.S.-based space launches do not use SRMs from Israel, Russia, China, or India because of statutory limitations or restrictions on technology transfers.

Commercial EELV (Delta IV & Atlas V) Solid Rocket Booster Procurement Calendar Year History & Forecast

Name	Supplier	Booster Details	2003	04	05	06	07	08	09	10	11	12	13	14
GEM-60 (Delta IV)	ATK	60 in dia HTPB								1		1		1
SRB (Atlas V)	AeroJet	61in dia HTPB	2	2	3	6			2	1	2	1	2	1
Number of *Boosters* Procured			**2**	**2**	**3**	**6**			**2**	**2**	**2**	**2**	**2**	**2**

Note: Historical commercial launches were primarily Atlas V vehicles

Source: US Military Satellite Manifest, Small World Communications, 18 June 2008

Figure 12

The combination of government and commercial launches during the late 1990s and early 2000s resulted in SRM manufacturers providing greater than 100 SRMs per year. Today, U.S. manufacturers produce less than 10 SRMs per year for space launch with approximately the same facilities sized for large SRM production – ATK's Bacchus and Promontory sites and Aerojet's Sacramento facility. The only rationalization of facilities occurred when Pratt and Whitney's CSD facility experienced two explosions in 2003 and Pratt and Whitney decided to exit the market.

The SRM industrial base has been evaluated several times over the past 10 years. All evaluations indicate that there is not enough business to sustain two large SRM producers. ATK has most of the Department and NASA production contracts for large SRMs; with Aerojet surviving mostly on its work with the Air Force R&D program. Aerojet and ATK share the small SRM production work.

Research and Development (R&D)

R&D funding is the combined funding for S&T activities within the Department and Service R&D missile programs. The industrial capabilities necessary to develop and produce SRMs for missiles are defense unique and require continuing DoD investments to sustain technology development, design skills, manufacturing and system integration capability. R&D funding provides the basis for maintaining an ability to design and develop new products for future national security requirements. The facilities, essential knowledge, and workforce skills needed to develop next generation systems or to repair and replace existing systems will be at risk without sustaining technology development efforts.

The Department funding levels for SRM S&T and R&D are declining significantly as reflected by a 35 percent decrease from FY 2007 to FY 2013. Figure 13 shows the decline and indicates that the greatest declines are in missile programs with R&D and in basic S&T activities. Propulsion Application Program (PAP) funding is increasing from FY 09 through FY 13 as the Air Force develops strategic propulsion capability through projects exploring improvements and/or alternatives to current propulsion systems, conducting studies assessing application of new technologies to meet future common propulsion system requirements, assessing opportunities for applying common materials and technology between the ICBM, submarine-launched ballistic missile (SLBM) propulsion systems, and other solid rocket motor propulsion capabilities to demonstrate a potential family of motors capability. The program contains component testing as well as static and flight testing of various motor sizes across the FYDP. The Navy sister S&T equivalent was terminated due to budget constraints. In an effort to show only those funds allocated for SRMs, the figure below used the percentages of the funding for SRMs by business segment given earlier in the production discussion to equalize the SRM funding for missile programs with SRMs. For more detail on which R&D missile programs have funds allocated to SRMs and a list of the Department's SRM S&T funding, see Appendix D.

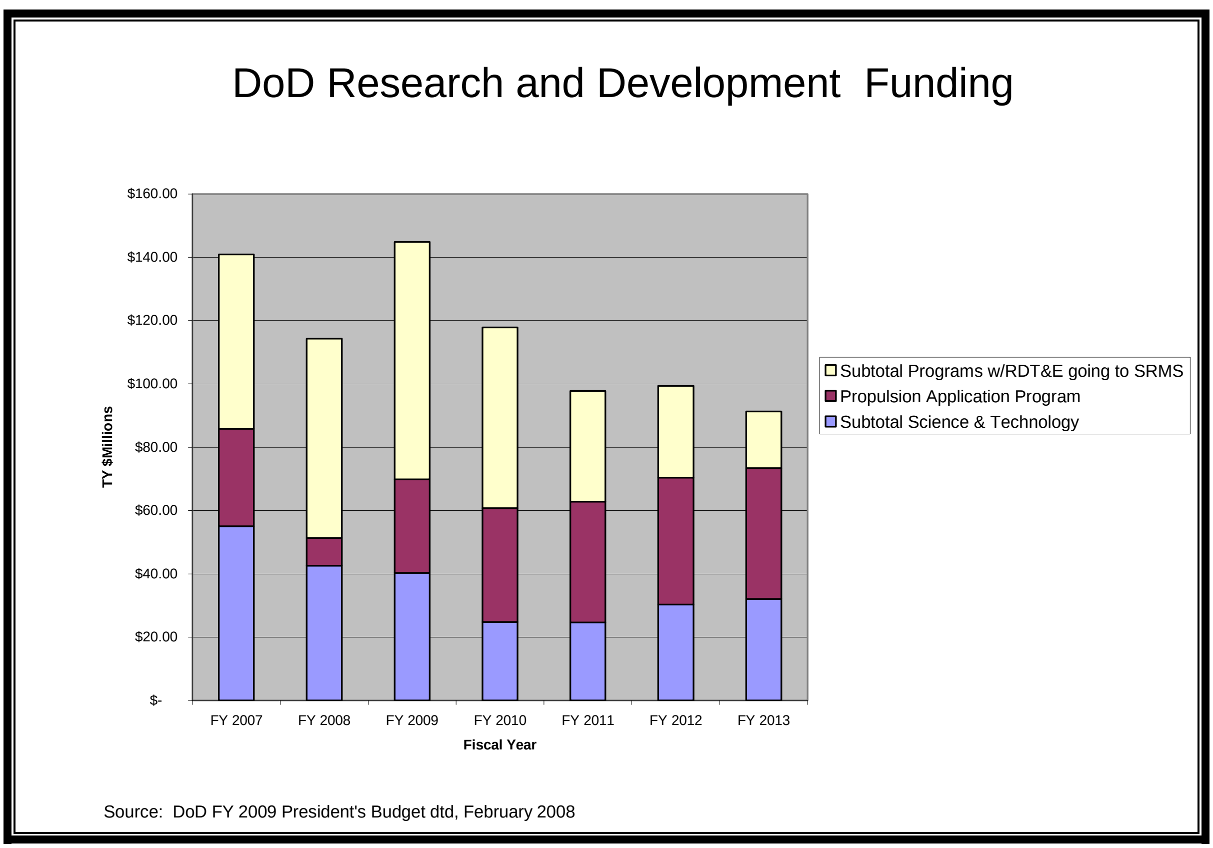


Figure 13

Only a few of the missile R&D programs affect the SRM industry – Joint Air-to-Ground Missile (JAGM), NLOS PAM, SM-6, Patriot MEADS/MSE and GMLRS. The R&D missile programs include only one new development program of record that will be competed – the JAGM, a tactical missile with a small SRM. Two of the other missile R&D programs have already been competed and are nearing production (NLOS PAM and SM-6) and two are enhancements to existing programs (Patriot MEADS/MSE and GMLRS). The Conventional Prompt Global Strike (CPGS) is a DoD-wide concept development that if it is successful and continues into development will be a competitive opportunity for a large SRM. There are a number of missile R&D programs that do not have SRM efforts – AMRAAM, AIM-9X, Advanced Anti-Radiation Guided Missile (AARGM), Tomahawk, and Harpoon. Other munitions programs don't have an SRM – JASSM, JSOW and JDAM.

As shown in Figure 14 on strategic propulsion S&T and intercontinental ballistic missile/submarine-launched ballistic missile (ICBM/SLBM) sustainment funding, the funding in the recent past for large SRMs has been dominated by the Minuteman III PRP program, which amounted to about $300 million per year for the period FY 2004-2007. The last year of funding for the PRP program is FY 2009, and hence the total S&T and sustainment funding after FY 2009 is substantially less than previous period. Still, the projected continuation of low rate production of D-5 motor sets and the Air Force PAP results in a funding level for sustainment activities in the order of $130 million per year for FY 2010 and beyond. Total DoD S&T funding for the IHPRPT and Technology for Sustainment of Strategic Systems (TSSS) programs (and prospective follow-ons) has been somewhat over $100 million per year in the recent past, but decreased in FY 2008 (from $112 million in FY 2007 to $95 million) and the FY 2009 request has been reduced again (to $89 million). The SRM and post boost control system (PBCS) work shown here is dropping from ~$25 to 17M/year. The Navy S&T investments in strategic systems related to propulsion have declined over the last few years and are currently unfunded.

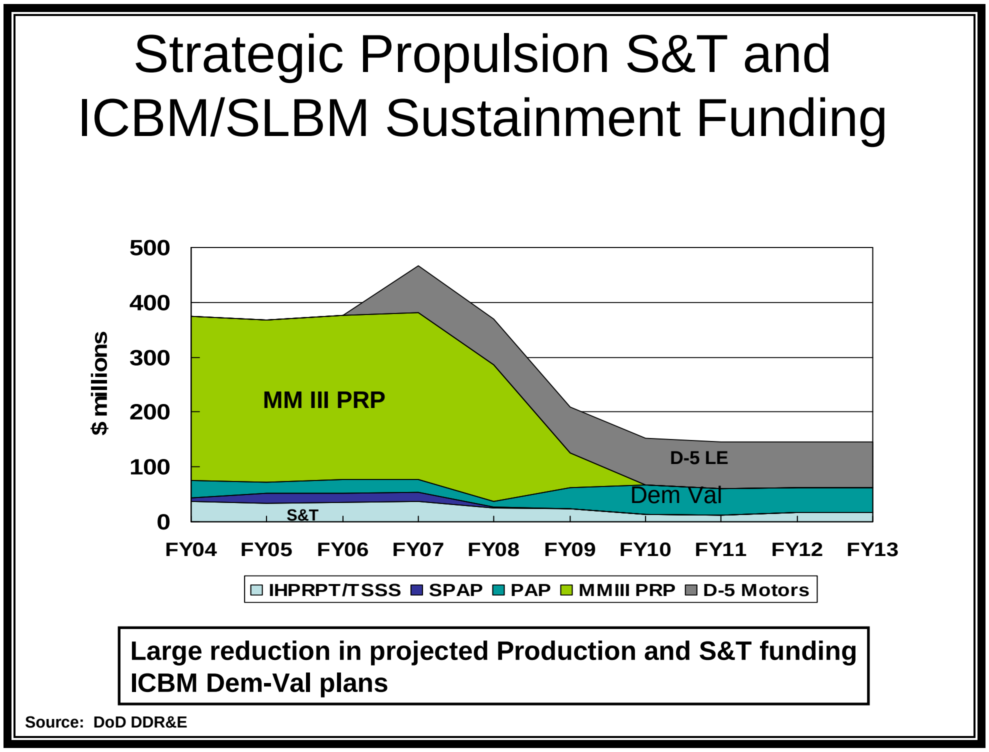


Figure 14

In order for the SRM industry to remain innovative, flexible and viable, the Department and NASA must provide new programs to continually grow future SRM scientists and engineers. The current workforce is aging and programs necessary to attract a new generation of scientists and engineers are not now planned. The lack of competitive opportunities for the SRM industry is of significant concern to the Department, but of greater concern in the large SRM area due to higher cost and schedule risks. The Department has been acquiring missile and launch systems with large SRMs since 1959 and SRM prime contractors have had numerous competitive opportunities to sustain their ability to design, develop and produce the next generation SRMs as indicated in Figure 15. It appears that there was a 7 year gap between the Poseidon C-3 and Castor IV systems produced beginning in 1970 and the Trident I C-4 in 1978, but the development for those systems produced in the late 1970s and 1980s began in the earlier 1970s thereby maintaining the design engineering workforce. There appears to be a nine year gap after the production of the Atlas V solid rocket booster (SRB) in 2003 to the production of the Ares I in 2012. The significant difference between what occurred in the 1970s and now is that, today there is no forecast for future systems.

