Aviation Week Program Excellence Award

eSR-73 Solid Rocket Motor Pathfinder Program

Submitted by:
Aerojet Rocketdyne, Inc.

May 2022

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Aviation Week Program Excellence

eSR-73 Solid Rocket Motor Pathfinder Program

Aerojet Rocketdyne's eSR-73 Solid Rocket Motor (SRM) Pathfinder represents part of a $100M effort to transition, expand, modernize, and transform its large SRM development and production capabilities

CATEGORY: SPECIAL PROJECTS

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(This section must be signed)

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Thank you for participating,

Gregory Hamilton
President
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Acknowledged, agreed, and submitted by

Michael Krogen — 25 May 2022

Nominee's Signature — Date

Nominee's Name (please print): Michael Krogen

Title (please print): eSR-73 Program Manager

Company (please print): Aerojet Rocketdyne

NOMINATION FORM

Name of Program: eSR-73 Solid Rocket Motor Pathfinder Program

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- ☐ Customer Approved - Not applicable – AR Internal Research and Development Program
  - Date: ____
  - Customer Contact (name/title/organization/phone): ______________________________
- ☐ Supplier Approved (if named in this nomination form) Not applicable
  - Date: ____
  - Supplier Contact (name/title/organization/phone): ______________________________

PLEASE REFER TO PROGRAM EXCELLENCE DIRECTIONS
AS YOU COMPLETE THIS FORM.

EXECUTIVE SUMMARY: MAKE THE CASE FOR EXCELLENCE *(VALUE: 10 PTS)*
What is the vision for this program/project? What unique characteristics and properties qualify this program for consideration?

Aerojet Rocketdyne's eSR-73 Solid Rocket Motor (SRM) Pathfinder represents part of a $100M effort to transition, expand, modernize, and transform its large SRM development and production capabilities.

With an eye towards the future, Aerojet Rocketdyne (AR) made bold moves in the past five years to improve long-term affordability of propulsion products for its defense customers. The focus was primarily on:

- Increased Product Affordability
- Reduced Overhead Costs
- Optimized Facilities.

The eSR-73 pathfinder program led the way for the newest large solid rocket motor facilities in the world

- Consolidation into new optimized facilities and organizational structure provides AR customers with potential cost improvements in an industry that hasn't significantly changed since the 1980s
- The eSR-73 design, manufacture and test represents the first tangible result of this bold effort

The Ground Based Strategic Deterrent weapon system (now called Sentinel) represented one of the largest SRM new business opportunities in a generation. To prepare for that and other comparable opportunities, AR created and implemented a strategy to transform the way we design, develop, and manufacture large SRMs. This strategy included assessment and modification of virtually every aspect of our large SRM business model. Key tenets of that strategy included:

- Transitioning key large SRM capability (Program Management, Engineering, Operations) from sites where it had been resident for decades
- Pursuing affordability through technology selections that allowed reduced costs in procurement, long term stability to reduce obsolescence risk, and development of long-life propellants.

Through this strategy, AR made the tough decision to abandon the growing inefficiencies of the past to position for a streamlined and lean future, investing over $100M towards that goal. The eSR-73 was the first large SRM designed at the newly-established Huntsville, AL, headquarters facility and it was the first SRM cast in the new large motor complex in Camden, AR.

The eSR-73 project completed in September 2021 with the successful static firing of the SRM in the Camden, AR, facility (Figure 1). Through eSR73, AR validated the successful transition and expansion of large SRM capabilities to new, modernized facilities. Michael Krogen led as program manager.

Figure 1. Static Test of the eSR-73 on September 15, 2021, validating the cost reduction, technology insertion and modernization efforts taken by Aerojet Rocketdyne.

VALUE CREATION *(Value: 15 pts)*

Please respond to the following prompt:

- Clearly define the value of this program/project for the corporation
- Clearly define the value of this program/project to your customer
- Clearly define the value of this program/project to members of your team
- Clearly define the contribution of this program/project to the greater good (society, security, etc.)

The design, manufacture, and static test of the eSR-73 validated the investments made by Aerojet Rocketdyne towards cost reduction, technology insertion and modernization efforts.

Potential eSR-73 customers benefit from lower cost for solid rocket motors.

