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Evaluating Contractor Engineering and Manufacturing Readiness

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Purpose

Provide information on the fundamentals, criteria and metrics for Engineering Manufacturing Readiness Levels (EMRLs)

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Need for EMRLs

- **Successful products require the capture of design and manufacturing knowledge early in product development**
- **DoD acquisition policy does not require the capture of design and manufacturing knowledge or sufficiently specific criteria/metrics to enter Product Development and Demonstration (Milestone B) and Production and Deployment (Milestone C) phases**
- **EMRLs provide the framework, with specific criteria and metrics, to capture the design and manufacturing knowledge for product development, demonstration, production and deployment**

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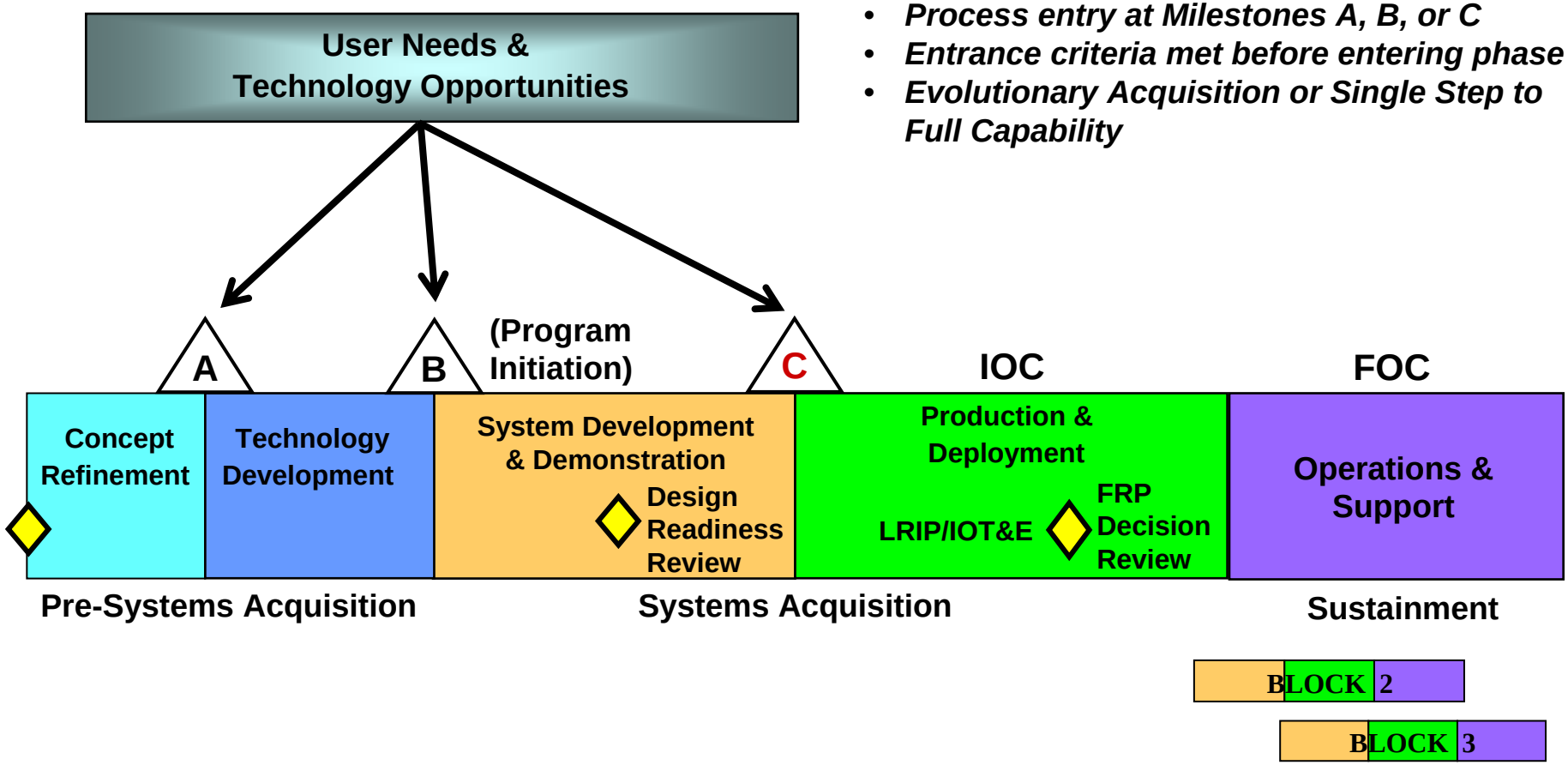
The Defense Acquisition Management Framework