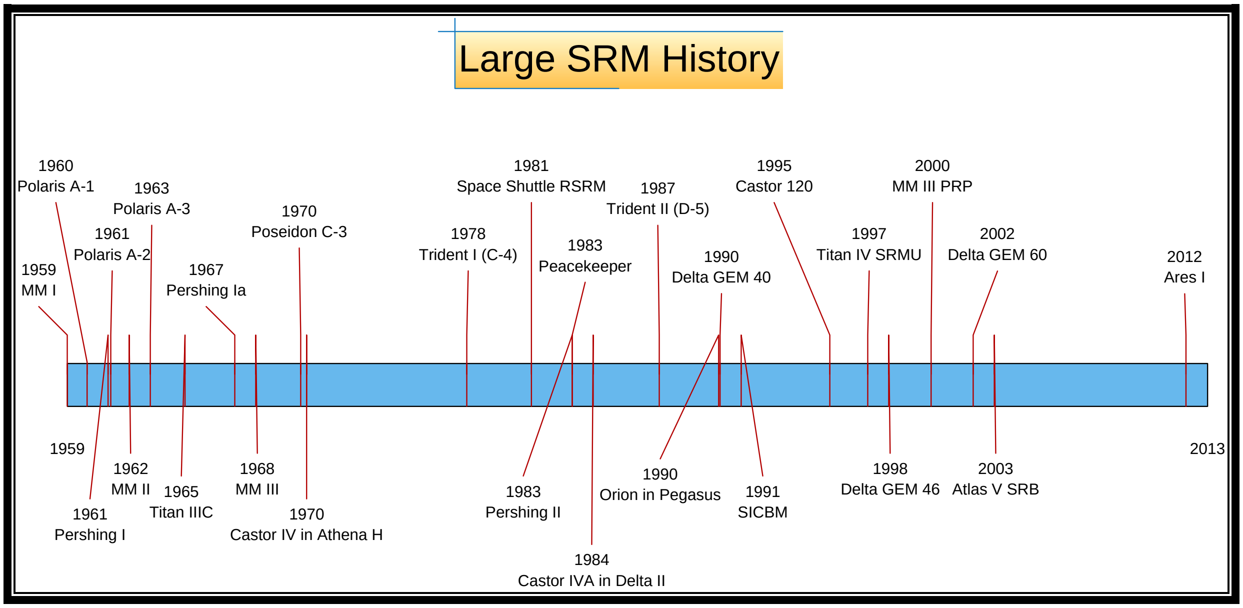


Figure 15

For the first time in fifty years, the Department is not developing a next generation large SRM. The last significant ICBM development program concluded in the early 1990's with the termination of the Small ICBM program. In the mid-90's the Air Force undertook a major remanufacturing effort to extend the life of all three Minuteman III motor stages, however this effort concludes in 2009. During this period the Navy has continued low rate manufacturing of the D-5. There are currently no near-term next generation ICBM or SLBM development efforts forecast, the MM III is expected to last through 2030 and the D-5 until 2042. The next generation NASA launch system, the Ares I and V, are using very much the same technology and production for their 5 segment SRMs as the Shuttle used with its 4 segment RSRMs. The commercial market for space launch does not offer our SRM prime contractors much relief as commercial launch relies more heavily on liquid rocket motors than solids. To further exacerbate the problem, SRM primes face a substantial challenge from foreign competitors.

The Department currently has no projected strategic system development or clearly defined strategy for long term viability of developmental skills and, without mitigation, there is increasing risk in the industrial area. The declining R&D funding levels could have the following impacts for the Department and the SRM industry:

- No funded enabling technology efforts and no funding for the Navy Strategic PAP to support the Trident II D-5 SLBM.
- The decrease in Air Force R&D for ICBM and termination of the MM III motor production in FY 2009 substantially reduce the ability to mitigate risks associated with motor aging and thereby ensure the viability of ICBM life extension from 2020 to 2030. Remaining R&D efforts are inadequate to support MM III ICBM sustainment and future nuclear strategic system development needs. The limited aging data currently available raises concerns about the ability to identify and

address problems that extending ICBM life an additional 10 years could generate in areas such as propellant cracking and liner separation.

- Loss of technical workforce and opportunities for training and education of both government and industry personnel qualified to sustain, develop and manufacture future missile propulsion systems and support current system upgrades.
- Erosion of domestic technological capabilities in the area of tactical missile solid propulsion and the ability to increase future system performance. No Navy S&T efforts are planned beyond FY 2009. The Air Force has had no S&T funding in this area for the past 10 years. Army SRM needs and limited S&T investments are primarily for smaller helicopter-launched missiles or short range ground-to-ground missile applications and activities focused on reduced sensitivity.

Excess Inventory

Current U.S. Space Transportation Policy (dated January 6, 2005) gives U.S. government agencies the ability to use excess ballistic missile assets to launch payloads into orbit, on a case-by-case basis, with the approval of the Secretary of Defense. One of the conditions requires the sponsoring agency to certify that such use results in a cost savings to the United States government compared to the use of available launch services that would also meet mission requirements, including performance and schedule, and limits the impact on the U.S. space transportation industry. The government is using excess ballistic missile assets (including SRMs) for the following reasons:

- MDA uses excess assets for target vehicles,
- NASA uses excess assets for abort test boosters,
- Air Force uses excess assets to support technology demonstration flights.

The use of excess inventory by government agencies is a business practice that benefits the government programs by reducing cost and schedule risk. Using known assets with proven performance and quality helps reduce program risk. This practice allows the government programs to more effectively use its limited resources on other programs needs instead of acquiring new SRM assets.

According to the Navy, the use of these excess SRM assets may result in added program cost and schedule risks. Government programs are trying to extend the life of retired motors but are encountering some problems:

- The Department of Energy (Sandia) is using retired Polaris motors for targets and experiments. The older Polaris A3P motors have been extensively repaired and the Navy expects the A3R motors to have similar issues due to design and material likeness. The last STARS flight failed due to a second stage motor problem.

- MDA is using retired C4 motors for target vehicles but success has yet to be demonstrated. MDA rejected several C4 first stage motors for age related defects during the build process for the first flight candidate even though MDA selected the newest motors from those available. A C4 system has not flown since 2001 when the age of the oldest motors flown ranged from 20-22 years (the oldest was 27 years) at retirement. The Navy acknowledged the C4 had known age related degradation when aging/surveillance programs ended a decade ago.

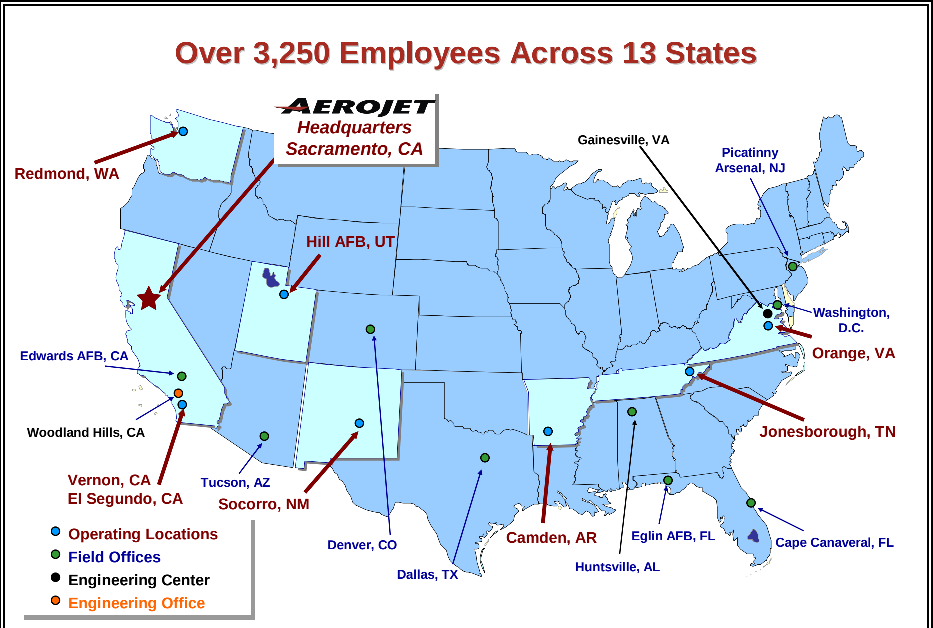
The long term reliability of retired motors is questionable and cannot be assumed without extensive testing, particularly flight testing. Repairs, when possible, require a robust motor industry to perform properly. Use of retired motors may cut government initial expense for some programs but the use of these retired motors carries an added risk due to unpredicted motor problems caused by aging that could cause program schedule delays and increase cost.

At the request of Congress (Senate Armed Services Committee Report 110-335, accompanying the National Defense Authorization Act for Fiscal Year 2009), the Department is contemplating a block purchase of launch vehicles as the most cost-effective solution to launching operationally responsive space (ORS) missions. With an appropriate aging surveillance program, ORS estimates that the United States will not need new small launch vehicles before 2030, so they are not investing in the SRM industry. The use of these existing launch vehicles along with the use of other excess ballistic missile assets reduces the potential buy of new large SRMs in an industry that already has substantial underutilized capacity and is struggling to sustain its engineering and production skills.

SRM Primes

Aerojet

Aerojet, a GenCorp Inc. (NYSE: GY) company, has its headquarters in Sacramento, CA. Aerojet is a space and defense contractor specializing in missile and space propulsion, and defense armaments. Aerojet also has a real estate segment that includes activities related to the entitlement, sale, and leasing of its excess real estate assets in the Sacramento area. The company was founded in 1942. Today, Aerojet has roughly 3,250 employees with 2007 revenues of $732 million. Figure 16 shows Aerojet’s offices and operating facilities in the United States.



Source: Aerojet

Figure 16

Aerojet categorizes its products in two general areas: defense systems and space systems. Aerojet's defense system products include liquid, solid, and air-breathing propulsion systems and components. In addition, Aerojet supplies both composite and metallic aerospace structural components, fire suppression systems and armament systems to the DoD and its prime customer. Product applications for Aerojet defense systems include strategic, tactical and precision strike missiles, missile defense systems, maneuvering propulsion systems, precision warfighting systems, and specialty metal products. Its space systems include liquid, solid, and electric propulsion systems and components. Product applications for Aerojet space systems include expendable and reusable launch vehicles, transatmospheric vehicles and spacecraft, separation and maneuvering systems, upper stage engines, satellites, large solid boosters, and integrated propulsion subsystems. Their SRM programs are listed by their market segment in Table 4.

Aerojet Programs by SRM Segments		
Segment	**Program**	**Facility**
Tactical	GMLRS	Camden, AR
	MLRS Reduced Range	Camden, AR
	ATACMS	Camden, AR
	Javelin	Camden, AR
	Tactical Tomahawk - MK 135	Camden, AR
	Stinger	Camden, AR
Missile Defense	Standard Missile 2/3/6 - MK 104	Camden, AR
	Standard Missile 3/6 - MK 72	Camden, AR
	Patriot PAC-3	Camden, AR
	Patriot/MEADS MSE Msl	Camden, AR
	THAAD	Sacramento, CA
	Standard Missile 3 TDACS	Sacramento, CA
Strategic	D5 Gas Generator (GG)	Orange, VA
Space Launch	Atlas V SRB	Sacramento, CA

Table 4

Their SRM capabilities accounted for 57 percent of the 2007 revenues as depicted in Figure 17 – roughly $417 million. Of this SRM total, 39 percent came from missile defense, 30 percent from tactical missiles, 18 percent from space launch, and 10 percent from strategic missile programs.

