APT
Advanced Product Transitions

EMRL Assessment of Product Maturity

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Why EMRLs?

- Over the last seven years various GAO audits and reports, Nunn-McCurdy breaches (high cost, delayed programs) and test/field failures all point to a DOD acquisition process that needs improvement. Some of the highlights of the GAO findings are:
  - There is little incentive for DOD program managers to capture knowledge early in the development process
  - In 2008 the cumulative cost growth of 96 major defense acquisition programs was $296 billion
  - The total acquisition costs for these programs increased 25% from first estimates
  - The average delay in deliver to the war-fighter was 22 months
  - DOD needs to do a better job ensuring acquisitions begin with realistic plans and baselines prior to the start of development

- The Apr 2009 GAO report further delineates a clear set of prerequisites that must be met by each program's acquisition strategy before a measurement of the program's health will be of real value
  - Establishing an evolutionary, knowledge-based business case for each acquisition
  - Separating technology development from product development
  - Limiting time and requirements for product development to manageable levels
  - Employing systems engineering early on in the process to arrive at realistic cost and schedule estimates

EMRL Background

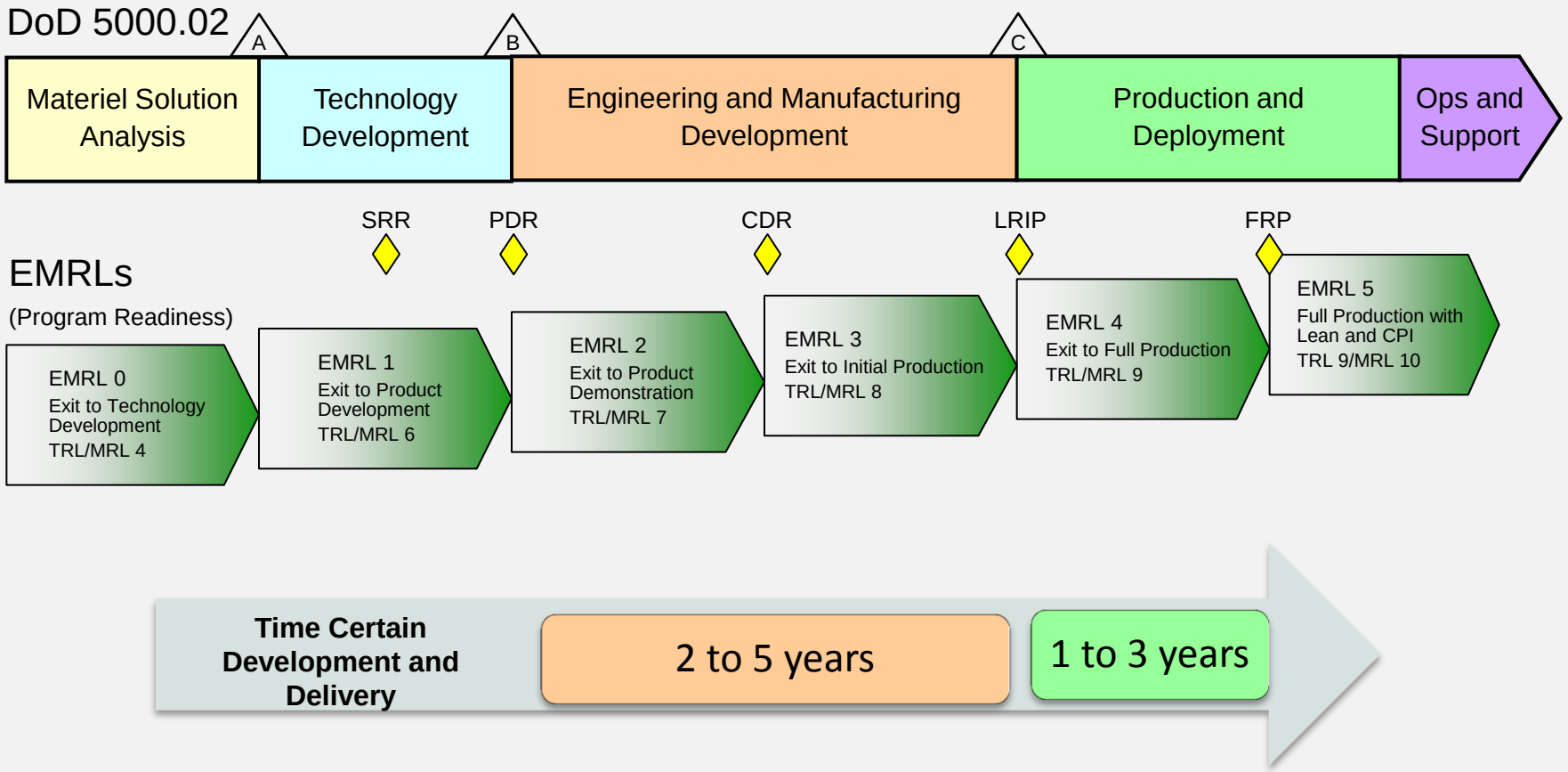
- EMRL Assessments were developed as a standardized assessment methodology for the Missile Defense Agency in 2002 utilizing
  - DoD and Industry Best Practices
  - Willoughby Templates
  - GAO recommendations
- EMRL criteria were refined and enhanced (EMRL2009) to improve their utility, while maintaining the concept of an easy-to-use tool to assess product status
- EMRLs have proven to be effective as a streamlined measure of product maturity at key milestones in programs such as:
  - MDA: Aegis BMD and THAAD
  - Others: H1 Helicopter, ARH-70A Helicopter, P-8A Aircraft, JSF, and F135 Engine

EMRL Definition

Engineering Manufacturing Readiness Levels (EMRLs) are a means of concisely and effectively assessing and communicating the degree to which a product is designed to be producible, reliable, and affordable