- *Process entry at Milestones A, B, or C*
- *Entrance criteria met before entering phase*
- *Evolutionary Acquisition or Single Step to Full Capability*



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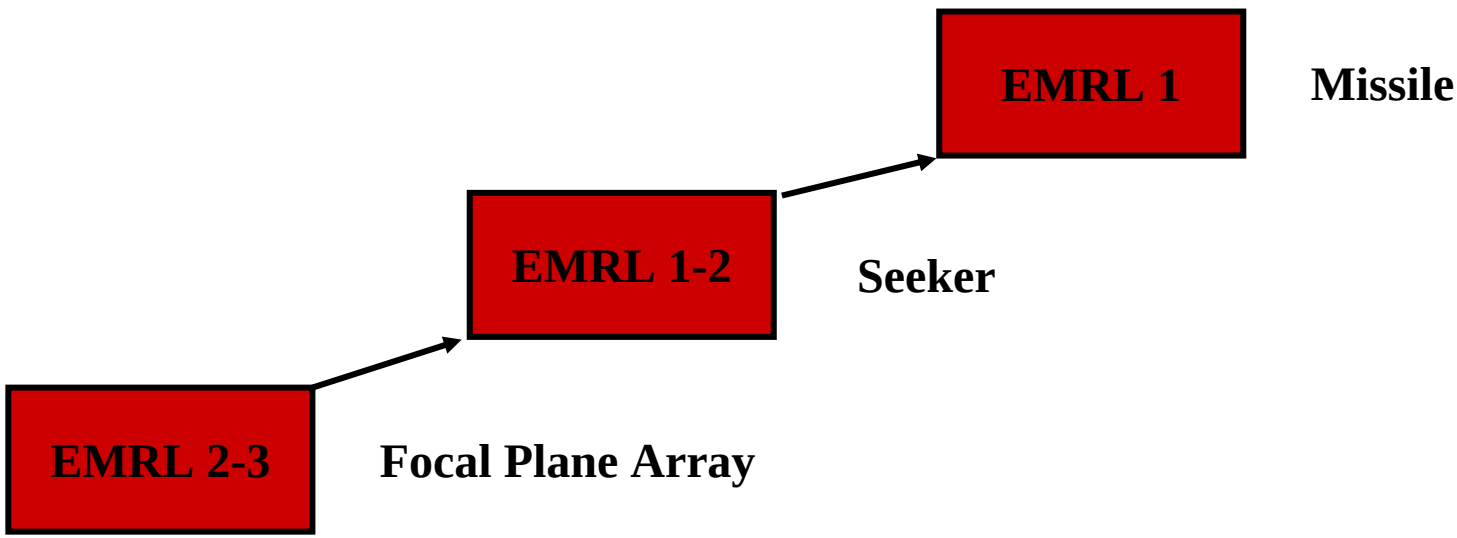
EMRLs and Work Breakdown Structure (WBS)

- **EMRLs can be tailored to apply at the item, component, subsystem and system levels**
- **Each lower WBS product should be at a higher level EMRL (level of readiness) than the higher level product; i.e., if the missile has met the exit criteria for Milestone B, the seeker should be at or near DRR and the focal plane should be ready for LRIP.**