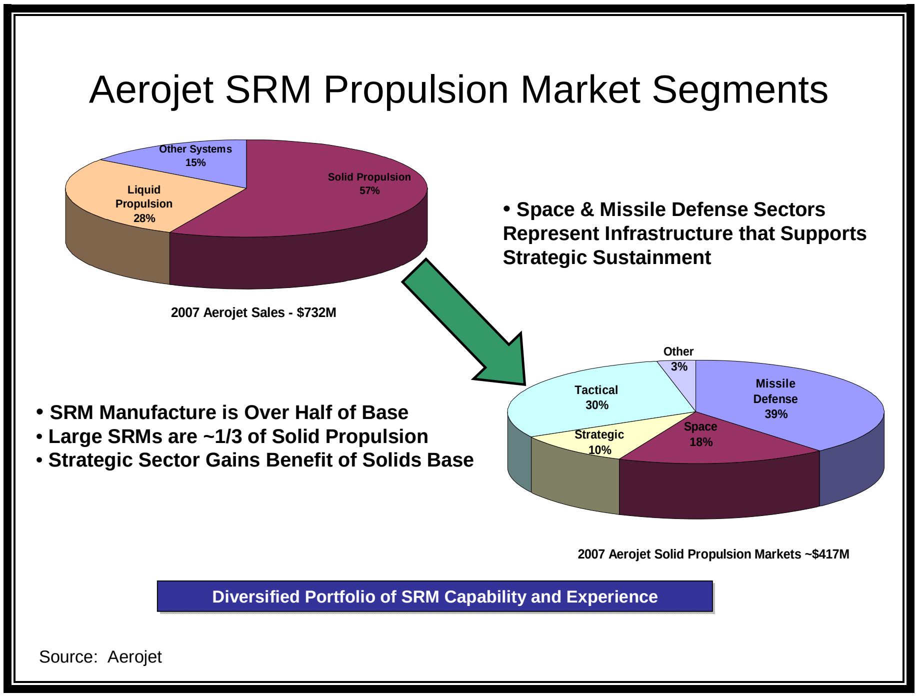


Figure 17

Aerojet has the industrial capabilities – facilities, personnel, and manufacturing processes – necessary to design, develop and produce all categories of SRMs – space launch, strategic, missile defense, and tactical. They have three facilities capable of manufacturing SRMs. In Sacramento, CA, they produce SRMs in the space launch, strategic, and missile defense segments. Their strategic SRMs are associated with R&D contracts. They produce tactical and missile defense SRMs at their Camden, AR, facility. While their Orange, VA, facility mostly supports R&D, they do have the capabilities to produce SRMs that support the strategic segment -- Trident II D-5 missile PBCS gas generator which has a 14 inch diameter SRM.

Aerojet has roughly 20 percent of the SRM market by dollar value. They currently do not have any DoD large SRM production work other than the occasional order for an Atlas V SRB. Their large SRM activities have been in the R&D programs such as the IHPRPT Phase II motor and the MM III 2nd and 3rd stage PAP motors. Aerojet plans to compete for the CPGS program which will use a large SRM. Aerojet has a fairly stable portion of both the tactical and missile defense SRM market segments.

ATK

ATK is a roughly $4.6 billion aerospace and defense company with approximately 17,000 employees and operations in 22 states. Its headquarters is located in Minneapolis, MN. ATK provides aerospace and defense products to the U.S government, allied nations, and prime contractors in the United States. The company also supplies ammunition and related accessories to law enforcement agencies and commercial customers. ATK has just recently organized into three operating groups or business segments aligned along the following product areas; Armament Systems, Mission Systems and Space Systems as shown in Figure 18.

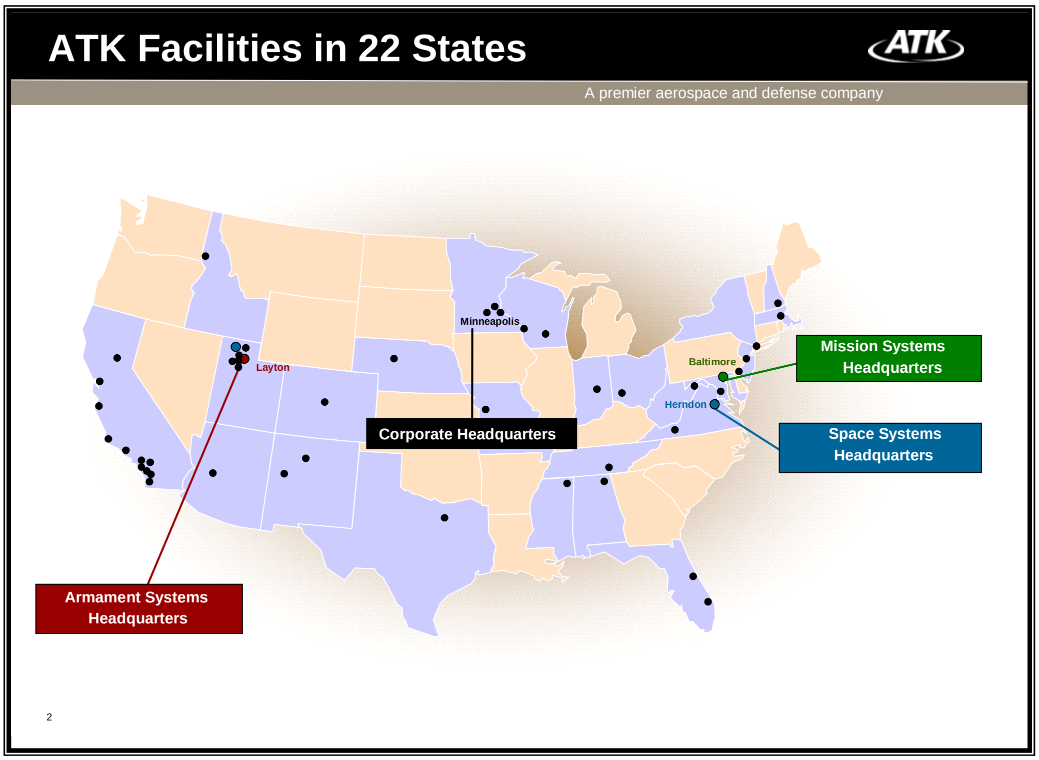


Figure 18

Source: ATK

Figure 19 shows the percentage of revenue for specific programs in 2007. The largest program by far is the Space Shuttle RSRM, followed by the MM III PRP which ends production in 2009, and the Ares/Constellation SRM.

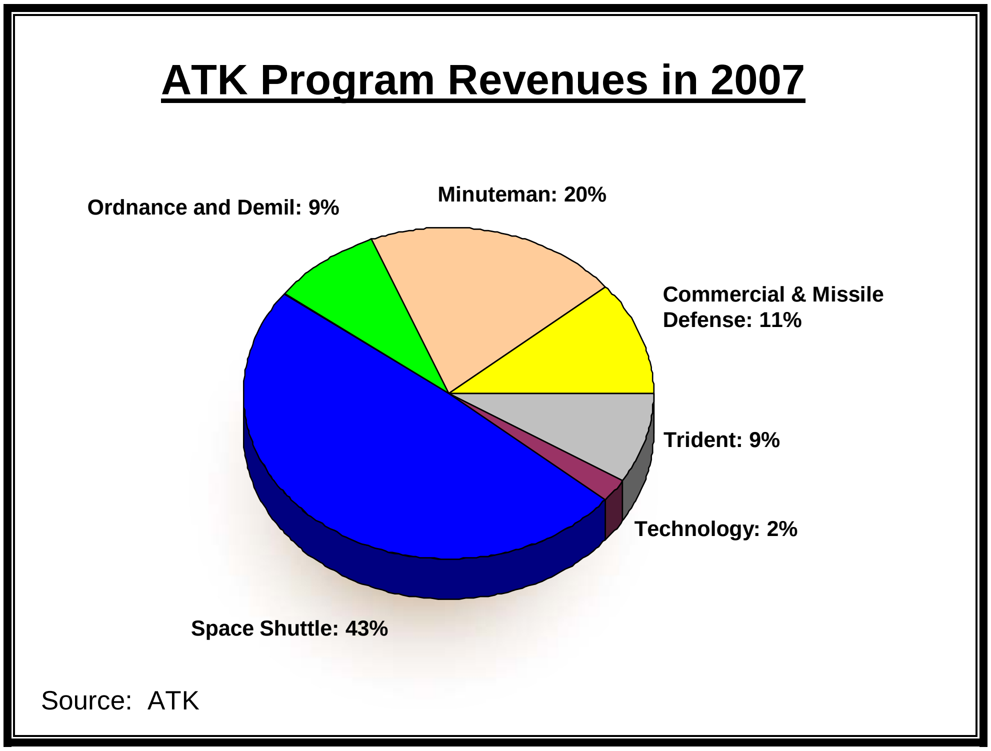


Figure 19

Armament Systems develops and produces military small and medium caliber ammunition, energetic systems, commercial and civil ammunition, and accessories. They produce the 5.56 and 7.62 mm small-caliber training and combat ammunition rounds at the Lake City Army Ammunition Plant in Independence, MO. The Lake City business represented approximately 14 percent of ATK's total fiscal 2007 sales. Their medium caliber ammunition produced at the Lake City and Radford Army Ammunition Plants is used in ground and air combat platforms like the Bradley Fighting Vehicle, the Apache helicopter, and the A-10 close combat support aircraft. ATK has developed and produced more than 25 types of military ammunition and rocket systems. They are the only North American supplier of military-specification nitrocellulose used in ammunition propellant and SRMs. They provide commercial and civil ammunition under several brand names, including Federal Premium®, Fusion®, CCI®, Speer®, Blazer®, and Estate Cartridge®.

Space Systems provides large satellite components and subsystems, small satellite systems, and engineering and technical services, and develops and produces solid rocket motors for human-rated and unmanned space launch vehicles, strategic missiles, and missile defense interceptors. ATK Space Systems serves both commercial and government customers, including defense prime contractors: NASA, Air Force, Navy, Army, and Missile Defense Agency. Major products include Orion and Castor SRMs for commercial launch vehicles, Minuteman III and Trident D-5 strategic missile SRMs, the NASA space shuttle RSRM, and the NASA Ares I Crew and Ares V Cargo launch vehicles.

Mission Systems develops and produces weapon systems for ground, sea, and air platforms, and propulsion and control systems for missile defense, spacecraft-orbit transfer, missiles, and projectiles. They are developing hypervelocity and air-breathing propulsion systems for next-generation spacecraft and weapon systems, and high-strength composite and ceramic materials for spacecraft, aircraft, and weapon systems. They operate the Navy's production facility in Rocket Center, WV.

SRMs are developed and produced at both the Launch Systems and Mission Systems operating groups. ATK's current SRM production programs and the facilities where they are produced are given in Table 5.