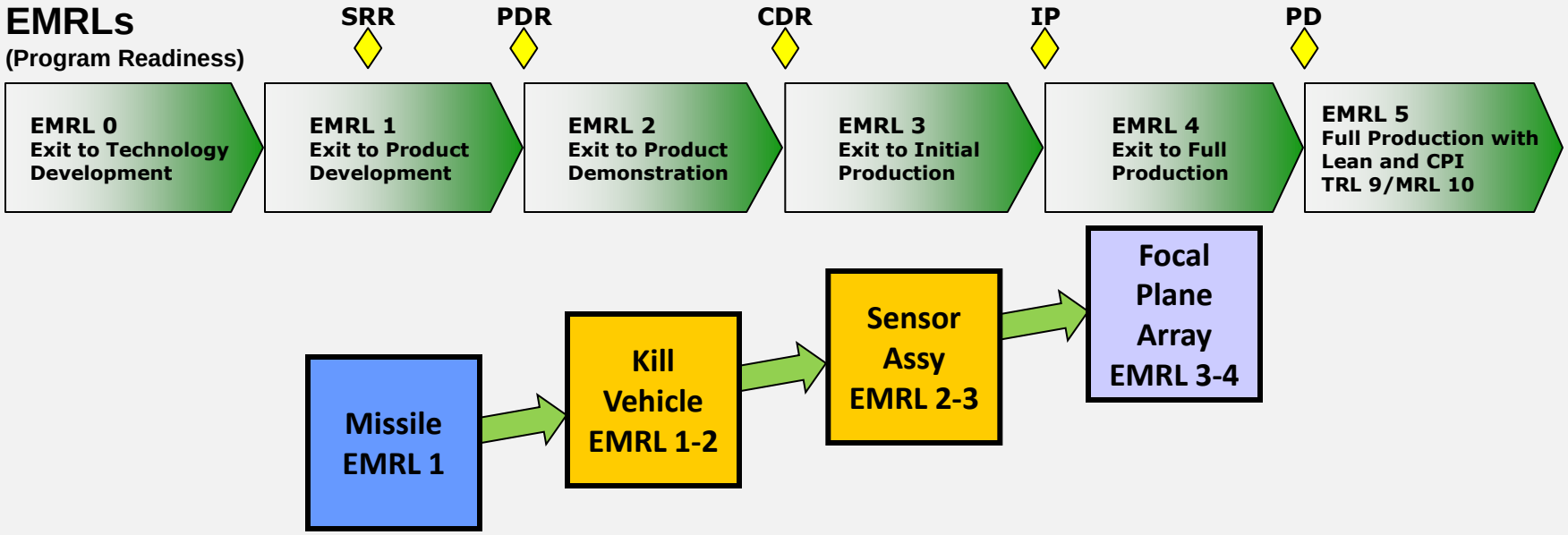
- Measure product or program maturity and progress during all phases of design, development, and production
- Capture the knowledge required to successfully transition with minimal risk
- EMRLs consist of six levels (0-5) and twenty criteria and metrics
- Each level is matched to an established product development milestone or gate
- Provides a concise, easy to use, measure of product maturity measured against the maturity required for the desired milestone or gate

Program Level Readiness

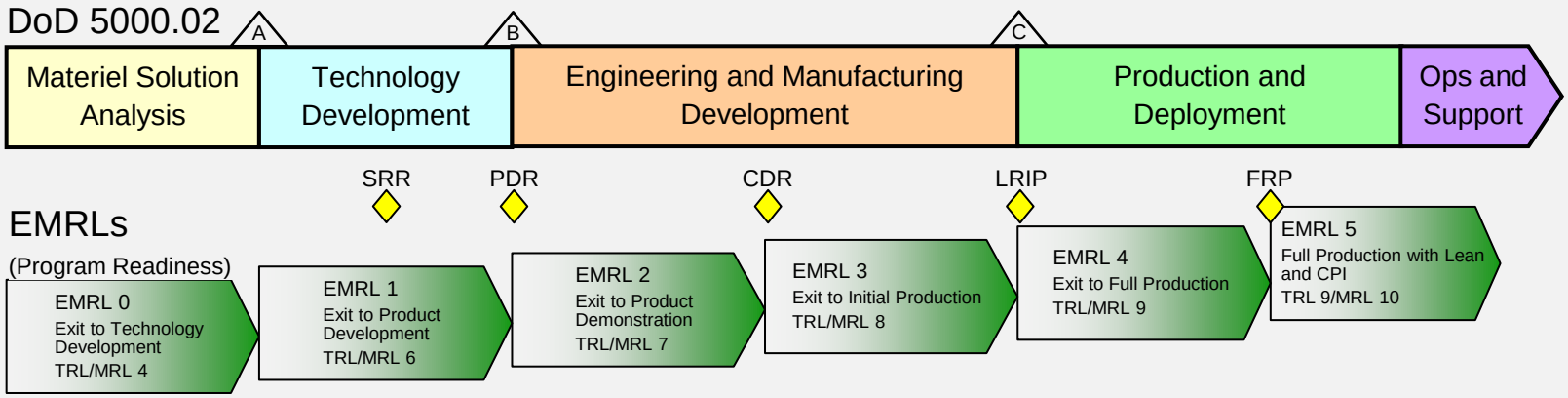


Phased Maturity

- Lower WBS product should be more mature in development (a higher EMRL) than the next higher level product
  - The Missile has met the entrance criteria for the Product Development Phase
  - The Kill Vehicle has met the entrance criteria for product demonstration
  - The Sensor Assembly should be at or near Initial Production
  - The Focal Plane should be at or ready for Production