Team members benefited from the knowledge transfer from our senior engineers to our younger workforce as they learned how to make larger sold rocket motors.

The effort lowers the risk and cost for Northrop Grumman and the US Air Force's Sentinel Stage 3 motor, the Missile Defense Agency's Next Generation Interceptor, and other large SRMs for the national defense of the United States.

METRICS (Value: 15 pts)

Please respond to the following prompt:

- What are your predictive metrics?
- How did you perform against these metrics?
- How do your predictive metrics drive action toward program excellence? Please provide examples.

Aerojet Rocketdyne uses primarily two types of predictive metrics, Program Cost Metrics and SRM Performance Metrics.

In 2017, AR determined that it needed to look at what it would take to be cost-competitive in the future. The scope included a broad reimagining of what we wanted to look like by 2030. We noted three major organizational goals:

- Increase Product Affordability through Lean Manufacturing
- Reduce Overhead Costs
- Optimized Facilities.

The two predictive metrics for this effort reflect our new business processes and are discussed below.

PROGRAM COST METRICS

The eSR-73 program produced the first cost and performance data that reflected the company-wide transformation of our cost structure. To increase product affordability, AR's goals were to:

- Reduce direct labor and material costs
- Drive greater utilization of lean manufacturing initiatives.

The measure of success for this metric is lower prices for our customers.

These efforts result in significant cost reductions across our Defense Business Unit. Three representative programs highlight the improvements:

- Program A, a mature, full rate production program, reduced the price 13%
- Program B, a program that transitioned from low rate production to full rate production program, reduced the price 48%
- Program C, a program that transitioned from low rate production to full rate production program, reduced the price 35%

We fully expect to see similar cost reductions for the manufacture of eSR-73 and other large SRMs made in Camden.

Through a careful review of our projected future needs, AR also developed a plan to decrease administrative & overhead costs. We consolidated our personnel and purchasing services into a "shared services" model for the entire Defense Business Unit. This reduced costs by better allocating indirect costs over the entire Defense organization, rather than having site-specific personnel for each area.

Because of these changes, AR saw a significant reduction in overhead costs, with a reduction of almost 20%. This translated to lower overall costs for our products, including on the eSR-73 SRM.

We also developed a plan for the future needs of the organization and the facilities required to support them. This allowed AR to unburden itself from the ghosts of the past, removing excess capacity and high maintenance costs.

AR consolidated sites with duplicate capabilities into the site with lowest cost. This allowed for the reduction of the overall facility footprint. AR invested approximately $100M in modern, efficient factories with state-of-the-art equipment and best-in-class processes.

We chose our Camden, AR facility to be our solid propulsion Center of Excellence. The site has over 40 years of efficient cost SRM manufacturing experience, with over 185 million pounds of HTPB propellant produced to date. It currently has a significant production base efficiently supporting a diverse mix of products, including Javelin, Stinger, THAAD, ATACMS, Coyote, PAC-3, Tactical Tomahawk, and Standard Missile. Camden also has a legacy of successful program transitions from other sites including taking programs from development to production, making it the logical choice as our center of excellence.

SOLID ROCKET MOTOR PERFORMANCE METRICS

To measure progress towards objectives on the eSR-73 program, two sets of key performance metrics were established and tracked: eSR-73 SRM Performance, and eSR-73 SRM Cost.

SRM performance of various vehicle configurations and technologies is predicted by AR's IMPULSE digital engineering performance optimization model (Figure 2). Given a set of constraints, IMPULSE will generate surface response maps to display the sensitivity and optimum values to the parameters of interest.