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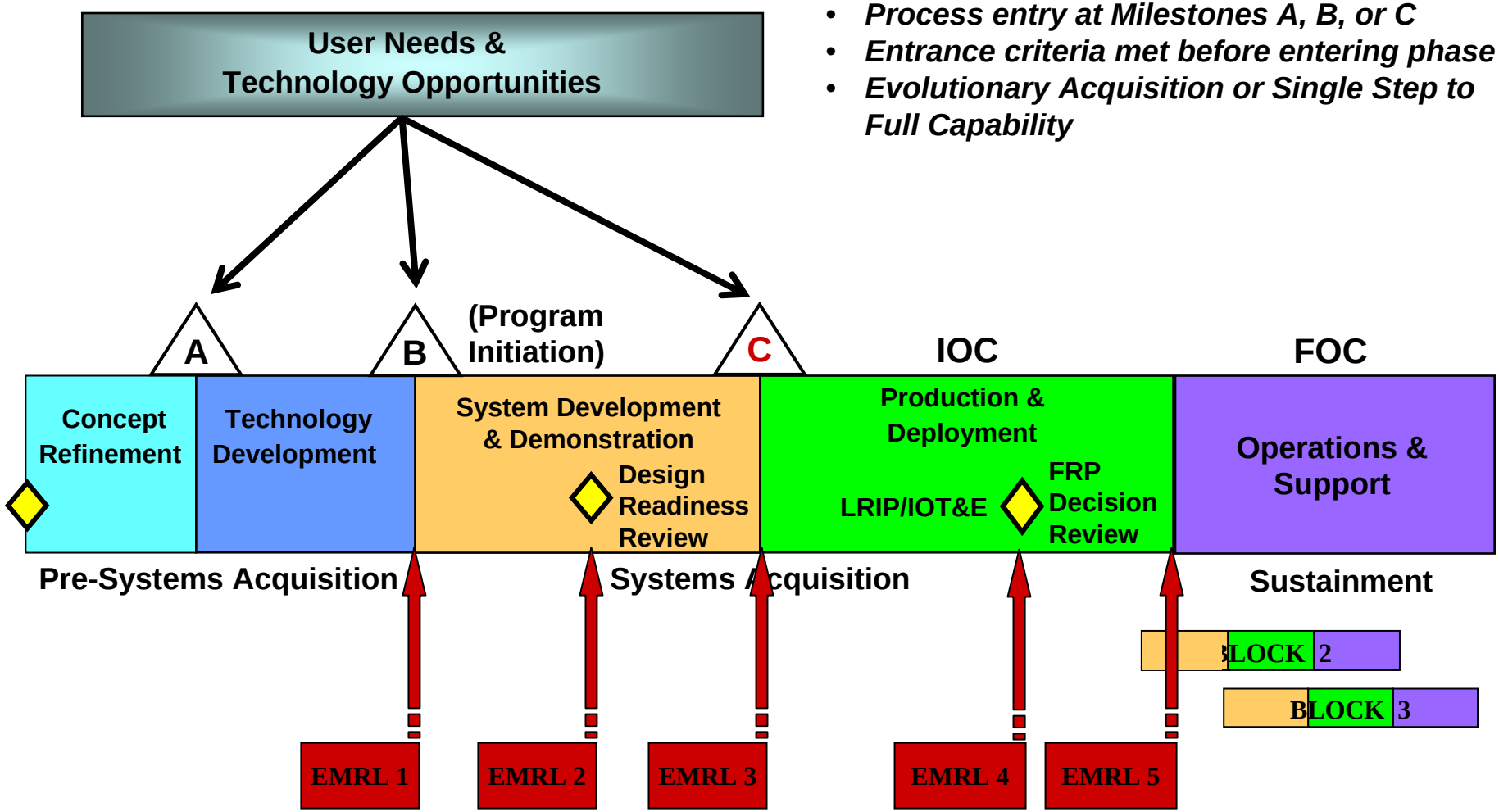
EMRLs and Acquisition Milestones

- *Process entry at Milestones A, B, or C*
- *Entrance criteria met before entering phase*
- *Evolutionary Acquisition or Single Step to Full Capability*



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EMRL Metrics and Exit Criteria

System EMRL 1 Capability Knowledge Point 1 Milestone B	System EMRL 2 Capability Knowledge Point 2 System DRR	System EMRL 3 Capability Knowledge Point 3 Milestone C
• Minimum system TRL=4 or 5 • All system engineering/design requirements defined; 50% validated • Component physical and functional interfaces 50% defined at system level • Materials, machines, tooling and test equipment demonstrated in a lab environment (system) • Manufacturing processes and system level integration demonstrated • Quality and reliability levels identified and established for 50% of the system • Key characteristics identified for 50% of the system • PDR complete at system level • 90% of items and components for system/major subsystem are proven designs or in production; EMRL 2-3 (hardware and software) and DRR complete • 75% of major subsystems (those representing 80% of cost) meet requirements of CKP2 and complete DRR • Failure modes, effects and criticality analysis required for all levels • Funding identified to proceed to CKP2 • Schedule and funding profile reflects achievement of CKP2 in 1-3 years • Developmental test plans complete for 75% of major subsystems • Developmental test plans initiated at system level • Safety assessment plans initiated • Design to cost goals established	• Minimum system TRL=6 or 7 • All system engineering/design requirements defined; 90% validated • Component physical and functional interfaces 90% defined at system level • System level manufacturing process and integration established in a production environment • Materials, machines, tooling and test equipment established in a production environment • Quality and reliability levels identified and established for 90% of the system • Key characteristics identified for 90% of the system • DRR complete at system level • All items and components at EMRL3, CKP3, and are ready for production or in production and meet cost, quality and reliability targets • 75% of major subsystems representing 80% of cost meet the requirements of CKP3 and are ready for or in LRIP • Failure modes, effects and criticality analysis complete on all items and components, 75% complete at system level • Funding identified to proceed to CKP3 • Schedule and funding profile reflects achievement of CKP3 in 1-3 years • Developmental test complete for major subsystems • Developmental test plans complete at system level • IOT&E plans complete • Safety assessment plans complete • Design to cost goals validated	• Minimum system TRL=8-9 • All system engineering/design requirements defined and validated • Minimal engineering changes • All component physical and functional interfaces defined and validated at system level • All manufacturing processes are understood and in control for LRIP • All materials, machines, tooling and test equipment purchased and ready for LRIP • All quality and reliability levels established and verified • All key characteristics identified and verified • Follow up issues from DRR cleared • All subsystems, items and components (hardware and software) are ready for on-time delivery (or delivered) • All subsystems, items and components meet cost, quality and reliability targets • Failure modes, effects and criticality analysis complete at system level • Reliability growth plan in place at all levels • Funding identified for reliability growth • All reliability growth testing is in place • Funding identified for LRIP • Schedule and funding profile reflects achievement of CPK4 in 1-2 years • Minimal developmental tests yet to be completed • All IOT&E plans complete • Initial Safety Assessment Complete • Design to cost goals met for LRIP