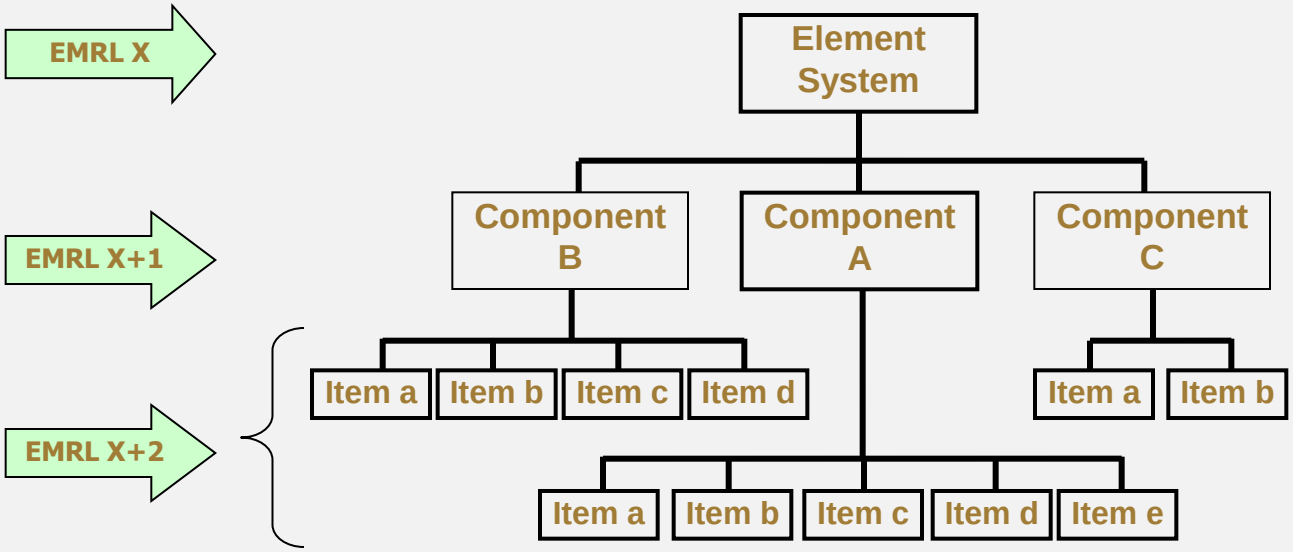


To Start an assessment



- To implement EMRL assessments in a program, the Program Manager must first determine where the program and the various components are in the development cycle based on the scheduled reviews and milestones
  - This will establish the readiness level against which the program and lower level products should be assessed
  - EMRL assessments can be performed from concept until the program is transitioned into operation
- To transition from one phase of development to the next with minimal risk, all of the exit criteria must be met

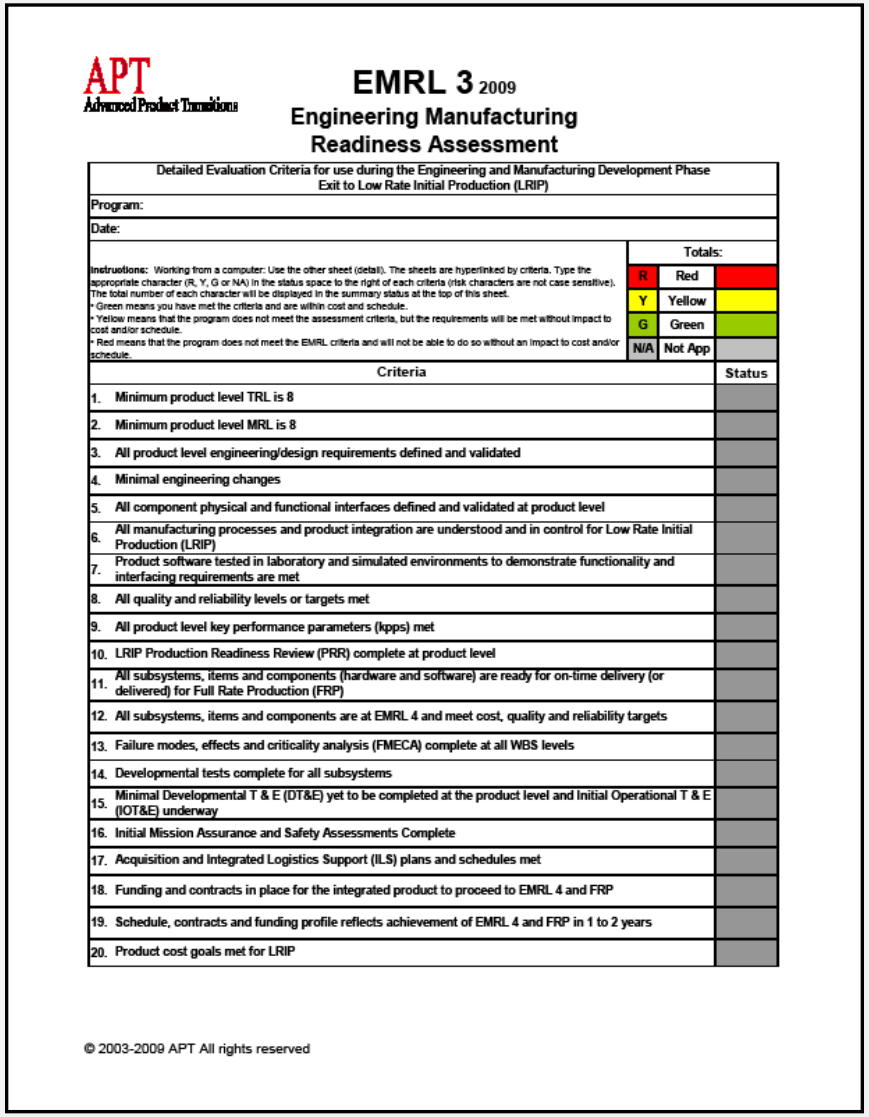
WBS Assessment Level



The Program Manager determines what level in the WBS structure to initiate the assessments

- Assessments are conducted using a top-down approach; the Program or Project should be decomposed at least two levels down to begin an assessment at the Program or Project level
- Typically, the WBS is limited to three levels of detail on contracts such that EMRLs will be used from the Item level to the Component level and up to the Element level

EMRL Templates



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EMRL 3 2009
Engineering Manufacturing Readiness Assessment

Detailed Evaluation Criteria for use during the Engineering and Manufacturing Development Phase
Exit to Low Rate Initial Production (LRIP)

Program:

Date:

Instructions: Working from a computer: Use the other sheet (detail). The sheets are hyperlinked by criteria. Type the appropriate character (R, Y, G or NA) in the status space to the right of each criteria (risk characters are not case sensitive). The total number of each character will be displayed in the summary status at the top of this sheet.
* Green means you have met the criteria and are within cost and schedule.
* Yellow means that the program does not meet the assessment criteria, but the requirements will be met without impact to cost and/or schedule.
* Red means that the program does not meet the EMRL criteria and will not be able to do so without an impact to cost and/or schedule.