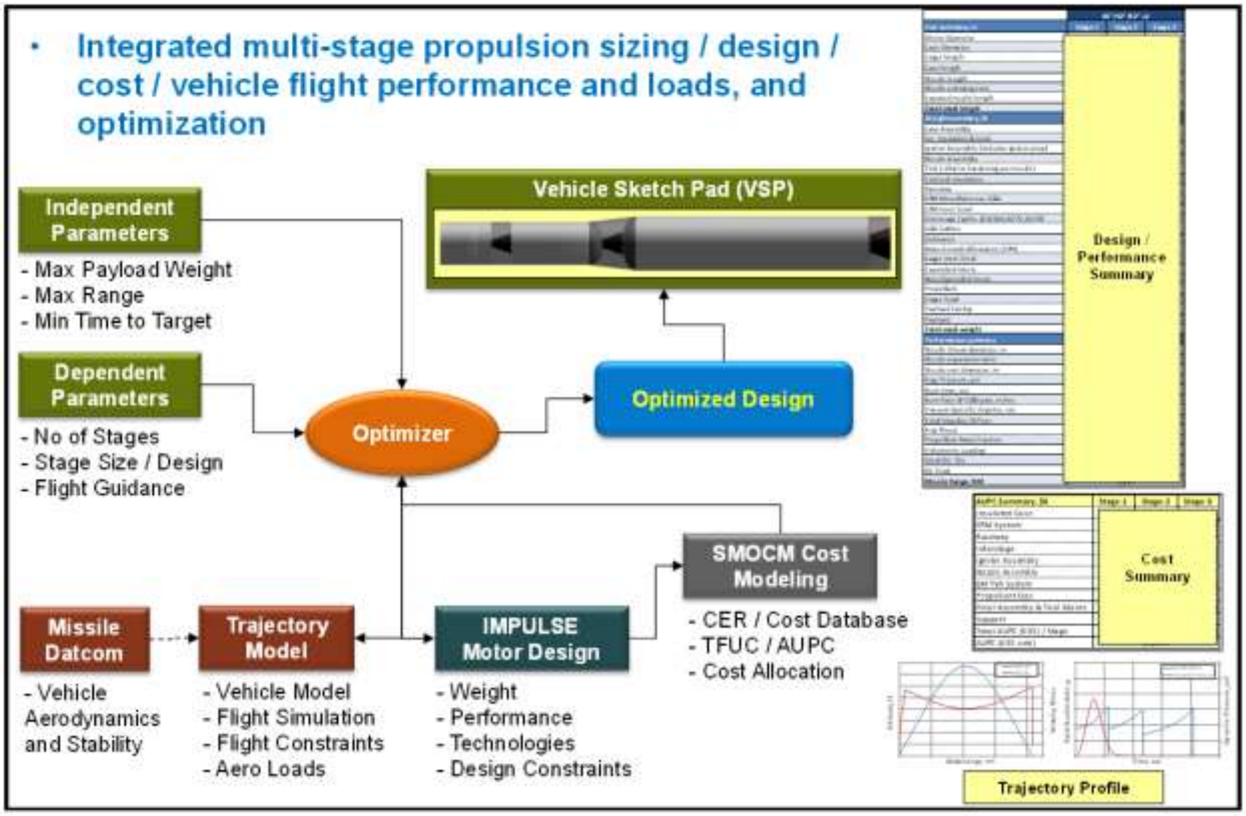

Figure 2. The AR Impulse tool demonstrates the advantages of Digital Engineering

AR used the IMPULSE tool to closely match the performance of the eSR-73 to the Minuteman III Stage 3 motor (SR-73), using modern materials and updated manufacturing techniques. Figure 3 shows a comparison between eSR-73 predicted and the eSR-73 demonstrated performance. The tool's performance was validated when the motor was static tested. The performance prediction agreed within 0.8% of the actual test data.

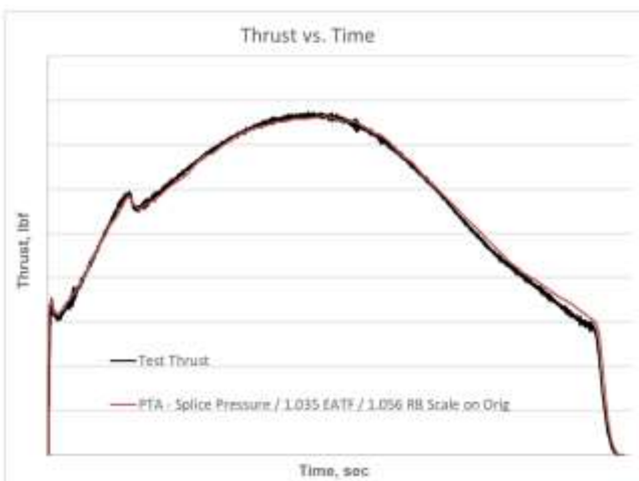

Figure 3. eSR-73 IMPULSE Performance Prediction vs. "As Tested" Data predicted motor total impulse within 0.8% of measured data.