ATK Programs by SRM Segments		
Segment	**Program**	**Facility**
Tactical	Hydra 70	Radford AAP
	ESSM	Rocket Center, WV
	Hellfire	Rocket Center, WV
	TOW 2	Rocket Center, WV
	RAM	Rocket Center, WV
	Tomahawk Gas Generator (GG)	Rocket Center, WV
	AMRAAM	Rocket Center, WV
	AIM-9X Sidewinder	Rocket Center, WV
	NLOS PAM	Rocket Center, WV
	AGM-65 Maverick	Rocket Center, WV
Missile Defense	KEI Gas Generator	Rocket Center, WV
	SM3 BL IA3rd Stage SRM (TSRM)	Elkton, MD
	SM3 BL IA SDACS	Elkton, MD
	SM3 BL IB TSRM - Mk136	Elkton, MD
	SM3 BL IB TSRM - Mk136 add	Elkton, MD
	GMD SRM Stage 1 (Orion)	Bacchus, UT
	GMD SRM Stage 2 (Orion)	Bacchus, UT
	GMD SRM Stage 3 (Orion)	Bacchus, UT
	KEI 2nd Stage (40S)	Elkton, MD
	KEI 1st Stage (40SL)	Bacchus, UT
Strategic	MM III Stage 1	Promontory, UT
	MM III Stage 2	Bacchus, UT
	MM III Stage 3	Bacchus, UT
	D5 Stage 1	Bacchus, UT
	D5 Stage 2	Bacchus, UT
	D5 Stage 3	Bacchus, UT
Space Launch	Shuttle RSRM	Promontory, UT
	Ares RSRMV	Promontory, UT
	Castor IV	Promontory, UT
	Castor 120	Promontory, UT
	GEM 60	Bacchus, UT
	GEM 46	Bacchus, UT
	GEM 40	Bacchus, UT
	STARS 48 motors	Elkton, MD

Table 5

SRM Industrial Capabilities

Prime Level

The ability to produce SRMs and respond to the Department's needs requires industrial capabilities in three essential areas: experienced design engineering personnel, a current touch labor workforce with production facilities, and a viable subtier supplier base that can provide design-unique materials and components. The types of facilities and personnel are similar across SRM manufacturers in function but are different in size and complexity. The major SRM industrial capabilities process areas can be separated into structures, propellant mixing, propellant cast and cure, inspection, final assembly and test. Some of the SRM industrial capabilities common at the prime contractor level include the workforce and facilities necessary for producing SRM case structures, mixing the SRM propellants and pouring the propellant into the case, inspecting the SRMs for bond line and propellant anomalies before and after completion of propellant cure, assembling the SRM into a finished product, testing the system for performance and environmental compliance, and ensuring quality assurance. For the small SRMs, the prime contractor may decide to buy cases instead of producing them, but the general list of characteristics is the same. Table 6 lays out the general industrial capabilities necessary to produce large and small SRMs.

PRODUCTION PROCESSES FOR LARGE AND SMALL SRMS	
SRM Production Process Area	**Process Operations**

Structures	• Case
	  o Composite case manufacturing
	  o Metal case manufacturing
	  o Electron-beam welders
	  o Ovens and autoclaves
	  o Insulation manufacture, assembly and cure
	• Nozzle
	  o Nozzle ablatives manufacturing
	• Nose fairing

Propellant Mix	• Propellant mixing • Oxidizer grinding • Fuels dispensing • Sampling
Propellant Cast/Cure	• Installing SRM case in casting pit • Evacuating pit • Positioning propellant mix bowl • Pouring propellant • Vacuum casting propellant • Curing SRMs in pit
Inspection	• Non-Destructive Inspection for bond line & propellant anomalies • Ultrasonic • X-ray • High energy computed tomography (HECT)
Final Assembly	• Assembly, integration and testing • Final assembly and check-out
Test	• Static test firings • Environmental test

Table 6

Large SRMs

The large solid rocket motor manufacturing facilities in the United States are located at ATK (Bacchus/Promontory, Utah) and Aerojet (Sacramento, CA). This number is down from two decades ago when there were five major vendors. The Department anticipated the downsizing of the industry. Studies ten years ago concluded that there was extensive overcapacity in the industry and some downsizing was necessary, inevitable and probably desirable. The studies also anticipated that a robust commercial space market was in the offing (the private communications market was on a fast growth curve at the time) and that SRM demand for satellite launch would compensate for the reduction in military orders. However, this scenario did not materialize. Additionally, strong foreign competition emerged limiting the commercial opportunities for U.S. companies. The distinguishing characteristics that separate the large SRMs from the small SRMs in large part are associated with the added complexity of size.

Small SRMs

The small SRM manufacturing facilities in the United States are located at ATK (Elkton, MD, and Naval Industrial Reserve Ordnance Plant (NIROP) Allegany Ballistics Laboratory (ABL) in Rocket City, WV) and Aerojet (Camden, AR).

Minuteman III Unique Industrial Capabilities

The MM III SRM is based on designs developed beginning in the 1950s with various modifications resulting in the original production buy ending in the late 1970s. The MM III production historic profile is given in Figure 20.

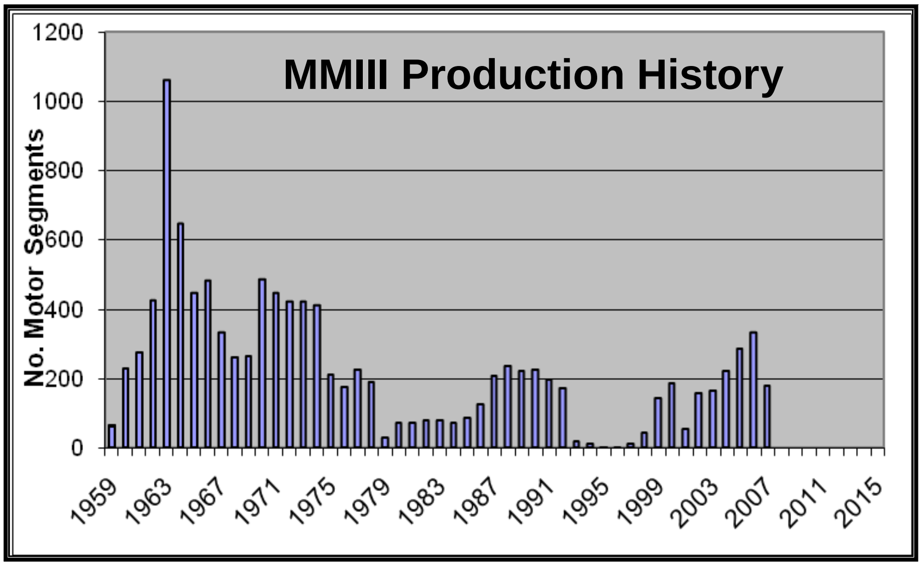


Figure 20

MM III SRMs have many unique characteristics, manufacturing skills and processes, and subtier suppliers that are not supported by other SRM programs. According to the SRM prime contractor, the MM III, D-5, and Shuttle RSRM share approximately 25 percent of their respective supplier bases. The Shuttle RSRM has man-rated requirements and is a reusable system resulting in little to no commonality with the manufacturing and processing systems used in the MM III. The Trident D-5 has a more energetic propellant than the MM III due to the low volume constraints for each SRM which drive significant differences in all manufacturing processes. In addition, the D-5 and commercial market systems use modern state-of-the-art designs with more automated processes making them vastly different from the MM III process and design.

Immediately following the conclusion of repouring MM III stages 2 & 3 in the early 1990's, the Air Force elected to undertake an RDT&E program to address age related degradation and take advantage of evolving technology opportunities rather than immediately return to repouring the stages. The RDT&E program was complex as the contractor was working with a 50-year old design. Specifically, the RDT&E effort was established to address the following issues:

1) Eliminate environmentally prohibited materials (asbestos and Freon);
2) Qualify replacement materials (combination of design changes and manufacturing sources);
3) Incorporate current technologies (transducers, pressure switches, casting, etc.).

The RDT&E effort was a $328M four year program, followed by low rate initial production beginning in FY99. Full-rate production for the Propulsion Replacement Program (PRP) began in 2001. The MM III PRP program comes to an end in FY 2009.

The MM III SRM stages possess unique design and processing characteristics. These 50 year old designs were reproducible only after seven years of development work to recreate the knowledge base necessary for production. Technical understanding of these systems again will decay upon completion of the MM III PRP. Many of the current components may not be reproducible due to obsolescence, and the design expertise necessary to evaluate new material qualification requirements may not be available.

Trident II D-5 Unique Industrial Capabilities

The D-5 is the latest in a line of Navy submarine launched ballistic missiles (SLBMs). Figure 21 shows the different generations of Navy booster systems: Polaris (A3), Poseidon (C3), Trident I (C4) and Trident II (D-5). SLBMs have been in continuous production at ATK (Bacchus/Promontory, UT) since the 1960s with the exception of the A3 First Stage (manufactured at Aerojet/Sacramento). The Navy accomplished this through a well planned and executed series of overlapping development and production programs that combined the latest technological advances with a solid track record of operational success. In this way obsolescence and significant service life issues were minimized. The Trident II D-5 SRM is nearing the end of its design life of twenty-five years on early production missiles that began in 1987. The D-5 Life Extension Program was instituted to address this issue, as well as other missile component life issues.

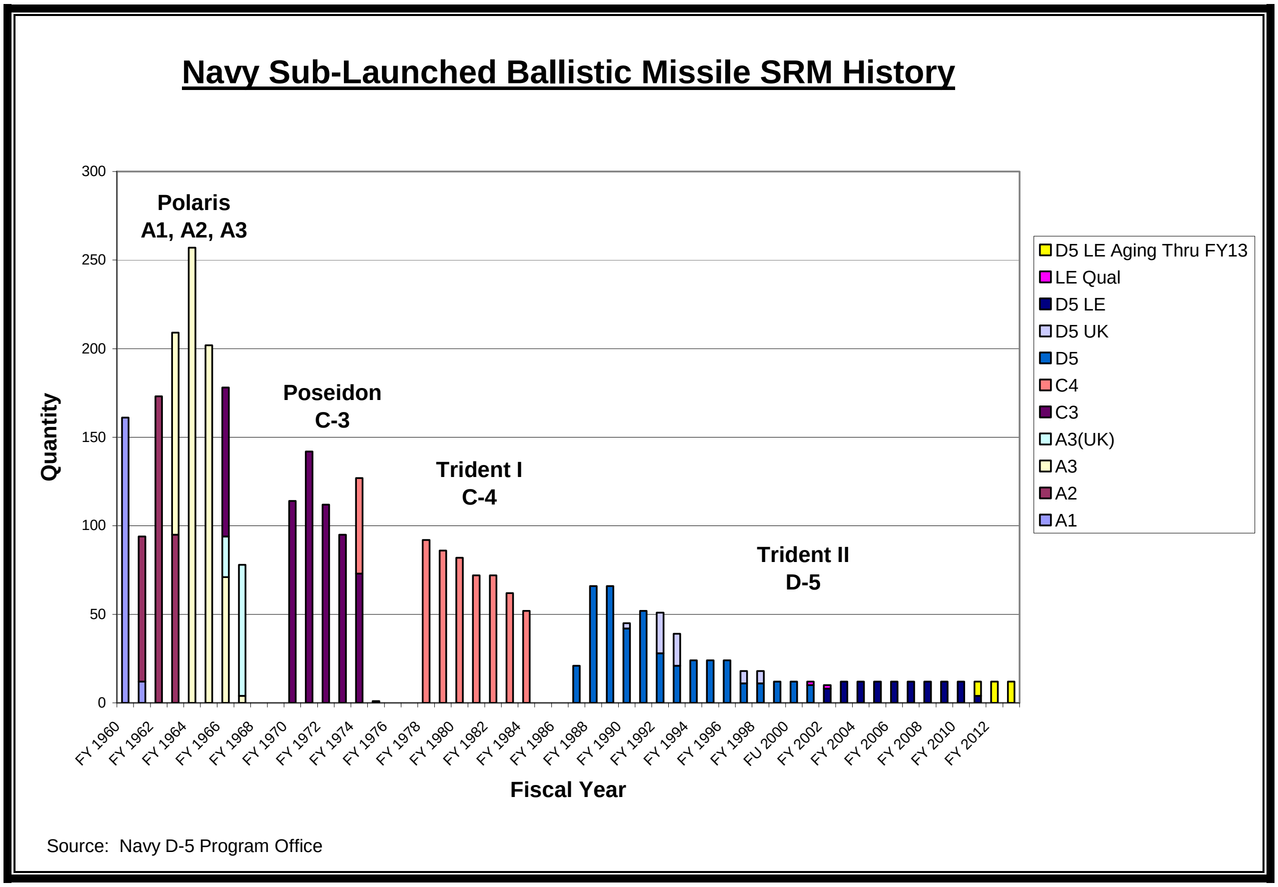


Figure 21

Like the MM III, the D-5 has unique SRM industrial capabilities and characteristics not supported by any other program. The specific requirements for submarine operations drive the need for many of these unique capabilities and skills. The solid propellant must meet high safety criteria because the submarine is a manned platform. The D-5 propellant is a nitrate ester polyether (NEPE) formulation. The D-5 requires this formulation for its high energy and high strain characteristics. The NEPE propellant requires unique manufacturing skills and facilities that are resident at the Bacchus facility.