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EMRL Metrics and Exit Criteria

System EMRL 4 Capability Knowledge Point 4 FRP	System EMRL 5 Capability Knowledge Point 5 Continuous Improvement
• System TRL=9 • All system engineering/design requirements defined validated and met • Essentially no engineering changes • All physical and functional interfaces defined and validated • All materials, machines, tooling and test equipment in place at system level and ready for FRP • All manufacturing processes are understood and in control for FRP • All quality and reliability levels or targets met • All Key system characteristics met • All follow up issues from system level FRP PRR cleared • All subsystems, item and components (hardware and software) are in FRP and are ready for on-time delivery or are delivered • All failure modes, effects and criticality analysis complete • Reliability growth program implemented at all levels • Reliability growth testing implemented at all levels • Funding in place for reliability growth • All subsystems, items and components meet design to cost goals • Funding identified for FRP • System level developmental tests complete • IOT&E complete • Safety assessment complete • System design to cost goals met for FRP	• System TRL=9 • All system engineering/design requirements defined validated and met • Engineering changes are made for process or product improvements • All physical and functional interfaces defined and validated • Materials, machines, tooling and test equipment updated, modified or replaced for quality, cost or schedule improvements • Manufacturing processes modified or changed for quality, cost or schedule improvements • Quality and reliability levels or targets improved beyond 3 sigma • All Key system characteristics met or exceeded • All subsystems, item and components (hardware and software) assessed for cost, quality and performance improvements • Reliability growth improvements implemented • Funding in place for continued reliability growth • All subsystems, items and components continue to meet or exceed design to cost goals • Funding identified for continued production • Funding identified for spiral improvements or block upgrades • Safety assessment complete • System design to cost goals met or exceeded