AR uses a special proprietary code as a parametric cost estimation tool. Both recurring and non-recurring costs can be modeled. The model is anchored by detailed costs for labor tasks, component costs and raw material costs. Lifecycle costs were assessed by imposing constraints on service life and by the selection of technologies that have low risk of obsolescence during production. These cost models were integrated into the IMPULSE performance model to create a multidisciplinary cost/performance model. This integrated cost/performance model has since been used in the concept trade phase of other medium and large solid rocket motor opportunities. This data was then used to inform the Design to Cost effort and then validated during the program with actual costs.

DEALING WITH PROGRAM COMPLEXITY (VOLATILITY, UNCERTAINTY, COMPLEXITY, AMBIGUITY, OR VUCA) *(Value: 25 pts)*

Please respond to the following prompts:

- *10 pts:* Describe areas of VUCA faced by your program and why.
- *15 pts:* Explain how your team responded to these challenges.

The eSR-73 program plan was established at the beginning of Aerojet Rocketdyne's Competitive Improvement Program Phase 2 (CIP-2). Key components of CIP-2 were the closing of the Sacramento, CA and Gainesville, VA facilities, transitioning of liquid propulsion programs to the Canoga Park, CA, and Redmond, WA, facilities, and transitioning solid propulsion manufacturing to the Camden, AR, facility. AR also stood up a new Defense Headquarters and an inert component manufacturing facility in Huntsville, AL.

This extensive relocation of talent resulted in a loss of experienced personnel at a time when US defense budgets were rising rapidly, bringing on a rate of new propulsion program starts not seen in many decades. We were faced with integrating a team in a new location. We had to find a way to be successful, despite facing challenges such as:

- Finding new talent to staff our engineering center and new operations facilities
- Using a large number of recent college graduates with little or no industry experience
- The loss of experienced engineers and their institutional knowledge
- The modification and adaptation of established design and manufacturing processes to new locations.

The successful test firing of the eSR-73 demonstrated that AR successfully navigated the massive uprooting of our decades-old locations and re-establishment at the new sites.

That did not come easy, however. The initial eSR-73 case design failed its pressure proof test, well below the expected failure pressure. The setback forced a major redesign. The design team, with many new engineers, overcame the issues and successfully improved the case design to pass on the second attempt.

ORGANIZATIONAL BEST PRACTICES AND TEAM LEADERSHIP *(Value: 35 pts)*

Please respond to the following prompts

- *15 pts:* Describe the innovative tools and systems used by your team
- *10 pts:* Define how you developed, led and managed people
- *10 pts:* How did you leverage skills and technologies of your suppliers?

The new eSR-73 Engineering team had a diverse background of experiences from the Sacramento, Gainesville and Orange, VA facilities, as well as new hires from across the country. Most of the team was new to AR and brought their own design experience from other companies and industries. The closure of the Sacramento facility also changed the manufacturing locations and processes.

INNOVATIVE SITE CONSOLIDATION EFFORTS

In order to ensure that we maintained a highly skilled workforce in the transition, we offered attractive retention & relocation incentives for critically skilled personnel. We experienced relocation and retention rates far above the expected rates (Figure 4).

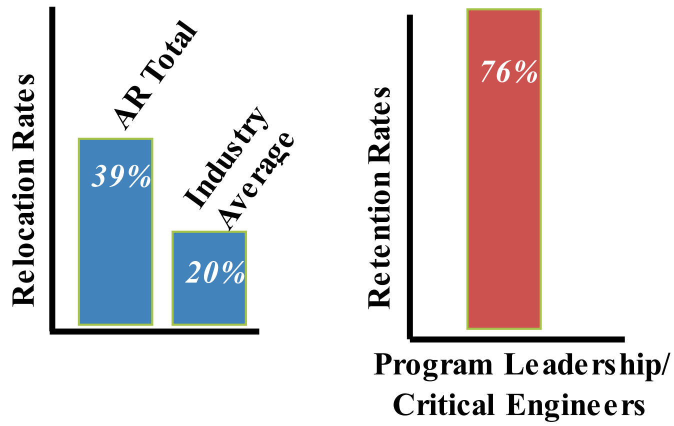

Figure 4. Relocation and retention rates were significantly higher than industry average, minimizing the disruption on the workforce for our SRM business.