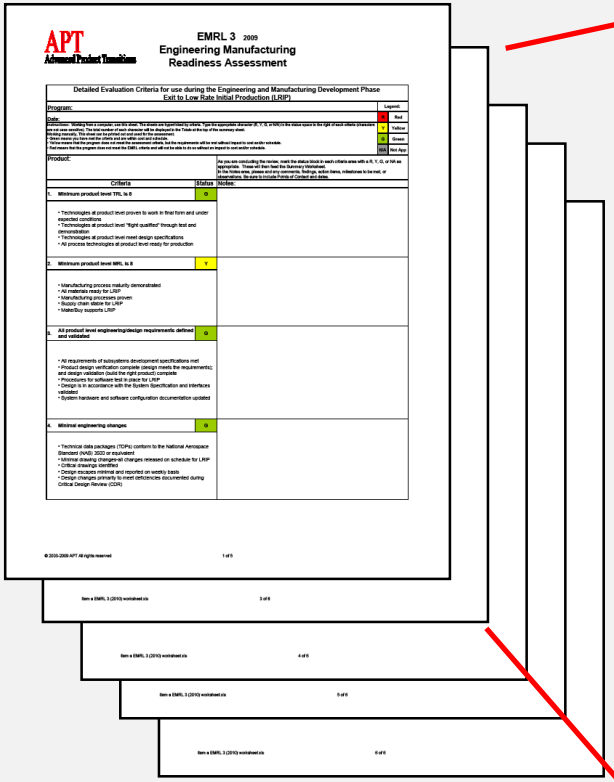
Totals:		
R	Red	
Y	Yellow	
G	Green	
N/A	Not App	

	Criteria	Status
1.	Minimum product level TRL is 8	
2.	Minimum product level MRL is 8	
3.	All product level engineering/design requirements defined and validated	
4.	Minimal engineering changes	
5.	All component physical and functional interfaces defined and validated at product level	
6.	All manufacturing processes and product integration are understood and in control for Low Rate Initial Production (LRIP)	
7.	Product software tested in laboratory and simulated environments to demonstrate functionality and interfacing requirements are met	
8.	All quality and reliability levels or targets met	
9.	All product level key performance parameters (kpps) met	
10.	LRIP Production Readiness Review (PRR) complete at product level	
11.	All subsystems, items and components (hardware and software) are ready for on-time delivery (or delivered) for Full Rate Production (FRP)	
12.	All subsystems, items and components are at EMRL 4 and meet cost, quality and reliability targets	
13.	Failure modes, effects and criticality analysis (FMECA) complete at all WBS levels	
14.	Developmental tests complete for all subsystems	
15.	Minimal Developmental T & E (DT&E) yet to be completed at the product level and Initial Operational T & E (IOT&E) underway	
16.	Initial Mission Assurance and Safety Assessments Complete	
17.	Acquisition and Integrated Logistics Support (ILS) plans and schedules met	
18.	Funding and contracts in place for the integrated product to proceed to EMRL 4 and FRP	
19.	Schedule, contracts and funding profile reflects achievement of EMRL 4 and FRP in 1 to 2 years	
20.	Product cost goals met for LRIP	

- The assessment templates consist of 6 Excel files, EMRL 0 to EMRL 5, two worksheets each
  - The first worksheet is a summary page
    - Shows the 20 exit criteria
    - Shows the one page score summary
    - Useful for reporting purposes
  - The second worksheet are detail pages
    - Lists several sub-factors or guidance for each criterion
    - Has area for notes
    - Automatically updates the summary page

Conduct the assessment using the detail sheets

EMRL Detail Sheets



- 20 criteria with subfactors
- Score each criteria
  - Not subfactors
- Include notes

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EMRL 3 2009
Engineering Manufacturing Readiness Assessment

Product:		As you are conducting the review, mark the status block in each criteria area with a R, Y, G, or NA as appropriate. These will then feed the Summary Worksheet. In the Notes area, please add any comments, findings, action items, milestones to be met, or observations. Be sure to include Points of Contact and dates.
Criteria	**Status**	**Notes:**
6. All component physical and functional interfaces defined and validated at product level	Y	
• Product in LRIP (initial production) configuration • All subsystem, component and item interface documentation complete • All subsystem, component and item physical, functional and operational interfaces verified and validated • All subsystem, component and item physical and functional interfaces meet design specifications • All subsystems, components and items integrate into the product as designed		
8. All manufacturing processes and product integration are understood and in control for Low Rate Initial Production (LRIP)	Y	Process controls in development scheduled to be in place within the week. Mfg processes not quite completed, no impact.
• Process controls in place for all manufacturing processes • Manufacturing processes established for early production builds • ESS standard practice for all electronic hardware and all ESS completed for subsystems, components and items • All tooling under configuration control and inventory control system in place • Special Test Equipment (STE) accuracies traceable to known measurement standards and continuously verified; calibration and reliability of STE consistent with LRIP requirements		
7. Product software tested in laboratory and simulated environments to demonstrate functionality and interfacing requirements are met	G	
• Algorithms and functions available on target hardware (digital and analog) • Algorithms and functions meet requirements and related Measures of Effectiveness (MOEs) and Technical Performance Measures (TPMs), etc. • Complete environment with representative tactical/system software has been tested in lab and simulated environments to demonstrate functionality and interface requirements are met • Software runs in full digital/analog environment (test stations, CIL, HWIL) and meets all requirements • Software qualification testing completed in accordance with approved plans		
8. All quality and reliability levels or targets met	G	
• Nonconforming materials system meets minimum requirements of a Parts, materials, and processes Mission Assurance Plan (PMAP) • Material Review Board in place and consists of engineering, manufacturing and quality representatives at minimum • All Product, subsystem and component qualification tests complete and qualification targets/requirements met • Subsystem and component removals significantly lower than CDR • Developmental T&E results demonstrate all product quality and reliability targets met		

Scoring Criteria Metrics by Color

The EMRL assessment utilizes a Green, Yellow, and Red color scheme to capture the readiness and maturity for each of the twenty exit criteria listed. The color scheme is as follows:

Green – Product being assessed meets the exit criterion or requirement for the level assessed and is within cost and schedule

Yellow – Product being assessed does not meet the exit criterion or requirement for the level assessed; however, the exit criterion or requirement will be met without impact to cost or schedule

Red – Product being assessed does not satisfy the exit criterion or requirement for the level assessed and meeting the criterion will impact cost, schedule, or both

N/A – Not applicable should be avoided as equivalence of supplier process is applied to subfactors and criteria; use only if the criterion does not apply at the level of product being assessed