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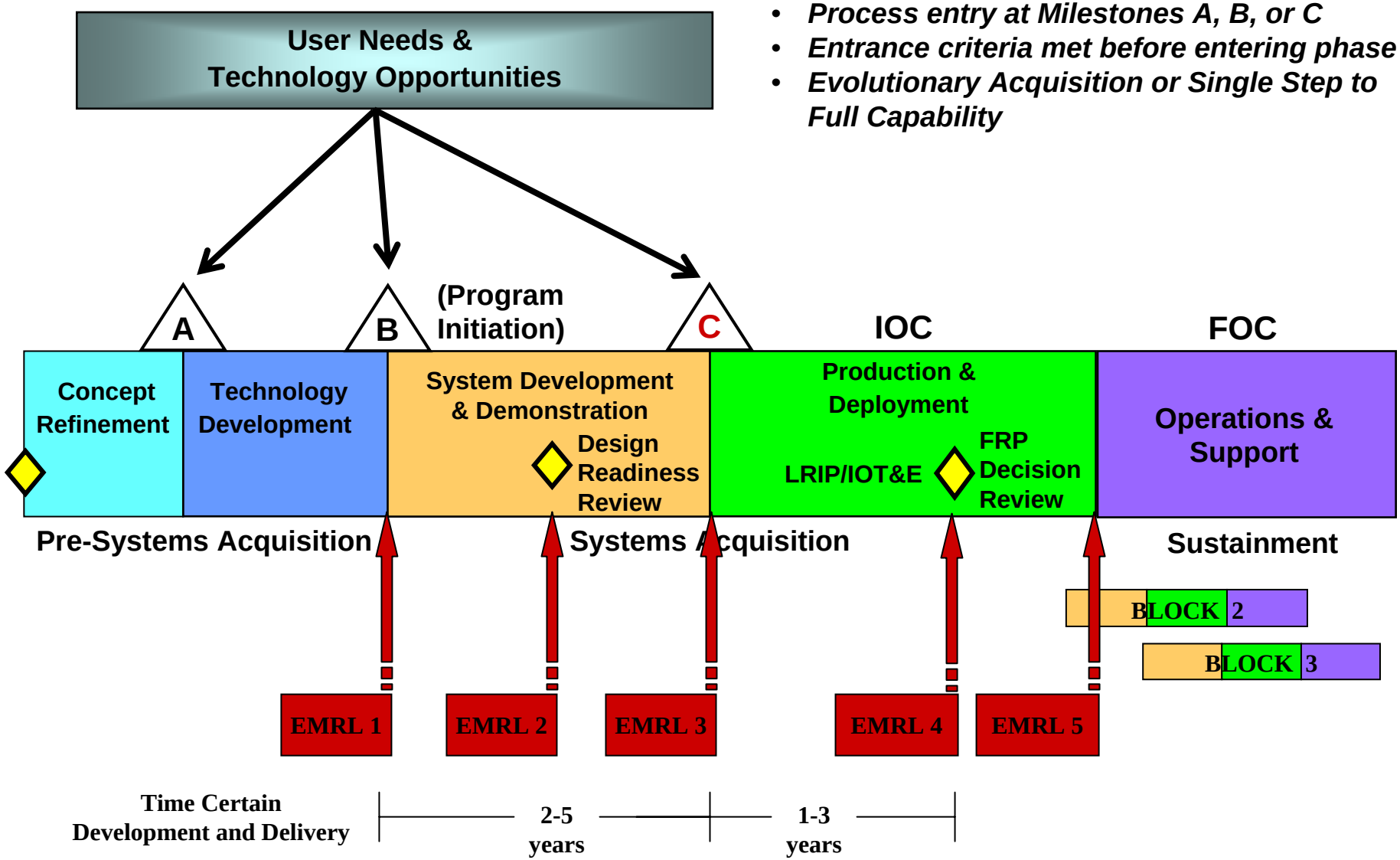
Time Certain Delivery

- *Process entry at Milestones A, B, or C*
- *Entrance criteria met before entering phase*
- *Evolutionary Acquisition or Single Step to Full Capability*



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Metrics Reporting and Roll Up

- **Criteria and metrics satisfied only with proof of performance**
- **Color coded success/failure for each question/requirement**
  - Meet 100% of the requirement (Green)
  - Requirement not met, requirement will be met within the current schedule and cost (Yellow)
  - Requirement not met, meeting requirement will impact current schedule or cost (Red)
- **Metrics are rolled up from lower level of WBS to higher level(s)**