One of the most effective ways of convincing people to relocate to our Engineering Center in Huntsville was to bring both the prospective transfer employee (and spouse) to see and spend a week in the area. By collaborating with the City of Huntsville, AL, we were able to give folks a chance to see the area, meet with realtors and explore their interests in the area. By getting a chance to see the area and learn from local employees, city officials, and the relators, many were convinced to make the move.

For our Camden AR facility, we focused on growing and educating the local workforce. We worked closely with the state and local governments to provide additional training and educational opportunities. As a result, AR is the largest employer within a 50-mile radius of our plant. We are also proud to have a number of third generation employees at the facility.

As a result of the site transition, AR's workforce got younger; the refresh of the workforce is a more controlled and conscious process before the retirement-eligible wave crashes upon us. Most of our new personnel will have 4-8 years overlap before we expect to see the most experienced personnel retire. This ensures that we "don't lose the recipe" as we go forward in the future (Figure 5).

Figure 5. eSR-73 Chief Engineer Bob Knoop (left) and Program Manager Mike Krogen (right) were key mentors to Project Engineer Kendall Dalkiewicz (center).

RETAINING KEY INSTITUTIONAL KNOWLEDGE

Because of the differences in processing approaches between large SRMs previously manufactured in Sacramento and the smaller motors made in Camden, we developed a detailed knowledge transfer process for those personnel not making the transition. The eSR-73 was the first large, multi-mix motor to exercise this knowledge transfer.

To address the new engineering staff, enhanced peer review processes were established to cross-train team members on established best practices and in critical thinking skills, asking questions to understand why successful designs worked. Formal Engineering Review Boards were conducted for key analyses and for all hardware discrepancies to provide a multidisciplinary review of all design changes.

Our investment in pathfinder motors (both the eSR-73 and the soon-to-be tested eSR-19) provide considerable knowledge transfer and workforce training for future large SRM production. Key areas included:

- SRM filament wound carbon fiber case design
- Moveable Nozzle Flexseal design
- Case, nozzle, propellant casting, and motor finishing tool design
- Material handling

- Multi-mix bowl propellant manufacture and casting production approaches.

Best practices were captured from Sacramento operations and transferred to Huntsville Engineering and Camden Operations personnel.

INNOVATIVE PROCESSES – AR 3P MANUFACTURING PROCESS TRANSFER FOR LARGE SRMS

AR uses the Lean Production Preparation Process (3P) as one of our tools for process improvement and waste elimination. As our largest production facility, Camden, AR uses the 3P process including simulation and analysis tools extensively to plan new production facilities and improve existing ones.

Manufacturing techniques differ between small SRMs and large SRMs. To help capture and understand those differences, and to layout a facility dedicated to the manufacture of large SRMs, AR performed an initial 3P event. A cross-functional engineering team included representatives from Design, Manufacturing, Quality, Operations, and Safety. The team concentrated on process flow, facilities, special tooling and support equipment. This initial simulation informed the final site layout, process flow, unique tooling and machinery needed in production.

LEVERAGING UNIQUE SUPPLIER SKILLS

One of the challenges we faced was the timely design and construction of our new facilities for the eSR-73. Typically, AR uses local contractors for building construction. Due to the accelerated schedule to get this facility on line to support the GBSD program, we had to open up the competition to a broader area. While it cost a bit more up front, we used a national firm that brought in the construction crews. We cut at least 6 months off the schedule with this process.

Manufacturing process development used a strategy to develop or maintain two sources for every component. This promoted long-term competition. It also provided protection if a company experienced yield issues or, as sometimes happened, chose to exit that business. Every component had planned process development and scheduled pathfinder hardware fabrication.

SUMMARY

Rocket propulsion is Aerojet Rocketdyne's (AR) core business. Aerojet Rocketdyne made the tough decision to consolidate facilities and relocate people to better position it for future business. The AR eSR-73 Pathfinder (Figure 6) represents part of an approximately $100M effort to expand and modernize its large sold rocket motor production capabilities.

Figure 6. The eSR-73 was a successful pathfinder for the transition of our large SRM manufacturing capabilities to our Camden, AR facility.