SRM Industrial Risk Areas

Engineering/Workforce

Declining markets for the development and production of SRM programs will have a negative impact on the SRM industry's ability to maintain design engineering teams and production processes necessary to support current and future SRM requirements. While ATK and Aerojet currently are able to sustain their workforce, both expressed deep concern with their ability to retain and attract the engineering, design, and labor workforce necessary to design, develop, and produce our next generation SRMs with the forecast of so few new SRM programs. Both have an aging workforce. While the total numbers for each company are different as ATK is substantially larger, both face the same "graying of the workforce" issue. This issue challenges the SRM industry with bringing in new talent as the market declines. The aging workforce issue is prevalent in both the engineering and the manufacturing skill sets.

As noted earlier in this report, there are many specialized and unique skill sets and production processes needed for SRM design, analysis, development and manufacturing. These technical skills can be skills needed for day-to-day sustainment of a deployed system; for solving technical problems that surface in an existing system; for modifying a system to extend its life or enhance its capability; or for designing, analyzing and developing a new system. These skills are not easily acquired. ATK experts believe that it takes up to five years to create a skilled SRM engineer and production worker.

The SRM industry is facing a severe "graying of the workforce" challenge as the average age of its engineering and manufacturing workforce is about 50 years old which could result in a large number of people choosing to retire in a short period of time. This will result in the loss of critical engineering and production skills as there is a limited talent pipeline to replace them. Even if there was sufficient talent in the pipeline, there are no new development programs to train and educate the next generation designers, engineers, and technical manufacturers.

Underutilized SRM facilities

The SRM industry has seen a significant consolidation over the last twenty years in terms of the number of companies now developing and producing SRMs. However, this has not resulted in an equivalent amount of reduction in the number of facilities. ATK acquired Thiokol which had 3 facilities that produced SRMs (Promontory, Elkton, and Huntsville) and Hercules which also had 3 facilities (Bacchus, ABL, and McGregor). Of those six facilities, four remain in production today with only the Huntsville and McGregor facilities being shutdown. Aerojet which had the Sacramento facility acquired ARC with its 3 facilities (Camden, Gainesville, and Orange County). All are still functioning with the Gainesville facility used primarily as an engineering complex for its smaller SRMs. United Technologies Chemical Systems Division's (CSD) Coyote facility closed after the two explosions in 2003. Therefore, eight SRM development and production facilities remain from an original eleven. Aerojet and ATK have taken steps to consolidate functions at their facilities to reduce duplication. While both Aerojet and ATK are actively consolidating operations within their facilities, it is not enough to maintain efficient utilization rates at their operating sites.

Time to Restart SRM Production

Restarting production operations for SRMs takes a significant amount of time and money. Once a program is shut down, even if the tooling is mothballed and the engineering and production processes are documented, a company cannot easily replace the in-depth process knowledge that is lost. Prime contractor experience indicates that from a warm base it typically takes 3-5 years to restart SRM production including subtier suppliers. If the Department needs to restart a program from a cold base, the time to reconstitute is estimated to be 6-8 years, if feasible at all.

As stated earlier, the MM III SRM took about seven years to get to full-rate production following a 20 year production gap for stage 1 and 1 and 3 years respectively for stages 2 and 3. ATK had warm production facilities from commercial launch platforms and the D-5 production. A significant part of the long restart time was due to the fact that the MM III stage 1 motor had not been produced for over two decades requiring significant development work to recreate the production processes knowledge base and subtier supplier management to requalify suppliers. The extended length of time between productions also required a large number of static tests.

When the Navy needed to restart the A3R SRM, the effort took six years to complete the necessary requalification. The A3 production had been out of production for more than 10 years which left three significant hurdles to overcome: material obsolescence, lost suppliers, and limited previous production process knowledge base. The material obsolescence problem occurred because many materials either were no longer available or in some cases could not be used due to stringent environmental laws. The A3 encountered subtier supplier issues because several suppliers no longer produced the necessary item or had gone out of business both of which required a substantial requalification effort. The A3 restart took six years despite the fact that the contractor was working from a warm base with an existing subtier supplier base. At the time, the Navy was still acquiring the Trident I C-4 program and the Trident II D-5 program was in development.

Government Regulations

The prime contractors developing and producing SRMs must comply with many different government regulations. Most of these regulations are derived from laws associated with the environment. The environmental laws that affect the SRM industry are:

- Resource Conservation and Recovery Act (RCRA): RCRA is a federal law that gives the Environmental Protection Agency (EPA) the authority to control hazardous waste generation, transportation, treatment, storage, and disposal.
- Clean Air Act (CAA): CAA is a federal law that provides the EPA with broad authority to implement and enforce regulations reducing air pollutant emissions.

- Clean Water Act (CWA): CWA is a federal law that protects the surface water quality in the United States. The law employs a variety of regulatory and nonregulatory tools to sharply reduce direct pollutant discharges into waterways.
- Emergency Planning and Community Right-to-Know Act (EPCRA): EPCRA established a national framework for EPA to mobilize local government officials, businesses, and other citizens to plan ahead for chemical accidents in their communities. EPCRA requires that facilities immediately report to appropriate state, local, and federal officials a sudden release of any hazardous substance that exceeds the reportable quantity.
- Toxic Substance Control Act (TSCA): TSCA is a federal law that provides EPA with the authority to require reporting, record-keeping and testing requirements, and restrictions relating to chemical substances and/or mixtures.
- Safe Drinking Water Act (SDWA): SDWA is the federal law that ensures the quality of American's drinking water. Under SDWA, EPA sets standards for drinking water quality and oversees the states, localities, and water suppliers who implement those standards.
- Comprehensive Environmental Response, Compensation and Liability Act (CERCLA): CERCLA, commonly know as Superfund, is a federal law that provided broad federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment.

Compliance with these environmental laws requires the prime contractor to obtain permits that in some cases must be renewed (most renewals are required every 2 – 5 years) and might require periodic reporting (usual reporting periods vary from annual to every 3 years). Permit renewal is part of the business and usually is comprised of a lengthy and on-going process – even for active operations.

SRM prime contractors and their subtier suppliers face a significant restart risk if development or production operations cease due to gaps caused by cancelled or completed programs. Once development or production operations halt, the associated permits are ended. This is not a problem in some cases because there is little risk of reinstating a permit. However, there could be substantial cost and schedule risk associated with trying to reinstate some permits because permit reapplication may be a multi-year process and the governing body may not be willing to reinstate the permit at the previous level if at all. For instance, ATK explained that it would be highly unlikely for the State of Utah to re-permit open burning activities at current levels which is covered under the RCRA. These activities are necessary for static testing of development and production SRMs.

In summary, the prime contractors allocate substantial resources to maintain their environmental permits. If there are gaps in development or production operations, the contractors permits would lapse and it may be difficult to restart operations because they may not be able to get approval to reinstate the permits to support new contracts.

Subtier Level

The SRM industrial base has been evaluated several times over the past 10 years as mentioned earlier. All successive findings indicate that there is not enough business to sustain two large producers and their subtier suppliers. There is not adequate demand to allow the producers and their suppliers to have a consistent and favorable return on their investments. As a result, when there is a fluctuation in the demand there is a corresponding ripple effect through the supply chain. In many cases, the industrial problem areas are not at the SRM prime level but at the subtier supplier level.

In many defense sectors, the demand for industrial capabilities is supported not only by the defense market but also by the commercial market. Generally, the more commercial the sector, the less dependent the sector is on defense. There is no commercial market for missiles of any size and while there is a limited market for commercial space launch vehicles, foreign competitors dominate that business. This predominantly puts the sustainability burden of the SRM industrial sector on government space launch and defense SRM requirements at a time when both are declining. This scenario presents many challenges not only to the SRM prime contractors but also to the SRM subtier suppliers. Challenges include:

- Maintaining qualified sources
  - Industry is constantly facing the loss of sub-tier suppliers
    - Exits from the industry are often unanticipated by the higher tiers
    - Suppliers are one program cancellation or one catastrophe away from closing business lines
  - Qualification of a new supplier or production process takes time and money
  - Many subtier suppliers are either sole or single sources
  - Many subtier suppliers are foreign owned
- Keeping skilled labor current
- Preserving the production processes
- Surviving downturns in demand and SRM production
  - Sub-tiers are equally affected by the lack of new programs and the decline in current requirements as the SRM prime contractors
- Right-sizing facilities for the market
- Meeting delivery schedules

With all these challenges, the subtier suppliers and niche providers may opt to exit the SRM business with little or no warning rather than support an unprofitable business line. The blue box on the next page titled, “Low Level Subtier Supplier – Big Impact,” describes how significant an SRM single or sole source supplier decision to exit the market can be to the industry. If the example supplier had exited the market, 43 programs would have been affected which would have required all the programs to qualify another source. And due to the nature of the SRM business, each system would have required its own requalification which would have accounted for possibly hundreds of millions of dollars and years of schedule delays.

Low Level Subtier Supplier—Big Impact

During a 2005 Missile Defense Agency (MDA) solid rocket motor (SRM) industrial assessment, Sartomer Company, Inc. informed the Department that it may be forced to leave the SRM business as early as the end of calendar year 2006. Sartomer, a sole source domestic producer, supplies the entire hydroxyl-terminated polybutadiene (HTPB) polymer used by DoD, NASA, and commercial space for solid rocket motor propellant and munitions. Sartomer produces two basic formulations of the HTPB; the HTLO product that is predominantly commercial and the R45M that is defense unique. Both are used in DoD solid rocket motors. Sartomer's production facility in Channelview, TX, needed between $7-15 million in capital investments to meet emerging Environmental Protection Agency requirements and make efficiency improvements. There were no additional domestic providers of this product.

Initially, Sartomer's parent company, Total, based in France, decided not to fund the required improvements due primarily to low profitability and their option to meet their commercial customers' needs from their foreign production sites. However, under current practices and procedures, the DoD/NASA programs using this product would be required to requalify the manufacturing processes of another source. Hence, if there were a change in the supplier for HTPB, those programs affected would incur substantial requalification costs and schedule delays.

The Department's practice is to only take action to maintain an industrial capability if the time or cost to regenerate that capability, once lost, would prohibit the Department from meeting its mission needs. The Department performed an assessment and determined that if Sartomer left the business, the impacts could have exceeded $100 million in costs and 18 months to several years in schedule delays.

The Department's SRM Task Force formed in 2006 reviewed the Sartomer issue and explored several options from doing nothing to finding ways for the Department to fund the required improvements to the Sartomer facility.

Before the Department decided on the way forward, Sartomer convinced its parent company to make the necessary investments and the Department was not forced to take any remediation actions. This example helps to emphasize the Department's position to encourage its prime contractors to resolve industrial capabilities issues.

The Department expects the system prime contractors to identify any industrial issues and then implement remedies to resolve them. Alternative means of obtaining supplies generally are not considered until all the prime contractor efforts have been explored or there is a crisis, i.e., a sole supplier announces his exit or reliance on an unreliable foreign supplier is unavoidable.

The SRM primes have identified a few subtier suppliers or materials they consider risk areas. Three of these risk areas are ingredients for the SRM booster. American Pacific is a sole source supplier that provides ammonium perchlorate (AP) for all government needs. Sartomer provides the HTPB binder discussed in the previous blue box. Copperhead Chemical provides Butanetriol Trinitrate (BTTN). The BTTN issue is discussed in the next blue box.