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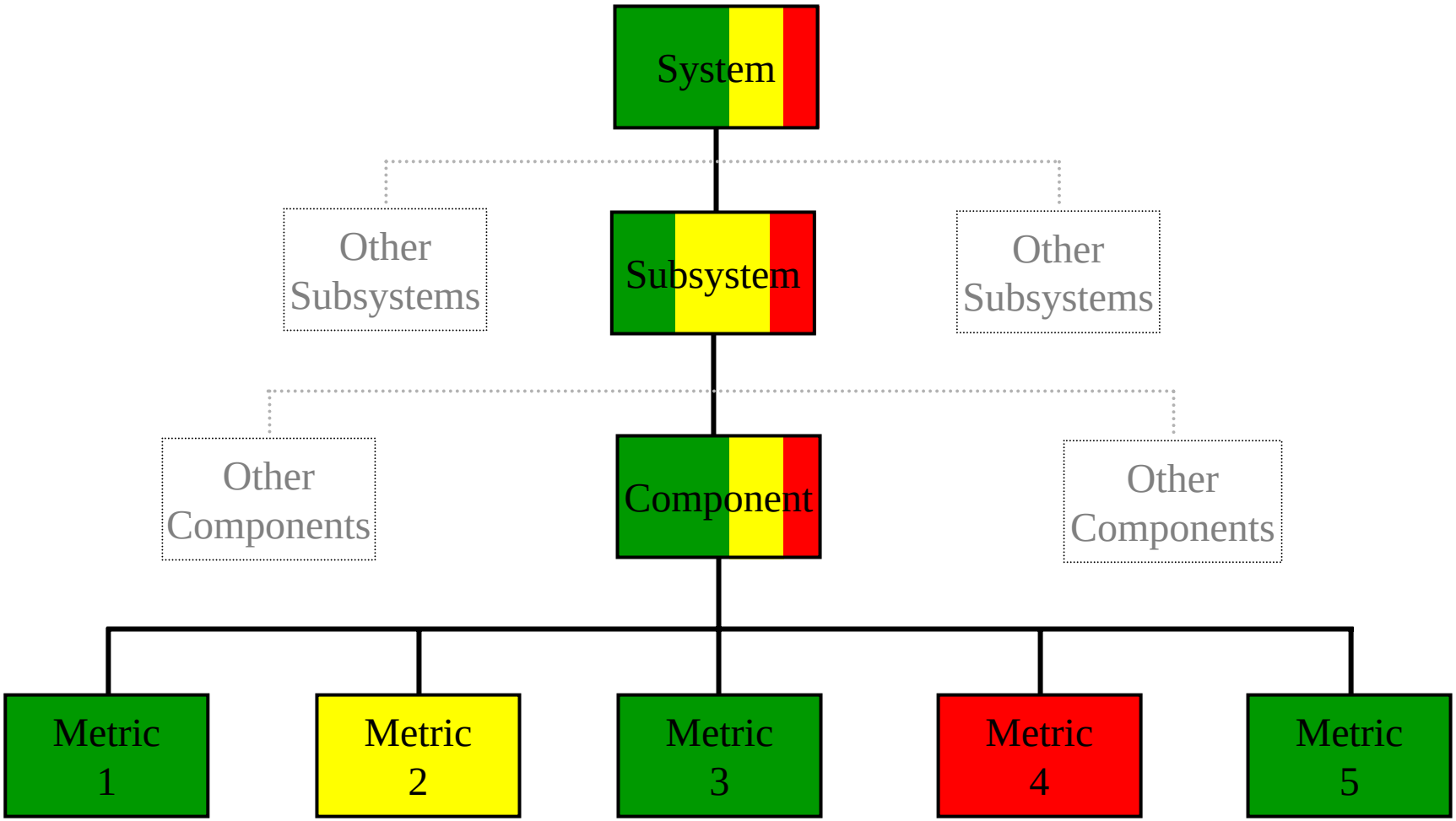
Metric Roll Up Chart



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EMRL Rollup Example
Actual Program Data

Original Assessment Date:	7/14	8/17	8/24	8/24	9/1	9/9	9/15	9/21	9/21			10/4	10/4		10/4
Updated Assessment Date:	10/4		9/30	10/4	9/30										
Updated: 10/04 **EMRL-3 Criteria Updated: 10/04**	CTR 1	CTR 2	CTR 3	CTR 4	CTR 5	CTR 6	CTR 7	CTR 8	CTR 9	CTR 10	CTR 11	CTR 12	CTR 13		Rollup
C.3.1 •Minimum Component TRL of 8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Yellow	Yellow		Yellow
C.3.2 •All system engineering/design requirements defined, verified and validated	NA	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Red			Yellow	Yellow		Red
C.3.3 •Minimal engineering changes	Green	Green	Green	Green	Green	Green	Green	Red	Red			Green	Green		Red
C.3.4 •All physical and functional interfaces defined at Component level, verified and validated	Green	Yellow	Green	Green	Green	Green	Green	Green	Red			Green	Green		Red
C.3.5 •All manufacturing processes are understood and in control for Block Production	Yellow	Green	Green	Yellow	Green	Yellow	Yellow	Yellow	Yellow			Yellow	Yellow		Yellow
C.3.6 •All machines, tooling and test equipment purchased and ready for Block Production	Yellow	Green	Green	Green	Green	Yellow	Yellow	Yellow	Yellow			Yellow	Yellow		Yellow
C.3.7 •Follow up issues from Component level CDR cleared	Green	Green	Green	Green	Green	Yellow	Yellow	Red	Red			Yellow	Yellow		Red
C.3.8 •All hardware and software is ready for on-time delivery (or delivered)	Green	Yellow	Yellow	Green	Yellow	Red	Yellow	Red	Red			Yellow	Yellow		Red
C.3.9 •Failure modes and effects analysis complete at the Component level	Green	Green	Green	Green	Green	Yellow	Green	Yellow	Yellow			Yellow	Yellow		Yellow
C.3.10 •Funding Identified for Block Production	Green	Green	Green	Green	Green	Green	Green	Green	Green			Green	Green		Green
C.3.11 •All Developmental Test complete	Green	Green	Yellow	Green	Green	Yellow	Yellow	Yellow	Yellow			Yellow	Yellow		Yellow
C.3.14 •Safety requirement complete	Green	Green	Green	Green	Green	Yellow	Green	Green	Green			Yellow	Green		Yellow
C.3.15 •All Quality levels have been established and verified	Green	Green	Green	Green	Green	Green	Green	Green	Green			Green	Green		Green
C.3.16 •All Reliability levels have been established and verified	Green	Green	Green	Green	Green	Yellow	Green	Yellow	Yellow			Yellow	Yellow		Yellow