EMRL Assessment Reporting

Sample 1

Assessment Date:		12/15/09		11/30/09	11/30/09	11/15/09	11/30/09	12/1/09	12/2/09	12/3/09	11/26/09	11/27/09	11/28/09	11/29/09	11/30/09	11/15/09	11/15/09
		EMRL 1		EMRL 2			EMRL 3										
Criteria Number		ELEMENT		Component A	Component B	Component C	Item a (A)	Item b (A)	Item c (A)	Item d (A)	Item e (A)	Item a (B)	Item b (B)	Item c (B)	Item d (B)	Item a (C)	Item b (C)
1																	
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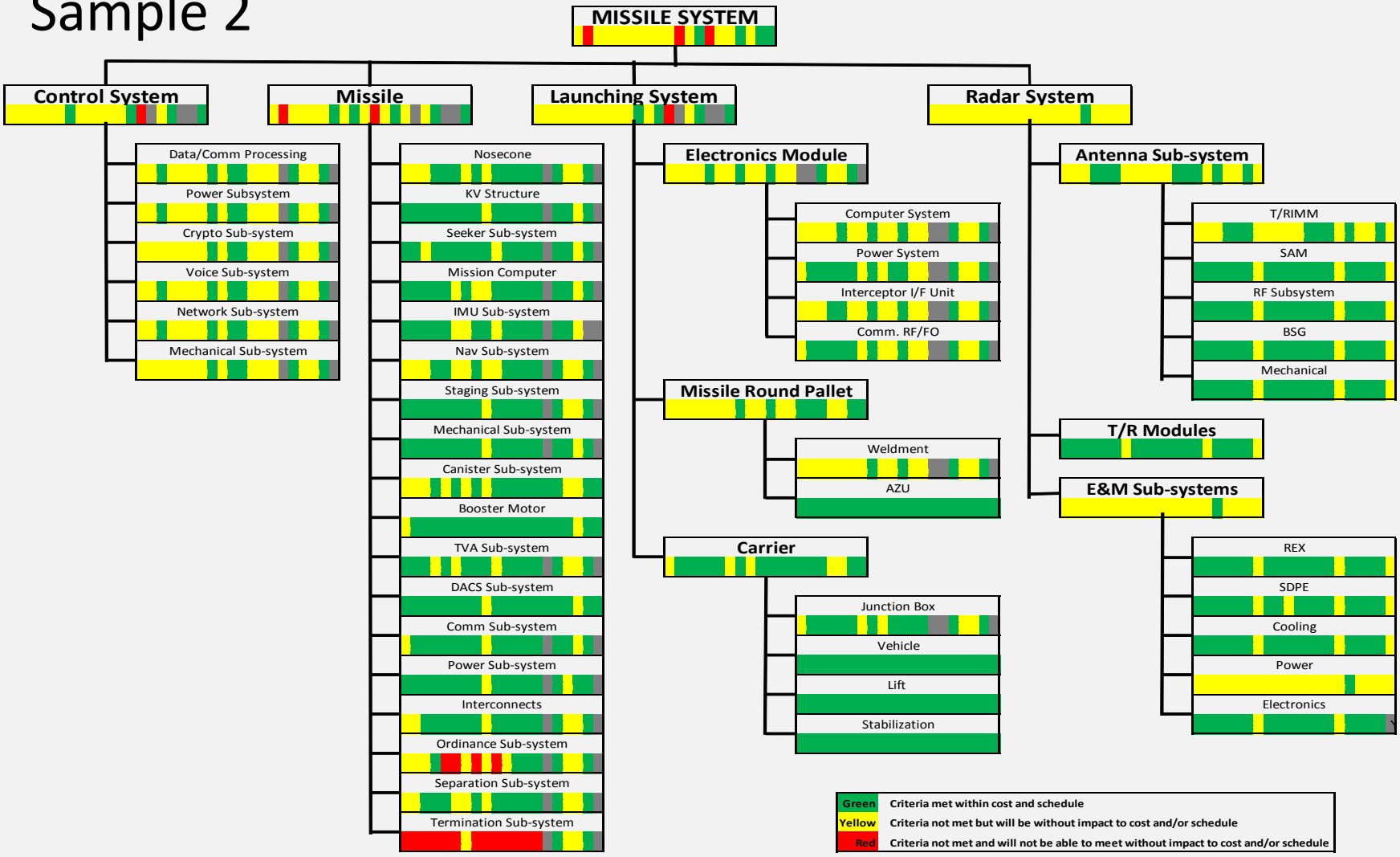
- **Based on WBS and EMRL assessments performed an overview of the program can be constructed**
- **Level of detail determined by lowest level of high risk**

EMRL Assessment Reporting

Sample 2



Summary

- EMRL Assessments have proven to be effective and efficient in measuring product maturity and assessing the risks to transition from one phase to the next
- EMRLs Assessments performed in conjunction with required reviews (e.g. PDR, CDR, PRRs) have minimal impact on resources
- High risks identified as part of EMRL Assessments are incorporated into overall program risk management
- EMRLs have been implemented successfully by MDA, DCMA, and others and have proven to be effective as a streamlined measure of product maturity at key milestones in the acquisition cycle

Backup

Roles and Responsibilities

The Program Manager has the Right (Role) to:

- Be candid and forthcoming without fear of personal consequences
- Speak for his program and have his judgment respected
- Access to all resources to assist the execution of his program

The Program Manager has the Responsibility to:

- Execute his program while balancing cost, schedule, technical performance and risk
- Be customer-focused and provide the user with the best cost-effective capabilities
- Identify weaknesses, innovate, propose optimal solutions, seek better ways to manage and provide lessons-learned to those who follow
- Be candid about program status, risk, problems, potential solutions and likely outcomes

EMRL Development

- EMRLs:
  - Have been around since the early 2000
  - Were originally developed specifically for MDA and are currently in use by MDA, DCMA, and other DoD organizations
  - Have been refined for increased rigor and enhanced with contractual and programmatic metrics
  - Are integrated with both the MDA Capabilities Development Process, DoD Acquisition Phases, and Technical Reviews
  - Are capable of being performed by one person during the course of PDR, CDR, PRR, or other standard review
  - Can also be performed in a meeting with a few key personnel in attendance

TRL Development

- Technology Readiness Levels (TRLs) provide a common language and widely-understood standard for:
  - Assessing the performance maturity of a technology and plans for its future maturation throughout the technology's life cycle
  - Understanding the level of performance risk in trying to transition the technology
  - Each successive level defines technology maturity on an increasingly more complex deterministic scale
- TRLs:
  - Have been around since the early 1980s
  - Are widely used by government (NASA/DoD) and industry
  - Are required at MS B and C
- TRLs leave major transition questions unanswered:
  - Is the technology producible?
  - What will these cost in production?
  - Can these be made in a production environment?
  - Are key materials and components available?