Limited Global Suppliers for Niche Products

Copperhead Chemical Company, located in Tamaqua, PA, is currently the only qualified source for Butanetriol Trinitrate (BTTN), a nitrate ester/plasticizer (part of the binder) used in the production of rocket motors for the Army's Hellfire, TOW-2, and Javelin missile systems. Butanetriol (BT) which is identified on the U.S. Munitions List (USML), is a chemical precursor needed by Copperhead to produce BTTN. Copperhead's previous BT source, Cytec Industries, discontinued production of the chemical in 2004. At that time, Copperhead acquired the remaining Cytec BT inventory and began looking for another supplier.

In 2007, the Army joined Copperhead in searching the globe for sources of BT. Only one source was identified that could produce at the quantities and quality required, Shanghai Fuda Fine Chemicals located in China. Section 1211 of the National Defense Authorization Act of 2006 has a prohibition on buying items listed on the USML from Communist Chinese military companies. Because Shanghai Fuda Fine is part of the defense industrial base of the People's Republic of China, it is a prohibited source.

The Secretary of the Army approved a waiver in November 2008 to allow the Army to buy BT from China on a one time basis. The Department is currently determining if additional waivers may be required because the International Traffic in Arms Regulation legislation states the Department cannot sell or buy items on the USML from specified countries and embargoed nations, including China.

The Indian Head Division, Naval Surface Warfare Center, has the remaining inventory of BT available for the production of BTTN. They originally acquired 20,000 pounds of BT for a program that was later canceled. Copperhead procured 10,000 pounds of Indian Head's BT in 2007. The Indian Head approved the Army request for the remaining 10,000 pounds from Indian Head which could sustain the Department's needs to March 2010.

The Army is working to develop a domestic source for BT. At this time, there are three organizations working to establish the capability to produce BT – ATK- Radford Army Ammunition Plant; Afid Therapeutics; and BAE-Holston Army Ammunition Plant – that could be used by Copperhead to produce BTTN.

If any of these suppliers left the market, the Department would face significant development and requalification costs. At this time, the AP and HTPB binder issues appear to be under control. The Department is carefully working through the issues associated with BTTN. Another risk area is for a rayon precursor material that does not have a supplier. The rayon precursor material was last produced by the North American Rayon Corporation (NARC) in 1997. The industry has been using a stockpile that is expected to run out around 2011. The SRM prime contractors, the Department and NASA are all working to qualify another source of material to fill the void. Rayon alternatives include C2 rayon prepreg manufactured by SNECMA Moteurs of France. This material has been qualified and flown on the Arianne V. Enka produces a textile rayon, similar to NARC, in Germany that has been qualified by the Shuttle program and also for the first, second and third stages of the D-5. The qualification of Enka, however, is for limited use in the exit cone region, not the throat area of the nozzles. The shuttle program is still using NARC for the throat material. MDA is currently qualifying Enka rayon for use on stages 1,2, and 3 of the Orion SRM used for the GMD program. MDA also is evaluating Lyocell which is manufactured by Lenzing.

In many cases, the subtier suppliers for the large and small SRM industries are the same. This is mostly a result of single sources at the materials level. For the most part, the subtier suppliers are able to provide the materials and produce the components needed by the SRM prime contractors. However, if the market continues to decline, the Department and SRM prime contractors can expect to see subtier suppliers choose to exit the SRM business.

SRM Issues/Concerns

As this report has pointed out, the Department, NASA, and the SRM industry are facing many challenges. Some of these challenges and issues are:

Limited Competitive Opportunities: The SRM industry has very few new competitive opportunities on the horizon. With the exception of the JAGM program, the only possible new program being forecast in the Department will be the DoD-wide CPGS concept demonstrator. The only other competitive opportunity is the Ullage Setting Motor on the NASA Ares I program. All other Ares SRMs have been competed and selected.

No Forecast for Future Systems: The Department does not forecast any new replacement for the MM III or D-5 for years. Without the forecast of future programs, SRM primes do not have the ability to retain or attract the high caliber designers, engineers, or labor workforce needed to design and produce DoD future systems.

Findings

- Both ATK and Aerojet have sufficient capacity, equipment, and expertise to compete for new programs in all business segments.
- The production demand for SRMs is declining:
  - The production demand for large SRMs (space launch, strategic missiles, and some missile defense programs) is significantly lower than historic levels primarily due to the completion of the NASA shuttle program, lower strategic requirements, the completion of the MM III PRP and the expectation of a commercial space launch market that never materialized.
  - The demand for missile defense programs is declining roughly 30 percent over the FYDP.
  - The limited commercial space launch business has strong competition from foreign suppliers.
- There are very few DoD opportunities on the horizon for SRM primes to compete for new systems – only the JAGM and the DoD-wide CPGS in the near term.

- There are no plans for a new strategic missile development as the expected operational lives of the MM III has been extended through 2030 and the Trident II D-5 to 2042.

- DoD funding levels for SRM S&T and R&D are declining significantly over the FYDP – 35 percent.

- Consolidation has occurred in terms of the number of prime contractors (five to two), but the actual rationalization of facilities has been limited affecting utilization rates at remaining facilities (11 facilities to 8 facilities remaining).

- In the large SRM sector, NASA programs (the Shuttle and the Ares) are still the key contributors to the viability of the SRM industrial base – prime and subtier.

- Large SRM facilities are experiencing low capacity utilization rates with little near-term projected demand to improve the current situation.

- There are a number of single and sole source suppliers in the SRM subtier sector.

- The SRM prime contractors have an aging workforce with the average age of both the production workers and the engineers around 50 years old.

- Firms at the prime and subtier levels express difficulty retaining skilled staff given low level of business demand.

- Two SRM materials are only available in rapidly dwindling inventories – BT and rayon precursor.

Conclusions

- The SRM industrial base – both prime and subtier suppliers –is capable of meeting most technological and production requirements.

- Inadequate investments are being made in SRM research and development, reducing the reliability and cost effectiveness of the SRM industrial base. If there are no new development programs, the SRM industry will continue to lose its capability to be able to design and produce new generation SRMs.

- The lack of meaningful production orders and limited development efforts for the next decade is not conducive to the long term well-being of the industry. The SRM industry needs deliberate government research & development (R&D) and production investments with corporate entities willing to invest in internal independent research and development (IRAD) to ensure the continued viability of the industrial base for the Department's current and future systems.

- The tactical and missile defense business segments, which generally use smaller SRMs, are positioned better to maintain their industrial capabilities in the near-term than the strategic and space launch business segments, which generally use large SRMs, because smaller SRMs are supported by multiple programs with more overall funding certainty than larger SRM programs.

- The limited competitive opportunities for SRM activities will make it hard for prime contractors to attract and retain a skilled engineering and manufacturing workforce which in turn will make it difficult to retain the design and engineering expertise necessary to develop and produce our next generation large and small SRMs.

- Delays in the NASA Ares program could have significant negative impact on the large SRM prime contractor industrial base and on some of the SRM subtier base, specifically material suppliers.

- While there has been consolidation at the prime contractor level, the low projected demand for large SRMs may cause ATK to consider rationalizing its large SRM facilities at Promontory and Bacchus to one for more efficient operations. A worst-case scenario from a competition standpoint would be further consolidation in the base reducing the number of primes from two to one. Where possible, government should coordinate its SRM activities to develop strategies that maintain competition.

- For Aerojet and subtier companies, liquid and non-rocket businesses help to keep SRM engineers engaged and absorb overhead costs.

- Foreign military sales (FMS) have had a positive impact on small SRM workload in the industry due to requests for tactical and missile defense weapon systems. However, FMS orders are not predictable and should not be expected to sustain the SRM industrial capabilities.

- Adherence to government environmental regulation, both domestic and foreign, has an adverse impact on the viability of the supplier base.

Assessment #2: Sustaining Strategic SRMs

Recognizing the reduction in large SRM production and R&D programs described in the industrial capabilities assessment, the Department is faced with a significant challenge to sustain its two primary strategic weapon systems – the Air Force Minuteman III (MMIII) Intercontinental Ballistic Missile (ICBM) Weapon System and the Navy Trident Submarine Launched Ballistic Missile (SLBM) D-5 – through their planned operational lives. The Air Force has a requirement to sustain the Minuteman III through fiscal year 2030 (FY 2030). The Navy pushed the service life requirement for the D-5 missile to fiscal year 2042 as the result of the TRIDENT SSBN submarine hull life extension.

Sustaining the Air Force MMIII

Section 139 of the John Warner National Defense Authorization Act for Fiscal Year 2007, Public Law 109-364, required the Air Force to maintain the MM III assets necessary to "sustain the deployed force of such missiles through 2030." The Air Force established an ICBM team to ensure the MM III strategic system can be sustained through its operational life. The ICBM Program Team consists of personnel from both the Air Force ICBM Systems Group and the ICBM Prime Integration Contract (IPIC) working together in integrated product teams (IPT) to sustain the weapon system.

The pre-Propulsion Replacement Program (PRP) motors and the PRP motors are both the same fundamental design. If the PRP motors age similarly to the pre-PRP motors, the first MM III stack to reach the 17 year operational life will be in 2016 and the last MM III stack will reach 17 years in 2026. While the Air Force took steps to address the issues associated with aging, sufficient data will not be available until 2014/2015 to assess the results.

Each of the three current MM III motors (stages 1, 2, and 3) is a unique chemical environment in and of itself, with chemical interactions all their own. As they stand alert for the strategic deterrent mission, their chemical makeup is continually changing, including bond strengths and propellant hardness. In other words, SRMs are chemistry in motion.

Each pre-PRP MM III stack had a design life of 10 years, and the objective that each stage ages out at the same time. However, in practice this plan has not always been realized. MM III stages 1, 2, and 3 have had significantly different aging experiences. Stage 1 first produced in 1959 and continuing through 1978 experienced actual life of 32 years. The first replacement for stage 1 came with the PRP program. MM III stage 2, which was produced from 1964 through 1979, and MM III stage 3, which was produced from 1968 through 1979, reached 17 years actual life. Both stages 2 and

3 were remanufactured in the 1980s and then again during the PRP program. The differences in the aging results should be expected. According to the SRM prime contractors, the motors are designed to last as long as possible. The actual design life is difficult to determine. These motors were also designed using older technology and manufacturing processes. The only way to know for sure how long a motor will last is to have an aging and surveillance program in place.

The Minuteman III solid fuel rocket motors (stages 1, 2, and 3) and their components will be sustained through FY 2030 via an aging surveillance and assessment program to monitor performance capability and age degradation. Field failures and depot actions are assessed with fault isolation and root cause analysis as required. Rocket motor aging surveillance tests will consume four motor sets every three years (three static firings plus one motor dissection for each Stage 1, 2, and 3 motor). Field failures and depot actions are assessed with closed loop failure analysis performed as required. All three stages were remanufactured in the PRP, which renewed age sensitive items and refurbished reusable hardware. Since some unknowns may have been introduced in material changes, new materials are being monitored in the aging surveillance program. Based on the planned assessment program, data gathered for the PRP MM III motors through aging surveillance tests will not be statistically meaningful to the operational MM III force until the 2015 timeframe when sufficient data samples will have been collected to begin showing any life-limiting trends. Northrop Grumman, the IPIC prime contractor, does not expect any life limiting trends for 20 years. They believe the current propulsion for the MM III is supportable to 2030 assuming no life limiting issues are discovered and that other SRM programs maintain the industrial base.

In addition to the specific propulsion hardware sustainment activities described above, other sustainment activities are necessary to sustain the propulsion systems through FY 2030. Depot capability must be maintained to ensure downstage repairs, technical data and parts as needed, and reach back to original equipment manufacturers (OEMs) (ATK, Moog, etc.) must be maintained.

Given an adequate level of operations and support through FY 2030, there are no technical reasons why Minuteman III solid rocket motors could not be maintained at current capabilities through FY 2030. The Air Force PAP program is intended to maintain the necessary technical design and engineering skills necessary to meet future common propulsion system requirements.