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Summary

- **EMRLs have proven to be effective and efficient in measuring product maturity and readiness to transition from one phase to the next in defense acquisition**
- **EMRLs offer specific criteria and metrics for the Government and Industry to measure product and process maturity, and thereby enhance risk assessment in the development of systems, subsystems and components**

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Backups

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TRL Definitions

Technology Readiness Level	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 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 it 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, requiring demonstration of an actual system prototype in an operational environment, such as an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.
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, TRL represents the end of the true system development. Examples include developmental test and evaluation 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. In almost all cases, this is the end of the last "bug fixing" aspects of system development. Examples include using the system under operational mission conditions.

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EMRLs And Capability Knowledge Points (CKPs)

- **EMRLs describe the basic level of knowledge and capability required for a given acquisition phase. System, component and item managers continuously assess progress against EMRL criteria**
- **CKPs are the exit criteria and metrics for each EMRL and indicate the degree of product maturity or readiness for entry into the next acquisition phase**

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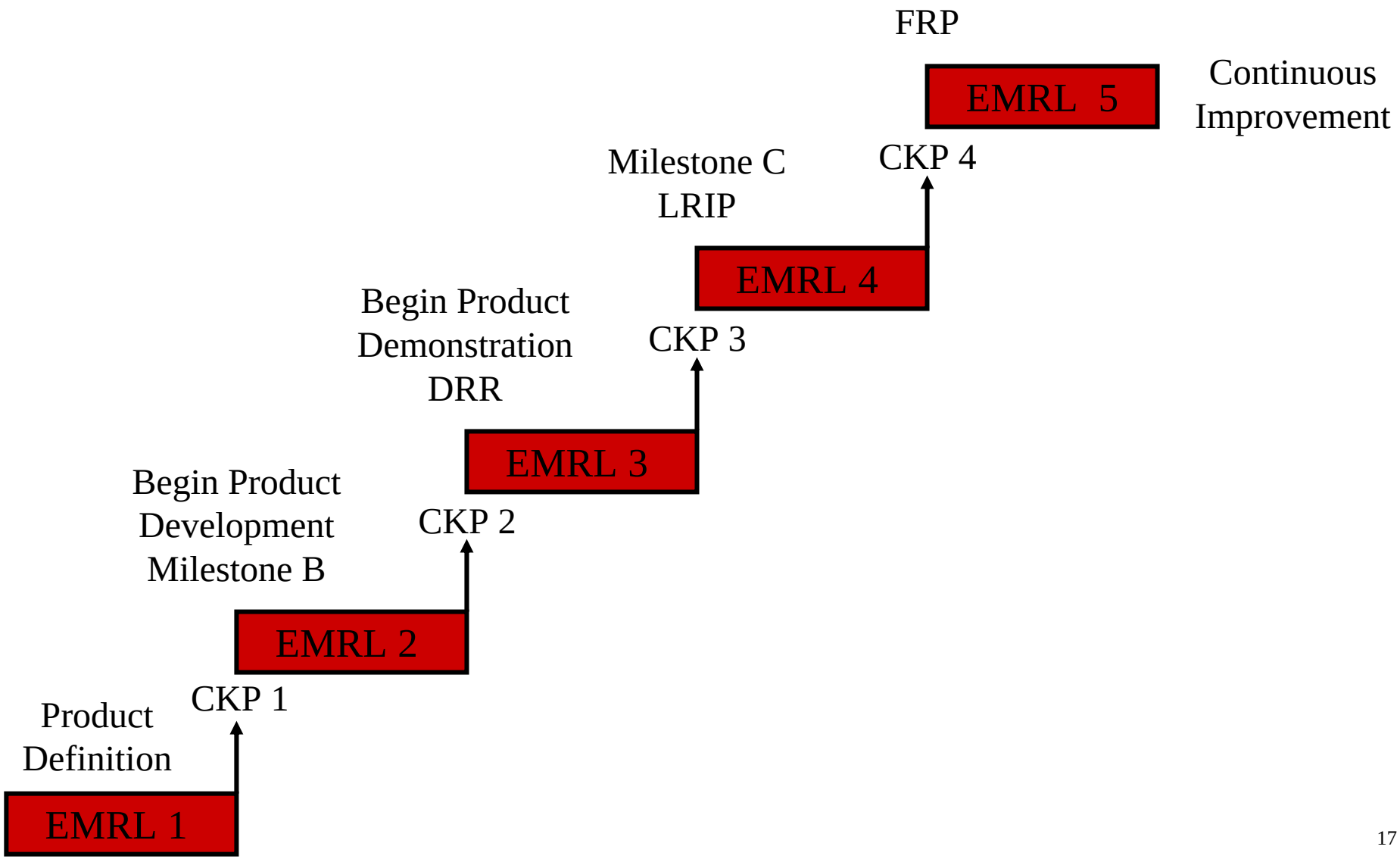
EMRLs and Acquisition Milestones



