PRESENTATION

# Rocket Motor Study

## DUSD(A&T) Business Process Review

Office of the Under Secretary of Defense
for Acquisition, Technology & Logistics/
DUSD(A&T)/PSA/LW&M
23 October 2008

# Background

- Concept Decision Review of March 2007

**Joint Air-to-Ground Missile**

**"The DUSD(A&T) will lead a Business Process Review to determine whether the projected 54-60 month development/certification time for rocket motors can be streamlined."**

**Concept Decision Memorandum of May 1, 2007**

# Purpose

- Provide overview of the methodology, results of the review, and next steps

# Approach

- Service Acquisition Executive buy-in up front
- Formed a Rocket Motor IPT - Service PEOs, OSD
- Selected a methodology for the review
  - Lean Six Sigma
- Formed a Project team – Nationwide SMEs from Service labs
- IPT used to oversee project

# Project Goal, Objective and Scope

- **Goal – Provide a recommendation on how to reduce the cycle time for the development and certification of rocket motors with an initial focus on joint weapons**
- **Objective - Develop a streamlined process for joint rocket motor development and certification with a duration of less than 5 years**
- **Scope**
  - All activities from concept decision to IOC, but focus on B to C
  - Qualification of rocket motor energetics
  - Development and test of rocket motor
  - Integration of rocket motor to weapon system
  - Integration of weapon system on the platform (aircraft, submarine, helicopter, surface ship, land-based, man-carried, ground vehicle)
- **Out of Scope**
  - Platform modifications
  - Other weapon components and system components

# Initial Assumptions

- Rocket motor is considered the critical path
- Service-unique requirements drive delays in joint development and/or certification of rocket motors
- Opportunities exist to lean the rocket motor process
- Rocket motor study can pilot the new/revised process with JAGM project
- IPT members and SMEs will be supportive with resources and hold to the project schedule
- All components will be ready to integrate with rocket motor (i.e., platform, other parts of the missile to include the warhead and guidance, etc.)
- Policy and regulations can be changed, if necessary

# Design for Six Sigma

## Define

- Identify key players
- Perform stakeholder analysis
- Create charter
- High-level process

## Measure

- Create detailed process maps
- Collect customer requirements and translate into design requirements
- Collect baseline data
- Prioritize requirements
- Benchmark organizations with world-class process/product

## Analyze

- Generate concepts which meet design requirements
- Organize potential causes for existing process failures
- Select concept for further analysis and design
- Develop high-level design (blueprint)

## Design

- Design detailed process/product
- Evaluate and select design/concept
- Test the design
- Pilot the design
- Develop pilot plan(s)
- Prepare for full-scale deployment