MRL Development

- Manufacturing Readiness is the ability to harness the manufacturing, production, quality assurance, and industrial functions to achieve an operational capability that satisfies mission needs—in the quantity and quality needed by the war-fighter to carry out assigned missions at the "best value" as measured by the warfighter.
- MRLs:
  - Have been around since the early 2005
  - Were developed under the DoD ManTech program by a government/industry working group
  - Were developed to mirror the TRL structure and process
  - Used the EMRL process as one of its source documents and body of knowledge
  - Are currently used by various DoD organizations (Army, Navy and Air Force)
  - Are tied to the DoD Life Cycle Framework and Acquisition Phases
- MRLs:
  - Resource intensive functional assessment of a program
  - Focused on manufacturing technology
  - MRL assessments do not provide a measure of program maturity

EMRL 0 2009 – Exit Criteria

Detailed Evaluation Criteria for the Materiel Solution Analysis Phase

1. Minimum product TRL is 4
2. Minimum product MRL is 4
3. All product level engineering/design requirements based on mission requirements and specifications traceable to requirements
4. All Design requirements baselined
5. Design standards/guidelines require open architecture designs and modular components and items with standard Form, Fit, and Function (FFF) interfaces
6. Product level manufacturing processes and product integration approach identified
7. Initial identification of product software qualities, common operating environment and hardware environment completed
8. Quality and reliability levels identified and established for 90% of the Analysis of Alternatives (AoA) or equivalent identified components and items
9. Minimum set of product performance parameters or knowledge points established and approved
10. Technology Development Strategy or equivalent complete
11. 75% of the AoA or selected major subsystems (representing 80% of cost) are at EMRL 1
12. 90% of AoA identified components and items meet the requirements of EMRL 2
13. Failure modes, effects and criticality analysis (FMECA) complete for 75% of AoA identified components and items
14. Developmental test plans initiated for major subsystems
15. Development Test and Evaluation (DT&E) and Initial Operational Test and Evaluation (IOT&E) strategies complete at the product level
16. Mission Assurance and Safety assessment strategy complete
17. Acquisition and Integrated Logistics Support (ILS) or equivalent strategies complete at product level
18. Funding and contract vehicles for the Technology Development Phase in place and ready for execution
19. Schedule, contracts and funding profile reflects achievement of EMRL 1 in 1 to 2 years
20. Product cost strategy complete

EMRL 1 2009 – Exit Criteria

Detailed Evaluation Criteria for the Technology Development Phase

1. Minimum product TRL is 6
2. Minimum product MRL is 6
3. All product level engineering/design requirements defined and 50% validated
4. Design release process in place and utilized
5. Component physical and functional interfaces 50% defined at product level
6. Product level manufacturing processes and product integration demonstrated
7. Product level software architecture developed and functional interface requirements specified
8. Quality and reliability levels identified and established for 50% of the product
9. 90% product performance parameters or knowledge points verified
10. Preliminary Design Review (PDR) complete at product level
11. 75% of the product major subsystems (representing 80% of cost) meet requirements of EMRL 2 and Critical Design Review (CDR) complete
12. 90% of the components and items for the product and major subsystems are proven designs or in production and are at EMRL 3
13. Failure modes, effects and criticality analysis (FMECA) required and underway for all WBS levels
14. Developmental test plans complete for 75% of major subsystems
15. Developmental Test & Evaluation (DT&E) and Initial Operational T & E (IOT&E) plans initiated at the product level
16. Mission Assurance and Safety assessment plans initiated
17. Acquisition and Integrated Logistics Support (ILS) or equivalent plans initiated at product level
18. Funding and contracts in place for the integrated product to proceed to EMRL 2
19. Schedule, contracts and funding profile reflects achievement of EMRL 2 in 1 to 3 years
20. Product cost goals established

EMRL 2 2009 – Exit Criteria

Detailed Evaluation Criteria for the Product Development Phase

1. Minimum product level TRL is 7
2. Minimum product level MRL is 7
3. All product level engineering/design requirements defined and 90% validated
4. All critical engineering drawings identified
5. Component physical and functional interfaces 90% defined at product level
6. Product level manufacturing processes and product integration established in a production environment
7. Product level software architecture completed and interface standards and detailed designs completed
8. Quality and reliability levels verified and validated for 90% of the product
9. All product performance parameters or knowledge points verified
10. Critical Design Review (CDR) complete at product level
11. 75% of major subsystems representing 80% of cost meet the requirements of EMRL 3 and are ready for or in Initial Production
12. All items and components for the product are at EMRL 3, in production, and meet cost, quality and reliability targets
13. Failure modes, effects and criticality analysis (FMECA) complete on all lower WBS levels and 75% complete at Product level
14. Developmental tests complete for major subsystems
15. Developmental Test & Evaluation (DT&E) and Initial Operational T & E (IOT&E) plans complete at the product level
16. Mission Assurance and Safety assessment plans complete
17. Acquisition and Integrated Logistics Support (ILS) or equivalent plans complete at product level
18. Funding and contracts in place for the integrated product to proceed to EMRL 3
19. Schedule, contracts and funding profile reflects achievement of EMRL 3 in 1 to 3 years
20. Product cost goals verified and validated

EMRL 3 2009 – Exit Criteria

Detailed Evaluation Criteria for the Product Development Phase

1. Minimum Product level TRL is 8
2. Minimum Product level MRL is 8
3. All product level engineering/design requirements defined and validated
4. Minimal engineering changes
5. All component physical and functional interfaces defined and validated at product level
6. All manufacturing processes and product integration are understood and in control for Initial Production
7. Product software tested in laboratory and simulated environments to demonstrate functionality and interfacing requirements are met
8. All quality and reliability levels or targets met
9. All product performance parameters or knowledge points met
10. Initial Production Readiness Review (PRR) complete at product level
11. All subsystems, items and components (hardware and software) are ready for on-time delivery (or delivered) for full Production
12. All subsystems, items and components are at EMRL 4 and meet cost, quality and reliability targets
13. Failure modes, effects and criticality analysis (FMECA) complete at all WBS levels
14. Developmental tests complete for all subsystems
15. Minimal Developmental T & E (DT&E) yet to be completed at the product level and Initial Operational T & E (IOT&E) underway
16. Initial Mission Assurance and Safety Assessment Complete
17. Acquisition and Integrated Logistics Support (ILS) or equivalent plans and schedules met
18. Funding and contracts in place for the integrated product to proceed to EMRL 4
19. Schedule, contracts and funding profile reflects achievement of EMRL 4 and Production in 1 to 2 years
20. Product cost goals met for Initial Production