This approach is the lower cost but higher risk approach and is dependent on not having any life-limiting trends identified and on the stability of other programs, such as the Trident D-5, to maintain the large SRM industrial base.

Sustaining the Navy D-5

The solid rocket motor manufacturing base for D-5 resides mostly within the commercial industrial community and is dependent on government business to survive. D-5 is the country's submarine-launched strategic deterrent for the next few decades (through 2042). The baseline missile for future U.K. and U.S. strategic submarine platforms is the D-5, which would require additional service life over that currently planned in the program of record. A service life estimate of 30 years for D-5 SRMs is based on best engineering judgment and more than 50 years of past Fleet Ballistic Missile (FBM) experience. Past experience also demonstrates that significant lead times and costs are involved to effect substantial repairs (when possible) or re-establish and qualify new motor production, even with a robust industry base available.

Navy programs have been the continuity at ATK for keeping the strategic production and infrastructure going. This has allowed Air Force and Missile Defense Agency programs to leverage available infrastructure with minimal issues/costs regarding:

- Facility start up
- Availability of skilled/trained operators
- A viable material supply chain
- Specialized tooling cross utilization (particularly Navy retention of MM III tools for a decade or more)

The service life need for D-5 missiles has been pushed to support an unprecedented 43 years (2042 for U.S.) as the result of TRIDENT SSBN submarine hull life extension. This immediately raised several concerns:

- High initial production rates heavily skews the population toward the older side (median age today of 14 years instead of 10 years).
- Program of record requires motor service life far beyond anything Navy FBM has previously demonstrated.
- D-5 flight and ground testing is performed less frequently than previous programs causing less likelihood of detecting an emerging problem.
- Spare motor quantities are low compared to previous programs (only two sets).
- Aging and surveillance programs have been reduced over time due to budget contraints.

Despite its age, the D-5 remains the most advanced missile in the strategic force. It has a much more modernized production process and is vastly more quantifiable due to its more recent design (1980s for the D-5 and 1950s for the MM III). The D-5 is unique for several reasons:

- The Navy uses Class 1.1 high energy propellant instead of the Class 1.3 propellants typically used by Air Force and NASA.
- High energy Class 1.1 propellant is necessary because:
    - U.S. Strategic Command demands adequate payload and long range coverage of key targets for global reach.

- Navy TRIDENT submarines are a volume constrained launch platform. High energy propellant is required to pack as much energy as possible into limited space. (The Air Force can construct a larger silo and NASA can build a larger launch pad.)
- Because the Navy platforms are manned, safety is a key concern. The Navy Class 1.1 propellants have mechanical properties superior to any Class 1.3 propellant for reasons of damage tolerance.
- Nitroglycerine is a key ingredient and manufacturing facilities are limited in the U.S. Also, shipping large quantities over distance is not good safety practice.

The D-5 missile was designed in the 1980s with a service life **GOAL** (not guarantee) of 25 years. By way of comparison, the Polaris (A3) goal was 3 years, the Poseidon (C3) goal was 5 years, and the Trident I (C4) goal was 10 years. All of the FBM systems have been deployed longer than their design service life goals but not without encountering service life issues and problems. Previously, the longest deployed FBM system had been the C4 at 27 years, although nothing older than 22 years was flown before removal from service. Several age related issues were being monitored and its true reliability at retirement is unknown. The Navy is nearing design life (25 years) of Trident II (D-5) on early production missiles (production commenced in 1987 – *tactical motors castings started in 1988*).

Various D-5 production options intended to help sustain the large SRM industrial base have been considered and studied over several years. They can be categorized in three main areas:

- OPTION 1: Continues production at low sustainable rate *(current baseline for FY 2011-2025)*
  - Most cost effective and lowest programmatic risk
  - Provides usable assets to offset aging or other attrition concerns
- OPTION 2: Gap and restart *(estimated total cost is two times more than current baseline for FY 2011-2025)*
  - Saves money in the short term but not long term
    - Involves costly shutdown/startup costs
    - Incurs cost without delivering product
  - Assumes there will be something to restart when the time comes
- OPTION 3: Gap and redesign *(estimated total cost is three times more than current baseline for FY 2011-2025)*
  - Same issues as gap and restart plus others
  - New design will have performance differences
    - Likely to cause ripple effect of costly design changes to other missile subsystems, platform and support infrastructure
  - Risky and costly for a mature missile system like D-5 with tight operating and safety parameters

D-5 has been producing at a minimum sustainable rate of 12 motor sets annually since FY 1999. The President's FY 2009 budget reflected continued motor production through FY 2013. The recent Program Objective Memorandum (POM) 2010 submission recommends continued production of rocket motors. The Navy plan is to continue motor production at a minimum sustainable rate until the rate has to be increased to mitigate a 30 year motor life. The rocket motors design life is 25 years. Based upon current engineering assessments, the Navy anticipates that a 30 year motor service life can be achieved. The Navy Strategic Systems Program (SSP) re-baselined its aging programs in FY 2007 in an attempt to isolate life limiting failure modes. Meanwhile, the SSP motor production budget is being stressed with increased overhead as other government programs end near term and the forecast for sizeable production orders or new starts are long term.

- Minuteman PRP (re-graining) ends FY 2009
- Space Shuttle SRM ends FY 2009, Ares full-rate production years away
- MDA interceptor quantities small and sporadic
    - GMD deliveries ended, small numbers planned 2010-2014
    - KEI in development, no production on contract, future unclear

In summary, continued D-5 production:

- Provides stability in the strategic industrial base
- Enables future systems development and production capabilities
- Addresses many of the concerns/issues in the Congressional tasking

Continuous rocket motor production is the most affordable, lowest cost and least risk option for sustaining the sub-launched strategic deterrent through 2042. The Navy is committed to continuing rocket motor production in order to support D-5 deployment through 2042. The current inventory of D-5 rocket motors is insufficient to support a service life of 30 years.

Appendix A: Acronyms

AARGM	Advanced Anti-Radiation Guided Missile
ABL	Allegany Ballistics Laboratory
AF	Air Force
AMRAAM	Advanced Medium-Range Air-to-Air Missile
AP	Ammonium Perchlorate
ATACMS	Army Tactical Missile System
ATK	Alliant Techsystems
BT	Butanetriol
BTTN	Butanetriol Trinitrate
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CSD	Chemical Systems Division
CWA	Clean Water Act
DoD	Department of Defense
EELV	Evolved Expendable Launch Vehicle
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ESSM	Evolved Sea Sparrow Missile
FBM	Fleet Ballistic Missile
FMS	Foreign Military Sales
FYDP	Future Year Defense Plan
GG	Gas Generator
GMD	Ground-based Missile Defense
GMLRS	Guided Multiple Launch Rocket System
HECT	High Energy Computed Tomography
HMX	Cyclotetramethylene Tetranitramine
HTPB	Hydroxyl-Terminated Polybutadiene
ICBM	Intercontinental Ballistic Missile
IHPRPT	Integrated High Payoff Rocket Propulsion Technology
IPIC	ICBM Prime Integration Contract
IPT	Integrated Product Team
IWG	Interagency Working Group
JAGM	Joint Air-to-Ground Missile
JASSM	Joint Air-to-Surface Standoff Missile
JDAM	Joint Direct Attack Munition
JSOW	Joint Stand-off Weapon
KEI	Kinetic Energy Interceptor
LITVC	Liquid Injection Thrust Vector Control
LV	Launch Vehicle

MD	Missile Defense
MDA	Missile Defense Agency
MEADS/MSE	Medium Extended Air Defense/Missile Segment Enhancement
MLRS	Multiple Launch Rocket System
MM III	Minuteman III
NARC	North American Rayon Corporation
NASA	National Aeronautics and Space Administration
NEPE	Nitrate Ester Polyether
NG	Nitroglycerine
NIROP	Navy Industrial Reserve Ordnance Plant
NLOS PAM	Non-Line of Sight Precision Attack Missile
OEM	Original Equipment Manufacturer
PAC-3	Patriot Advanced Capability -3
PAP	Propulsion Application Program
PBCS	Post Boost Control System
PGS	Prompt Global Strike
POM	Program Objective Memorandum
PRP	Propulsion Replacement Program
RAM	Rolling Airframe Missile
RCRA	Resource Conservation and Recovery Act
R&D	Research and Development
RDT&E	Research, Development, Test and Evaluation
RSRM	Reusable Solid Rocket Motor
RSRMV	Reusable Solid Rocket Motor - Five Segment Motor
SAG	Strategic Advisory Group
SDWA	Safe Drinking Water Act
S&A	Safe and Arm
S&T	Science & Technology
SDACS	Solid Divert and Attitude Control System
SICBM	Small Intercontinental Ballistic Missile
SLBM	Submarine-Launched Ballistic Missile
SM-3	Standard Missile 3
SM-6	Standard Missile 6
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SSBN	Fleet Ballistic Missile Submarines
SSP	Strategic Systems Program (Navy)
STRATCOM	United States Strategic Command
TDACS	Throttling Divert and Attitude Control System
THAAD	Terminal High-Altitude Area Defense
TOW 2	Tube-launched Optically-tracked Wire-guided 2
TSCA	Toxic Substance Control Act
TSRM	Third Stage Rocket Motor
TSSS	Technology for Sustainment of Strategic Systems
TVC	Thrust Vector Control

USML	United States Munitions List

Appendix B: DoD Funding Missile Funding Profiles

DoD Missile Procurement Funding ($M)
bv Business Seament FY 07 – TY 13

Missile Segment	Program	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Strategic Missiles	Trident II Mods	$ 914.40	$ 1,044.70	$ 1,093.20	$ 1,100.40	$ 1,113.30	$ 1,134.20	$ 1,150.90
	MM III PRP	$ 252.20	$ 249.10	$ 62.60	$ -	$ -	$ -	$ -
Total Strategic Missiles		$ 1,166.60	$ 1,293.80	$ 1,155.80	$ 1,100.40	$ 1,113.30	$ 1,134.20	$ 1,150.90
Tactical Missiles	Hellfire	$ 244.50	$ 91.10	$ 207.60	$ 180.40	$ 113.70	$ 60.70	$ 103.30
	GMLRS	$ 125.00	$ 201.80	$ 247.20	$ 311.30	$ 341.40	$ 368.40	$ 369.40
	MLRS Reduced Range	$ 20.80	$ 22.40	$ 25.30	$ 19.90	$ 20.40	$ 20.80	$ 21.30
	ATACMS	$ 76.30	$ -	$ -	$ -	$ -	$ -	$ -
	Javelin	$ 158.10	$ 166.80	$ 259.30	$ 141.00	$ 0.20	$ 3.60	$ 6.70
	TOW 2	$ 31.40	$ 87.30	$ 86.00	$ 46.00	$ 61.40	$ 11.80	$ 19.20
	Tomahawk	$ 353.00	$ 380.50	$ 281.10	$ 290.00	$ 304.80	$ 334.30	$ 337.10
	AMRAAM	$ 202.50	$ 280.20	$ 441.50	$ 431.00	$ 454.80	$ 479.40	$ 500.20
	AIM-9X Sidewinder	$ 83.90	$ 106.80	$ 134.70	$ 138.00	$ 121.30	$ 125.50	$ 127.60
	NLOS PAM	$ -	$ 12.30	$ 56.90	$ 131.80	$ 240.40	$ 275.10	$ 306.00
	Hydra 70	$ 168.10	$ 156.90	$ 142.50	$ 148.50	$ 123.80	$ 177.00	$ 243.80
	RAM	$ 56.60	$ 75.50	$ 74.30	$ 76.40	$ 87.70	$ 89.50	$ 91.30
	ESSM	$ 99.10	$ 82.70	$ 85.10	$ 74.40	$ 14.60	$ 9.90	$ 3.20
	AGM-65 Maverick	$ 0.20	$ 0.30	$ 0.30	$ 0.30	$ 0.30	$ 0.30	$ 0.30
Total Tactical Missiles		$ 1,619.50	$ 1,664.60	$ 2,041.80	$ 1,989.00	$ 1,884.80	$ 1,956.30	$ 2,129.40
Missile Defense	Patriot PAC-3	$ 494.60	$ 469.70	$ 512.10	$ 21.00	$ -	$ -	$ -
	Patriot/MEADS	$ -	$ -	$ 31.00	$ 400.20	$ 668.50	$ 1,032.90	$ 1,305.60
	THAAD	$ 913.11	$ 865.92	$ 843.10	$ 660.33	$ 561.93	$ 383.12	$ 263.80
	GMD	$ 2,985.14	$ 2,243.21	$ 2,076.66	$ 1,748.07	$ 1,385.26	$ 946.44	$ 1,103.53
	Standard Missile	$ 137.00	$ 158.60	$ 228.00	$ 298.60	$ 370.40	$ 572.70	$ 644.90
Total Missile Defense		$ 4,529.85	$ 3,737.43	$ 3,690.87	$ 3,128.20	$ 2,986.09	$ 2,935.16	$ 3,317.84
Space Launch	EELV	$ 852.05	$ 1,091.84	$ 1,205.28	$ 1,402.52	$ 1,101.79	$ 1,567.58	$ 1,266.91
Total Space Launch		$ 852.05	$ 1,091.84	$ 1,205.28	$ 1,402.52	$ 1,101.79	$ 1,567.58	$ 1,266.91
Total Missiles		$ 8,168.00	$ 7,787.67	$ 8,093.75	$ 7,620.12	$ 7,085.98	$ 7,593.24	$ 7,865.05