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EMRL 1 Definition

System, component or item validation in initial relevant engineering application and ready to enter Development Phase. Technologies must have matured to at least Technology Readiness Level (TRL) 4 or 5. Satisfying exit criteria metrics for Capability Knowledge Point (CKP)1 (Milestone B) and successful completion of system Preliminary Design Review (PDR) indicates readiness for the Product Development Phase.

This is the initial level of engineering and manufacturing readiness. Technologies must have matured to at least TRL 4 or 5. At this point all system engineering/design requirements defined and 50% validated. Component physical and functional interfaces 50% defined at system level. Manufacturing processes and system level integration demonstrated. 75% of major subsystems representing approximately 80% of cost meet requirements of CKP2. Overall quality and reliability levels and key characteristics identified and established for 50% of the system. Failure modes effects and criticality analysis required for all levels. Safety assessment plan initiated. Design to Cost goals established.

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EMRL 2 Definition

System, component or item in Product Development Phase ready to transition to Product Demonstration Phase. Technologies must have matured to at least TRL 6 or 7. Satisfying exit criteria metrics for CKP2, including successful completion of Product Design Readiness Review (DRR) indicates readiness for the Product Demonstration Phase.

Technologies must have matured to at least TRL 6-7. Systems engineering requirements are defined and 90% validated. Component physical and functional interfaces 90% defined at system level. Materials machines and tooling established in a production environment. 75% of major subsystems representing 80% of cost meet requirements of CKP3. Investments required for machines and tooling are identified. Inspection and test equipment tested in a manufacturing environment. Quality and reliability levels and key characteristics identified for 90% of the system. Failure modes effects and criticality analysis complete on all items and components and 75% complete at system level. Initial Operational Test and Evaluation (IOT&E) plans initiated. Safety assessment plan complete. Design to Cost goals validated.

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EMRL 3 Definition

System, component or item in Demonstration Phase ready to transition to Production Phase. Technologies must have matured to at least TRL 8 or 9. Satisfying exit criteria metrics for CKP3 (Milestone C) indicates readiness for Low Rate Initial Production (LRIP).

Technologies must have matured to at least TRL 8 or 9. All system engineering/design requirements defined and validated. Physical and functional interfaces defined and validated. Minimal design/system engineering changes. All materials are in production and readily available. Manufacturing processes and procedures under control and ready for low rate initial production. Machines, tooling and test equipment in place for LRIP. All quality and reliability requirements and key characteristics established and verified. Failure modes and criticality analyses completed at all levels. All subsystems, items and components are ready for on time delivery or delivered and meet cost, quality and reliability targets. IOT&E plans complete. Initial safety assessment complete. Design to cost goals met for LRIP.

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EMRL 4 Definition

System, component or item is in LRIP ready to transition to Full Rate Production (FRP). Technologies must have matured to at least TRL 9. Exit Criteria CKP4 indicates readiness for FRP.

Technologies must have matured to at least TRL 9. All systems engineering/design requirements met. Essentially no design/systems engineering changes. Materials are fully characterized, in production and readily available. Manufacturing processes and procedures are established and controlled in production to three-sigma or some other appropriate level. Machines tooling and test equipment in place for FRP. All quality and reliability requirements met and controlled to 3-sigma or other appropriate level. All key characteristics met and are controlled to three-sigma or some other appropriate quality level. All subsystems, items and components are delivered on time and meet schedule, cost, quality and reliability targets for FRP. IOT&E complete. Safety assessment complete. Design to Cost goals met for FRP.

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EMRL 5 Definition

System, component or item is in FRP with continuous product/process improvement. System, component or item ready for spiral development/block change.

This is the highest level of engineering and manufacturing readiness. System, component or item in FRP. All design/system engineering changes made for product and process improvements. All materials, manufacturing processes and procedures, inspection and test equipment, quality, reliability and key characteristics controlled in production to six-sigma or some other appropriate quality level. Lean enterprise practices in place to drive continuous improvement.