EMRL 4 2009 – Exit Criteria

Detailed Evaluation Criteria for the Initial Production Phase

1. Minimum Product level TRL is 9
2. Minimum Product level MRL is 9
3. All Product level engineering/design requirements met
4. Essentially no engineering changes
5. All physical and functional interfaces defined and validated
6. All manufacturing processes and Product integration understood and in control for full Production
7. Product software meets all allocated functional requirements and quality targets met in operational environments
8. All quality and reliability levels or targets met
9. All product performance parameters or knowledge points met
10. Production Readiness Review (PRR) complete at Product level
11. All subsystems, components, and items (hardware and software) are delivered on time for Production
12. All subsystems, components, and items meet cost, quality and reliability targets
13. Failure modes, effects and criticality analysis (FMECA) complete at all WBS levels
14. Developmental tests complete for all subsystems
15. Product level Developmental Test & Evaluation (DT&E) and Initial Operational T & E (IOT&E) complete
16. Mission Assurance and Safety assessment complete
17. Acquisition and Integrated Logistics Support (ILS) or equivalent plans and schedules met
18. Funding and contracts in place for the integrated Product for Production
19. Schedule, contracts and funding meet Production requirements
20. Product cost goals met for Production

EMRL 5 2009 – Exit Criteria

Detailed Evaluation Criteria for Production (moving to Lean and CPI)

1. Product level TRL is 9
2. Product level MRL is 10
3. All product level engineering/design requirements met
4. Engineering changes are made for process or product improvements
5. All physical and functional interfaces defined and validated
6. Manufacturing processes modified or changed for quality, cost, or schedule improvements
7. Product software optimized for quality, cost, or performance improvements
8. Quality and reliability levels or targets improved beyond 3 sigma
9. All product performance parameters or knowledge points met
10. Production Enhancement PRRs Complete
11. All subsystems, components, and items (hardware and software) assessed for on-time delivery efficiency improvements
12. All subsystems, components, and items assessed for cost, quality, and reliability improvements
13. Failure modes, effects and criticality analysis (FMECA) process assessed for improvement
14. Developmental tests identified for subsystem, component, and item improvements
15. Product level Developmental Test and Evaluation (DT&E) and Operational Test & Evaluation (OT&E) identified for block upgrades
16. Mission Assurance and Safety assessment complete
17. Acquisition and Integrated Logistics Support (ILS) or equivalent plans identified for block upgrades
18. Funding and contracts identified for continued production of the product
19. Funding identified for spiral improvements or block upgrades
20. Product cost goals met or exceeded

TRL Hardware Definitions

TRL Definition	Description
1. Basic Principles observed and reported.	Lowest Level of Technology Readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there is no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3. Analytical and experimental critical functions and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in laboratory.
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that they can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond TRL 5, is tested in a relevant environment. Represents a major step up in technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in a simulated operational environment.
7. System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g. in an aircraft, in a vehicle, or in space).
8. Actual system completed and "flight qualified" through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of the true system development. Examples include developmental test and evaluation (DT&E) of the system in its intended weapon system to determine if it meets design specifications.
9. Actual system "flight proven" through successful mission operations.	Actual Application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational mission conditions.

Source: TRA Deskbook, Jul 09

TRL Software Definitions

TRL Definition	Description
1. Basic principles observed and reported.	Lowest level of software technology readiness. A new software domain is being investigated by the basic research community. This level extends to the development of basic use, basic properties of software architecture, mathematical formulations, and general algorithms.
2. Technology concept and/or application formulated.	Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies using synthetic data.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active R&D is initiated. The level at which scientific feasibility is demonstrated through analytical and laboratory studies. This level extends to the development of limited functionality environments to validate critical properties and analytical predictions using non-integrated software components and partially representative data.
4. Module and/or subsystem validation in a laboratory environment (i.e., software prototype development environment).	Basic software components are integrated to establish that they will work together. They are relatively primitive with regard to efficiency and robustness compared with the eventual system. Architecture development initiated to include interoperability, reliability, maintainability, extensibility, scalability, and security issues. Emulation with current/legacy elements as appropriate. Prototypes developed to demonstrate different aspects of eventual system.
5. Module and/or subsystem validation in a relevant environment.	Level at which software technology is ready to start integration with existing systems. The prototype implementations conform to target environment/ interfaces. Experiments with realistic problems. Simulated interfaces to existing systems. System software architecture established. Algorithms run on a processor(s) with characteristics expected in the operational environment.
6. Module and/or subsystem validation in a relevant end-to-end environment.	Level at which the engineering feasibility of a software technology is demonstrated. This level extends to laboratory prototype implementations on full-scale realistic problems in which the software technology is partially integrated with existing hardware/software systems.
7. System prototype demonstration in an operational/high-fidelity environment.	Level at which the program feasibility of a software technology is demonstrated. This level extends to operational environment prototype implementations where critical technical risk functionality is available for demonstration and a test in which the software technology is well integrated with operational hardware/software systems.
8. Actual system completed and mission qualified through test and demonstration in an operational environment.	Level at which a software technology is fully integrated with operational hardware and software systems. Software development documentation is complete. All functionality tested in simulated and operational scenarios.
9. Actual system proven through successful mission proven operational capabilities.	Level at which a software technology is readily repeatable and reusable. The software based on the technology is fully integrated with operational hardware/software systems. All software documentation verified. Successful operational experience. Sustaining software engineering support in place. Actual system.