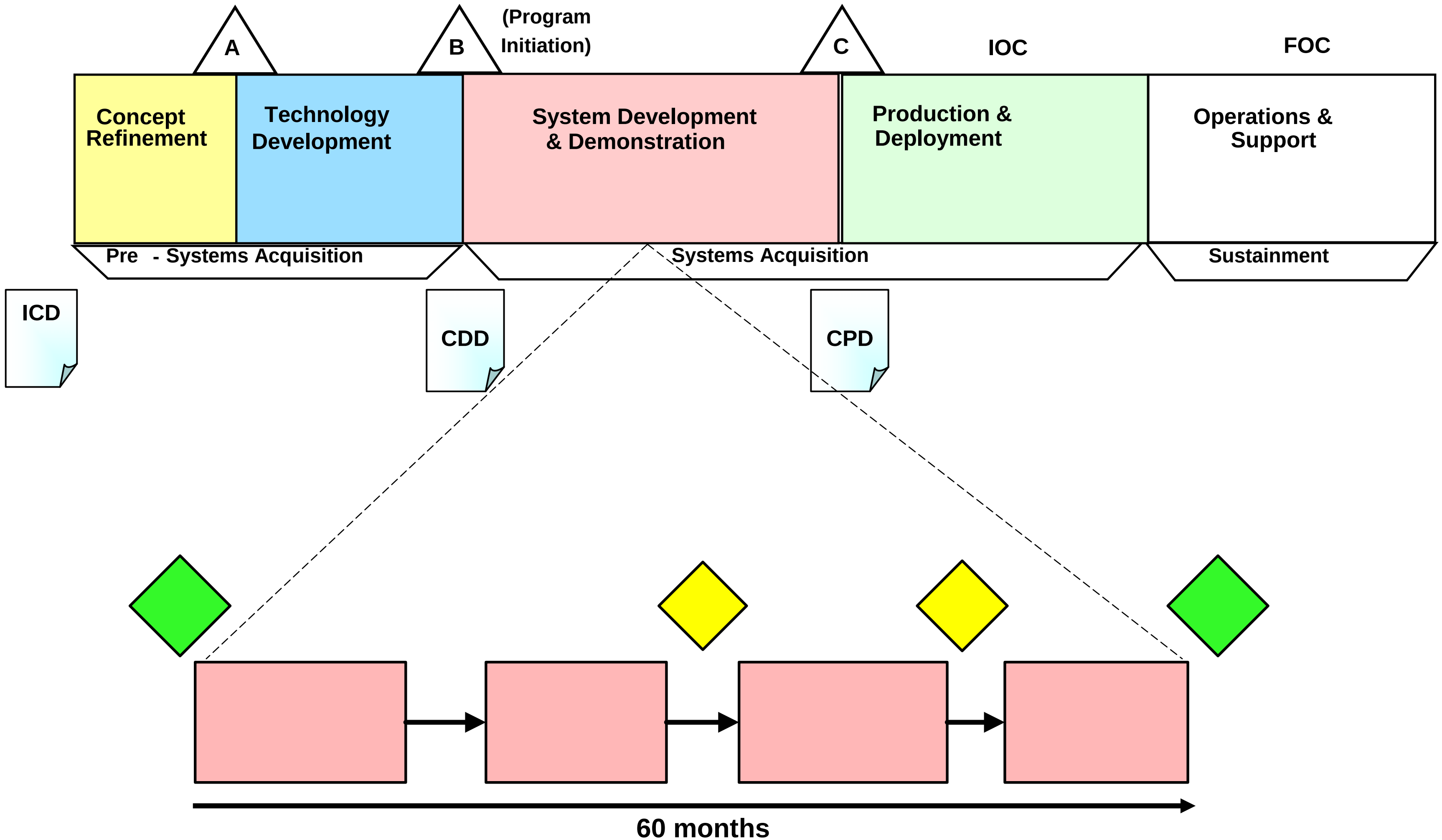
## Verify

- Pilot and validate the new process/product
- Implement the new design
- Train
- Close the project and release the team
- Prepare the project closure documentation
- Transition responsibility to the process owner