Source: DoD FY 2009 President's Budget dtd, February 2008

Note: THAAD and GMD production programs are RDT&E funded

DoD Missile Procurement Funding ($M)
bv SRM Prime FY 07 – TY 13

SRM Prime Contractor	Program	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Aerojet	Patriot PAC-3	$ 494.60	$ 469.70	$ 512.10	$ 21.00	$ -	$ -	$ -
	Patriot/MEADS	$ -	$ -	$ 31.00	$ 400.20	$ 668.50	$ 1,032.90	$ 1,305.60
	Javelin	$ 158.10	$ 166.80	$ 259.30	$ 141.00	$ 0.20	$ 3.60	$ 6.70
	GMLRS	$ 125.00	$ 201.80	$ 247.20	$ 311.30	$ 341.40	$ 368.40	$ 369.40
	MLRS Reduced Range	$ 20.80	$ 22.40	$ 25.30	$ 19.90	$ 20.40	$ 20.80	$ 21.30
	ATACMS	$ 76.30	$ -	$ -	$ -	$ -	$ -	$ -
	THAAD	$ 913.11	$ 865.92	$ 843.10	$ 660.33	$ 561.93	$ 383.12	$ 263.80
	Standard Missile	$ 137.00	$ 158.60	$ 228.00	$ 298.60	$ 370.40	$ 572.70	$ 644.90
	Atlas V SRB							
Aerojet Total		$ 1,924.91	$ 1,885.22	$ 2,146.00	$ 1,852.33	$ 1,962.83	$ 2,381.52	$ 2,611.70
ATK	Hellfire	$ 244.50	$ 91.10	$ 207.60	$ 180.40	$ 113.70	$ 60.70	$ 103.30
	Hydra 70	$ 168.10	$ 156.90	$ 142.50	$ 148.50	$ 123.80	$ 177.00	$ 243.80
	TOW 2	$ 31.40	$ 87.30	$ 86.00	$ 46.00	$ 61.40	$ 11.80	$ 19.20
	Tomahawk	$ 353.00	$ 380.50	$ 281.10	$ 290.00	$ 304.80	$ 334.30	$ 337.10
	AMRAAM	$ 202.50	$ 280.20	$ 441.50	$ 431.00	$ 454.80	$ 479.40	$ 500.20
	AIM-9X Sidewinder	$ 83.90	$ 106.80	$ 134.70	$ 138.00	$ 121.30	$ 125.50	$ 127.60
	RAM	$ 56.60	$ 75.50	$ 74.30	$ 76.40	$ 87.70	$ 89.50	$ 91.30
	ESSM	$ 99.10	$ 82.70	$ 85.10	$ 74.40	$ 14.60	$ 9.90	$ 3.20
	NLOS PAM	0	$ 12.30	$ 56.90	$ 131.80	$ 240.40	$ 275.10	$ 306.00
	AGM-65 Maverick	$ 0.20	$ 0.30	$ 0.30	$ 0.30	$ 0.30	$ 0.30	$ 0.30
	MM III PRP	$ 252.20	$ 249.10	$ 62.60	$ -	$ -	$ -	$ -
	GMD	$ 2,985.14	$ 2,243.21	$ 2,076.66	$ 1,748.07	$ 1,385.26	$ 946.44	$ 1,103.53
	Trident II Mods	$ 914.40	$ 1,044.70	$ 1,093.20	$ 1,100.40	$ 1,113.30	$ 1,134.20	$ 1,150.90
	Delta IV GEM							
ATK Total		$ 5,391.04	$ 4,810.61	$ 4,742.46	$ 4,365.27	$ 4,021.36	$ 3,644.14	$ 3,986.43
Total Missiles		$ 7,315.95	$ 6,695.83	$ 6,888.47	$ 6,217.60	$ 5,984.19	$ 6,025.66	$ 6,598.14

Source: DoD FY 2009 President's Budget dtd, February 2008

Note: THAAD and GMD production programs are RDT&E funded

Foreign Military Sales (FMS) for Missiles
FY 2002 – FY 2008

Summary FMS for Missiles Fiscal Years 2002-2008							
	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
Missiles Delivered	$ 719,971,993.00	$ 565,616,953.00	$ 152,787,460.00	$ 282,804,169.00	$ 35,401,418.00	$ 4,660,578.00	$ -
Missiles Accepted	$ 93,601,749.00	$ 229,819,154.00	$ 420,585,811.00	$ 945,553,384.00	$ 1,139,023,100.00	$ 473,001,689.00	$ 2,049,709,451.00
Total FMS	$ 813,573,742.00	$ 795,436,107.00	$ 573,373,271.00	$ 1,228,357,553.00	$ 1,174,424,518.00	$ 477,662,267.00	$ 2,049,709,451.00

Source: DCSA 1200 System data

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Appendix C: Comparing SRMs

Comparing Space Shuttle RSRM to other SRMs		
Program	Lbs. Propellant	Equivalent # of SRMs for one Shuttle RSRM
Shuttle RSRM	1,106,059	1
Ares RSRMV	1,427,807	1
D5	110,200	10
Castor 120	108,036	10
Atlas V SRB	81,201	14
MM III	66,642	17
GEM 60	65,471	17
GMD	43,469	25
GEM 46	37,180	30
GEM 40	25,960	43
Castor IVB	21,990	50
KEI	20,026	55
SM-3	2,034	544
SM-6	1,826	606
ATACMS	1,595	693
SM-2	791	1,398
Patriot PAC-3	350	3,160
Patriot/MEADS	350	3,160
Tactical Tomahawk	325	3,403
ESSM	265	4,174
GMLRS	216	5,121
MLRS Reduced Range	216	5,121
AMRAAM	113	9,788
AGM-65 Maverick	76	14,553
RAM	60	18,434
AIM-9X	60	18,434
NLOS PAM	31	35,679
Hellfire	20	55,303
TOW 2	7	158,008
Javelin	3	368,686
Stinger	3	368,686

Source: ATK and Aerojet

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Appendix D: Research and Development Funding ($M)

DoD Programs with RDT&E going to SRMs	**FY 2007**	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**	**FY 2012**	**FY 2013**
Army Patriot/MEADS MSE	$ 11.00	$ 5.80	$ 8.00	$ 11.71	$ 8.50	$ 8.67	$ 1.54
Joint Air-to-Gound Missile (JAGM)	$ -	$ 3.39	$ 9.04	$ 10.46	$ 12.30	$ 13.26	$ 10.65
Non-line-of-Sight (PAM)	$ 6.82	$ 7.41	$ 6.71	$ 1.20	$ 0.18	$ -	$ -
GMLRS	$ 5.62	$ 5.80	$ 6.75	$ 1.82	$ 0.34	$ 0.35	$ 0.35
Standard Missile - 6 (SM-6)	$ 31.69	$ 40.53	$ 44.51	$ 31.85	$ 13.71	$ 6.62	$ 5.34
Subtotal Programs w/RDT&E going to SRMS	$ 55.12	$ 62.92	$ 75.01	$ 57.05	$ 35.03	$ 28.90	$ 17.88

Note: This table was developed using the percent SRM to unit cost percentage.

Note: Patriot/MEADS Missile Segment Enhancement (MSE) for FY 10-13 is estimated at 2% of the total based on the actual numbers from FY 07-09.

Note: The JAGM is estimated at 5 percent of the total funding because the SRM is estimated to be 5 percent of the unit cost.

Note: NLOS-PAM funding is estimated at 60% of total for FY 10-11 and is only for the PAM and excludes funding for the Container Launch Unit (CLU) – The SRM is estimated at 5 percent of the unit cost

Note: GMLRS is estimated at 13 percent of the total funding cost because the SRM is 13 percent of the unit cost.

Note: SM-6 SRM is estimated at 20 percent of the total funding because the SRM is roughly 20 percent of the unit cost.

S&T Program	**FY 2007**	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**	**FY 2012**	**FY 2013**
AF Aerospace Propulsion/Rocket Propulsion Technology*	$ 18.52	$ 10.65	$ 9.19	$ 10.70	$ 7.51	$ 11.76	$ 12.07
AF Aeropspace Propulsion and Power Technology/Space and Missile Rocket Propulsion	$ 4.65	$ 4.70	$ 5.08	$ 2.09	$ 2.85	$ 5.47	$ 4.12
AF Materials Applied Research/ Space Materials Development	$ 2.00	$ 0.50	$ -	$ -	$ -	$ -	$ -
AF Advanced Materials	$ 1.00	$ -	$ -	$ -	$ -	$ -	$ -
Navy Power Projection/Strategic Sustainment	$ 13.38	$ 6.66	$ -	$ -	$ -	$ -	$ -
Navy Power Projection/High Speed Propulsion	$ 4.00	$ 4.00	$ 4.00	$ -	$ -	$ -	$ -
Army Missile Technology/ Missile Technology	$ 6.23	$ 8.24	$ 7.28	TBD	TBD	TBD	TBD
Army Missile and Rocket Advanced Technology	$ 1.20	$ 1.29	$ 2.39	TBD	TBD	TBD	TBD
OSD Insensitive Munitions	4.1	5	6	6	6	6	6
OSD Insensitive Munitions AT	$ -	$ 1.60	$ 6.40	$ 6.00	$ 8.30	$ 7.10	$ 9.90
Subtotal Science & Technology	**$ 55.07**	**$ 42.65**	**$ 40.34**	**$ 24.80**	**$ 24.66**	**$ 30.33**	**$ 32.10**

Source: DoD FY 2009 President's Budget dtd, February 2008

Propulsion Application Program	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
AF Propulsion Application Program	$ 13.59	$ 8.71	$ 29.52	$ 35.98	$ 38.12	$ 40.11	$ 41.29
Navy Propulsion Application Program	$ 17.15	$ -	$ -	$ -	$ -	$ -	$ -
Propulsion Application Program	**$ 30.74**	**$ 8.71**	**$ 29.52**	**$ 35.98**	**$ 38.12**	**$ 40.11**	**$ 41.29**

Note: Air Force PAP for SRMs in FY 2010 - 2013 is estimated at 85% of total; 85% used because that's the percentage in FY 2009.