Source: TRA Deskbook, Jul 09

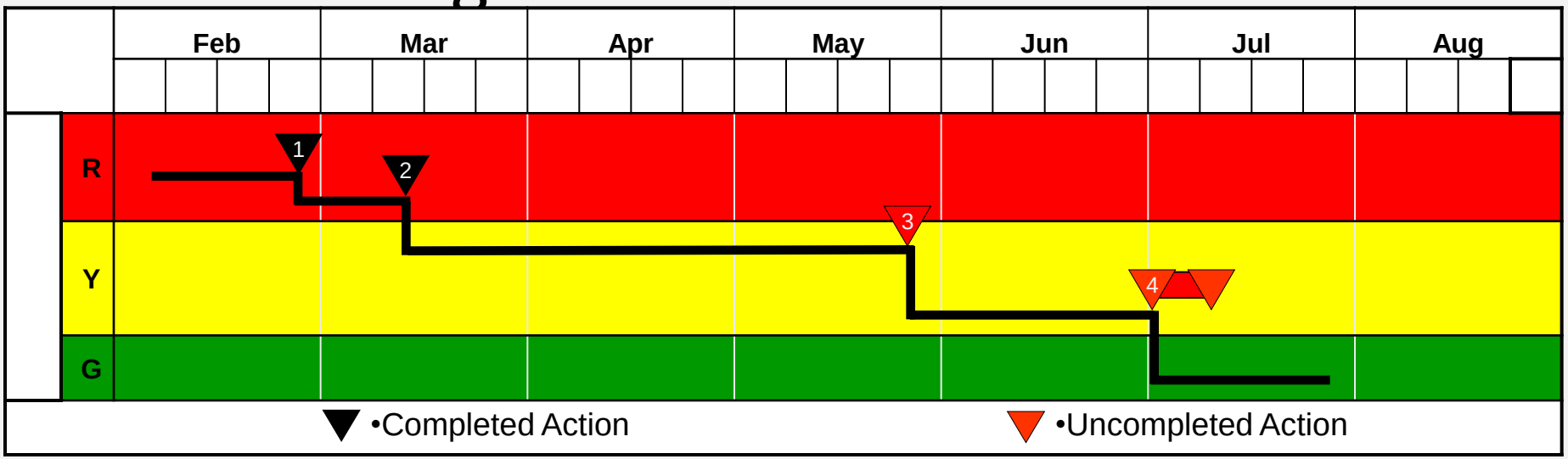
MRL Levels

MRL/Definition	Description	Phase
1. Basic Manufacturing Implications Identified	Basic research activities expand scientific principles that may have manufacturing implications. The focus is on a high level assessment of manufacturing opportunities. The research is unfettered	Pre-Materiel Solution Analysis
2. Manufacturing Concepts Identified	Invention begins. Manufacturing science and/or concept is described in application context. Identification of material and process approaches are limited to paper studies and analysis. Initial manufacturing feasibility and issues are emerging	Pre-Materiel Solution Analysis
3. Manufacturing Proof of Concept Developed	Analytical or laboratory experiments are conducted to validate paper studies. Experimental hardware or processes have been created, but are not yet integrated or representative. Materials and/or processes have been characterized for manufacturability and availability but further evaluation and demonstration is required	Pre-Materiel Solution Analysis
4. Capability to produce the technology in a laboratory environment	Required investments, such as manufacturing technology development identified. Processes to ensure manufacturability, producibility and quality are in place and are sufficient to produce technology demonstrators. Manufacturing risks identified for prototype build. Manufacturing cost drivers identified. Producibility assessments of design concepts have been completed. Key Performance Parameters (KPP) identified. Special needs identified for tooling, facilities, material handling and skills	Materiel Solution Analysis (MSA) leading to a Milestone A decision
5. Capability to produce prototype components in a production relevant environment	Mfg strategy refined and integrated with Risk Mgt Plan. Identification of enabling/critical technologies and components is complete. Prototype materials, tooling and test equipment, as well as personnel skills have been demonstrated on components in a production relevant environment, but many manufacturing processes and procedures are still in development. Mfg technology development efforts initiated or ongoing. Producibility assessments of key technologies and components ongoing. Cost model based upon detailed end-to-end value stream map	Technology Development (TD) Phase
6. Capability to produce a prototype system or subsystem in a production relevant environment	Initial mfg approach developed. Majority of manufacturing processes have been defined and characterized, but there are still significant engineering/design changes. Preliminary design of critical components completed. Producibility assessments of key technologies complete. Prototype materials, tooling and test equipment, as well as personnel skills have been demonstrated on subsystems/ systems in a production relevant environment. Detailed cost analyze includes design trades. Cost targets allocated. Producibility considerations shape system development plans. Long lead and key supply chain elements identified. Industrial Capabilities Assessment (ICA) for MS B completed	Technology Development (TD) phase leading to a Milestone B decision

MRL Levels (cont)

MRL/Definition	Description	Phase
7. Capability to produce systems, subsystems or components in a production representative environment	Detailed design is underway. Material specifications are approved. Materials available to meet planned pilot line build schedule. Manufacturing processes and procedures demonstrated in a production representative environment. Detailed producibility trade studies and risk assessments underway. Cost models updated with detailed designs, rolled up to system level and tracked against targets. Unit cost reduction efforts underway. Supply chain and supplier QA assessed. Long lead procurement plans in place. Production tooling and test equipment design & development initiated	Engineering and Manufacturing Development
8. Pilot line capability demonstrated. Ready to begin low rate production	Detailed system design essentially complete and sufficiently stable to enter low rate production. All materials are available to meet planned low rate production schedule. Manufacturing and quality processes and procedures proven in a pilot line environment, under control and ready for low rate production. Known producibility risks pose no significant risk for low rate production. Engineering cost model driven by detailed design and validated. Supply chain established and stable. ICA for MS C completed	Engineering and Manufacturing Development leading to a Milestone C decision
9. Low Rate Production demonstrated. Capability in place to begin Full Rate Production	Major system design features are stable and proven in test and evaluation. Materials are available to meet planned rate production schedules. Manufacturing processes and procedures are established and controlled to three-sigma or some other appropriate quality level to meet design key characteristic tolerances in a low rate production environment. Production risk monitoring ongoing. LRIP cost goals met, learning curve validated. Actual cost model developed for FRP environment, with impact of Continuous improvement	Production & Deployment leading to a Full Rate Production (FRP) decision
10. Full Rate Production demonstrated and lean production practices in place	This is the highest level of production readiness. Engineering/design changes are few and generally limited to quality and cost improvements. System, components or items are in rate production and meet all engineering, performance, quality and reliability requirements. All materials, manufacturing processes and procedures, inspection and test equipment are in production and controlled to six-sigma or some other appropriate quality level. FRP unit cost meets goal, funding sufficient for production at required rates. Lean practices well established and continuous process improvements ongoing	Full Rate Production/ Sustainment

Risk Mitigation Plans for EMRL High Risk Items



Minimum Reporting for EMRL identified risks:

- Which Criteria
- Cause
- Cost/Schedule Impact
- Completion Date
- Risk Analysis
- Plan to mitigate