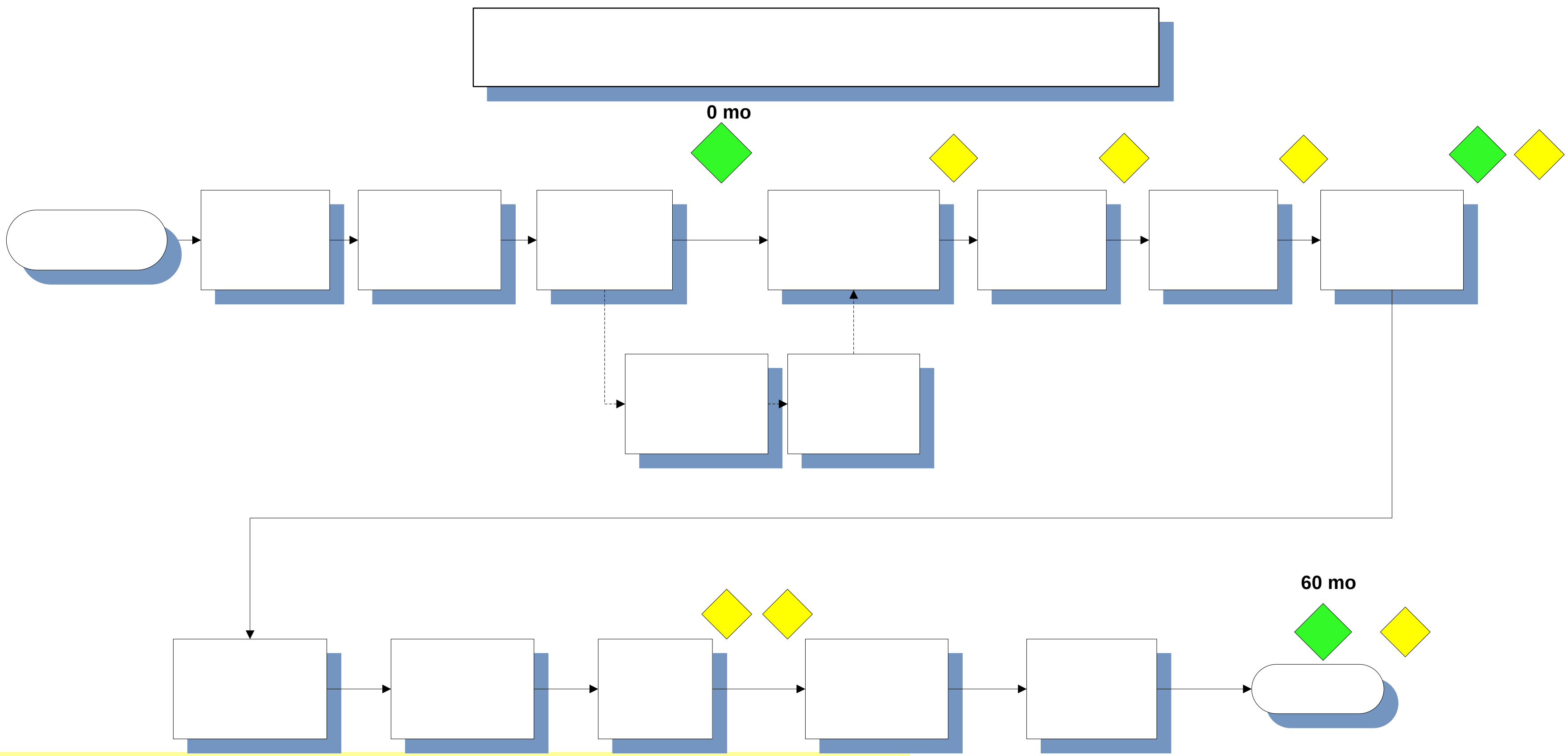
Jan 08 — 3 months — Mar 08 — 2.5 months — Jun 08 — 1.5 months — Jul 08 — 2 months — Sep 08

▲ IPT/Toll Gate Reviews

# Service-unique high-level processes developed



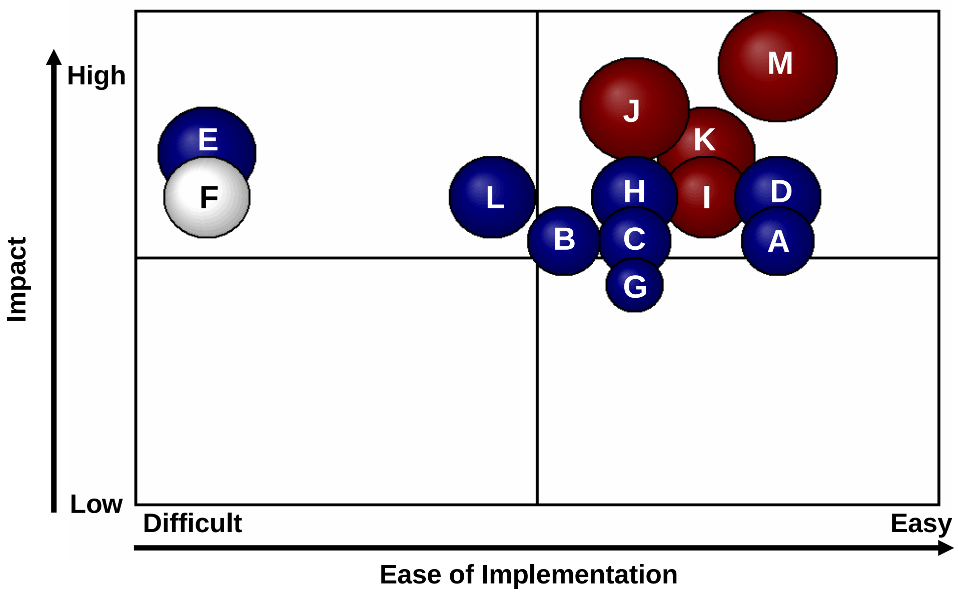
# Joint process for DoD tactical rocket motor development and qualification




MS-A – Milestone A
CA – Contract Award
IPDR – Internal Preliminary Design Review
PDR - Preliminary Design Review
MS-B – Milestone B

OE – (Contract) Option Executed
ICDR – Internal Critical Design Review
CDR - Critical Design Review
MS-C – Milestone C
LRIP – Low Rate initial Production

# Recommendations were assessed by the team based on the impact to the process cycle time and ease of implementation.




Notes:

- Size of circle equates to cycle time impact

| Recommendation Impact – Implementation Quadrant Key | | |
|---|---|---|
| Area of Impact | Recommendation | Id |
| Risk Reduction | Include Safety and Testing Community Early in Process | A |
| | Establish a Joint Rocket Motor Advisory Group | B |
| | Require Successes and Failures be Reported in an Open Forum | C |
| | Establish Criteria for technology and Manufacturing Readiness Levels | D |
| | Coordinate end-to-end Modeling and Simulation | E |
| | Conduct Cost v. Performance Trade Study | G |
| | Prepare the Draft CDD before Milestone A to guide Technology Development Strategy | H |
| | Form a team of Rocket Motor Manufacturing Experts Between Government, Prime, and Subcontractors to Review Designs | L |
| Cycle Time | Issue technology Maturation Contract to 2 or more Qualified Rocket Motor Sources | I |
| | Establish Contract options for Prototype Contract | J |
| | Initiate Advance materiel Purchase for Qualification during EMDD | K |
| | Conduct a Study on the System Developmental Test (DT) and Operational Test (OT) and Evaluation Processes | M |
| Product Quality | Support the US Tactical Rocket Motor Industrial base | F |

# The Rocket Motor Study included the 3 Services working independently for 6 months and together as one DoD team in July. In summary, the results and conclusions from the study are…

**Partial Study Results**

- Each Service defined their individual process for rocket motor development and qualification.
- A joint process for DoD rocket motor development and qualification was defined by the DoD team.
- The team formed recommendations which will improve the process cycle time, enhance decision making, improve product quality and capability, and mature technology, and reduce risk.

**Study Conclusions**

- Although the DoD rocket motor development and qualification process will take approximately 5 years, the process is less risky than the old rocket motor development and qualification process. The process is designed for the most expensive failures to occur early in the process.
- The DoD rocket motor development and qualification process is designed for joint rocket motor programs and single-Service or smaller programs.

# Recommendations binned by IPT

- **Implement**
  - B - Establish a Joint Rocket Motor Advisory Group
  - D - Establish Criteria for Technology and Manufacturing Readiness Levels
  - E - Coordinate end-to-end Modeling and Simulation
  - M - Conduct a Study on the system Developmental Test (DT) and Evaluation and Operational Test (OT) and Evaluation process
- **Best practices**
  - A - Include the safety and testing community early in the process
  - G - Conduct Cost vs. Performance Trade Study
  - H - Prepare the draft CDD before Milestone A to guide Technology Development Strategy
  - L - Form a team of RM mfg experts between the Prime, Government, and RM Sub to review Designs
- **Big picture item**
  - F - Support the US Tactical Rocket Motor Industrial Base
- **Need more work**
  - C - Require successes and failures be reported (presented in a technical session or workshop) in an open forum
  - I - Issue Technology Maturation Contract to Two or More Qualified RM Sources
  - J - Establish Contract Options for Prototype Contract
  - K - Initiate Advance Materiel Purchase for Qualification during EMDD

# Next Steps

- JAGM PM/PEO Msls & Space assessing recommendations for implementation into JAGM and Army missile portfolio
- SSE moving out on two recommendations (M&S and DT/OT study)
- Outreach (SE Forum in Oct, JANAAF, etc.)
- IPT will continue to monitor/advocate implementation of study recommendations

**Back-up Slides**

# Lessons Learned

- **What worked very well**
  - Getting top-down leadership buy-in from the Services early-on in the process
  - Getting outside contractor support for facilitation and administration
  - Finding dedicated, hard-working and self-motivated team of SMEs
  - Benchmarking
- **Challenges**
  - Project duration – keeping leadership attention and continuity
  - Industry involvement
  - Steep learning curve for many “outside of building” SMEs on our DoD processes
- **Jury Still Out**
  - Lean Six Sigma

# Each development effort for a rocket motor utilizes different design characteristics. The various characteristics of the design were identified for future analysis by the Navy.

| Rocket Motor | Propellant | Nozzle | Case | Grain design/ complexity | igniter/ignition system/Arming Firing Device (AFD) | Electronics/TVC | Other | Rocket Motor cycle time (months) |
|---|---|---|---|---|---|---|---|---|
| ***New Starts*** | | | | | | | | |
| MK 104 | N | M | M | N | N | | High volumetric loading, wanted as much performance as possible | 60 |
| VLA | M | M | N | N | M | N | New technology; 1st fielded vertical ship launch missile | 78 |
| MK 72 | M | M | M | N | M | N | New geometry, high volumetric loading, highest mass flow rate; rocket motor that limits the vertical launch system design; built to the max limit to fit within the weight limit; heavily restricted so it could be launched from a ship; complicated TVC, short stubby nozzle (4 nozzles) | 108 |
| MK 111 | M | N | M | N | N | N | New Rocket Motor Manufacturer Grain design caused 2 catastrophic failures. Difficult nozzle design | 77 + 35 for mini-qual |
| ESSM/ MK 134 | N | M | M | N | N | M | Laser AFD; HTPE propellant (spent 10 years pre CA developing) -- large production mixes moisture sensitive & had to discard first batches of propellant; international program | 48 |
| TSRM | M | M | N | N | N | N | Altitude control system; Composite case -- utilized spiral development | 117 |
| ***Evolutionary*** | | | | | | | | |
| AMRAAM +5 | E | E | E | M | M | | Extended rocket motor length by 5" | 23 |
| Sparrow Mod 6 | M | E | E | E | E | | New source of polymer (fire at Philips petroleum plant -- lost existing polymer) | 26 |
| Tactical Tomahawk MK135 | M | M | M | M | M | M | Utilized known & proven technology -- simplified TVC, propellant | 48 |

N New technology

M Modified technology

E Existing technology

# Each development effort for a rocket motor utilizes different design characteristics. The various characteristics of the design were identified for future analysis by the Army.

| Rocket Motor | Propellant | Nozzle | Case | Grain design/ complexity | igniter/ignition system/Arming Firing Device (AFD) | Electronics/TVC | Other | Cycle time |
|---|---|---|---|---|---|---|---|---|
| FGM-148 Javelin | M | M | M | M | E | | New Pressure relief system/launch tube burst disk & weight goals drove many design changes & risk | 39 mo (CA to Qual) |
| NLOS B/S | M | M | N | M | N | M | NLOS B/S (boost sustained) -modified Sidewinder propellant, bonded end closure composite case new technology offers significant cost savings, Use of EFI technology in ISD | 40 mo (CA to Qual) |
| PATRIOT PAC-3 | E | M | N | M | M | | PAC- was first tactically fielded composite motor case; performance requirements resulted in highest volumetric loading ever fielded for an Army tactical motor; grain complexity difficult to manufacture | 44 mo (CA to Qual) |
| NLOS - Pintle | M | N | E | M | E | M | Program Terminated: Dec 06<br>Pintle technology never fielded resulted in materials issues,weight and cost and choice of propellant; integrating pintle electronics with TVC also an issue; Propellant choice to lower flame temperature resulted in two propellants, both had issues eventually killing the pintle motor design. | 39 mo (CA to CDR) |

N New technology

M Modified technology

E Existing technology

Define → Measure → Analyze → Design → Verify

# Each development effort for a rocket motor utilizes different design characteristics. The various characteristics of the design were identified for future analysis by the Air Force.

| Rocket Motor | Propellant | Nozzle | Case | Grain design/ complexity | igniter/ignition system/Arming Firing Device (AFD) | Electronics/TVC | New Technology & Risk Factors | Start Dev to RM Qual |
|---|---|---|---|---|---|---|---|---|
| **New Starts** | | | | | | | | |
| Maverick (SR109-TC-1) | N | N | N | N | N | N | New design | 36 |
| SRAM A (SR75-LP-1) | N | N | N | N | N | N | Aggressive new design: pulse motor, very high burn rate catalyst | 24 |
| BLU-106 | E | N | E | N | E | N | Small rocket booster for submunitions assembly | 27 |
| HARM (YSR113-TC-1) | N | N | N | E | E | E | New design | 60 |
| AMRAAM (WPU-6/B ATK) | N | N | M | N | M | N | New baseline design, used new reduced smoke binder (HTPB), Manufacturing validation issues | 48 |
| **Evolutionary** | | | | | | | | |
| Sidewinder (SR-116-HP-1) | N | M | M | N | M | M | Replaced Mk 17 (15 year age out) with new reduced smoke HTPB composite propellant | 25 |
| Maverick RS (SR114-TC-1) | N | M | | N | E | E | New non-metallized propellant formulation | 60 |
| AMRAAM (WPU-6/B AJ) | N | N | M | N | M | E | Second Source. Utilized boost and sustain propellants; qual problems: insulation unbonded; grain design problems, motor test problems (ultrasonic testing of insulation destroyed grain integrity; resulted in 12+ month delay | 60 |

N New technology

M Modified technology

E Existing technology

Define → Measure → Analyze → Design → Verify

# The rocket motor design factors gathered in the Measure Phase were analyzed. As expected, the cycle time for the rocket motor process was less when using existing or modified technology.

| Rocket Motor | Propellant | Nozzle | Case | Grain design/ complexity | igniter/ignition system/Arming Firing Device (AFD) | Electronics/TVC | Problem areas | Rocket Motor cycle time (months) | Drivers |
|---|---|---|---|---|---|---|---|---|---|
| *New Starts* | | | | | | | | | |
| MK 104 | N | N | M | N | N | | -Catastrophic failure with nozzle - nozzle ejection problems<br>-Propellant - solids loading created a mfg challenge; unable to make the propellant; needed innovative process to mix propellant<br>-Government requested extra performance in the same volume as MK56 that was being replaced | 60 | Performance |
| VLA | M | M | N | N | M | N | -Boot flap too long (fixed); TVC problem fixed; This was the last government designed motor;<br>-Started at Indian Head and transitioned to private industry-Elkton (qualified at Elkton); change in manufacturer | 78 | 2 Sequential Manufacturers |
| MK 72 | M | M | M | N | M | N | -Mass flow rate too high; inadequate flow-down of requirements and integration to the launcher | 108 | System integration |
| MK 111 | M | N | M | N | N | N | -Two failed motors; grain design and nozzle problems (materials issue); igniter design did not work; hard prototype; used 2 sources; manufacturer had not developed a tactical RM previously; development contract was a fixed-price contract and cut corners after failures. | 77 + 35 for mini-qual | Performance |
| ESSM/ MK 134 | N | M | M | N | N | N | -Developed a new propellant (moisture sensitive);<br>-Laser AFD failed in manufacturing (manufacturer did not know numerous failure modes for manufacturing laser AFD) | 48 | IM improvement |
| TSRM | M | N | N | N | N | N | -1st pulse motor in Service; 1st attitude control system; gas generator; 1st wrap on case composite in Navy; spiral development program (came from ASAT) | 117 | Performance Schedule |
| *Evolutionary* | | | | | | | | | |
| AMRAAM +5 | E | E | E | M | M | | -no failures and no new technology; manufacturer and location qualified the original AMRAAM; contract ran by China Lake | 23 | Incremental Performance |
| Sparrow Mod 6 | M | E | E | E | E | | -no failures | 26 | Factory burned down; ingredient unavailable, re-qual |
| Tactical Tomahawk MK135 | M | M | M | M | M | M | -minor problem with nozzle (changed nozzle design) | 48 | CO$T (less expensive) |

**Yellow highlight indicates a design factor that impacted the cycle time for that rocket motor**

E= Existing/evolutionary
N= New technology; new type, family or way of doing things
M= Modified

Define → Measure → Analyze → Design → Verify