# Reducing Manufacturing Risk
## Manufacturing Readiness Levels

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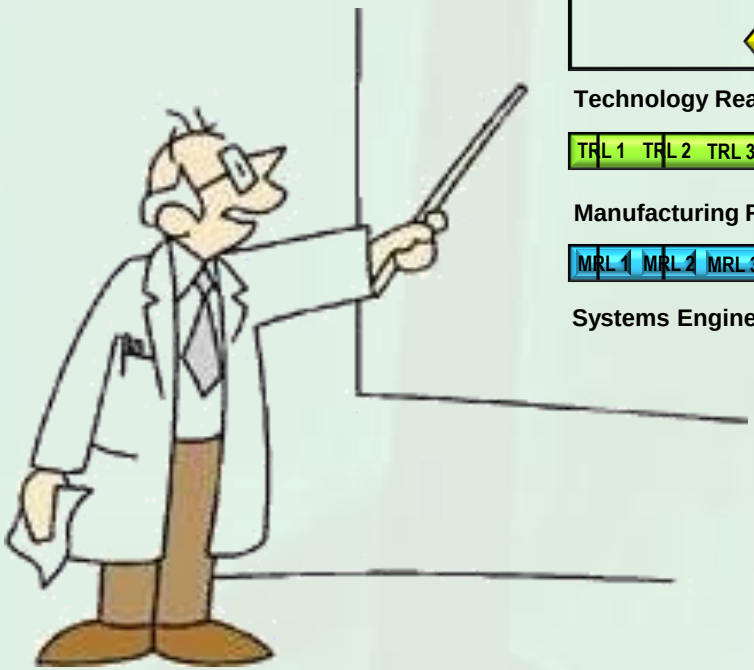
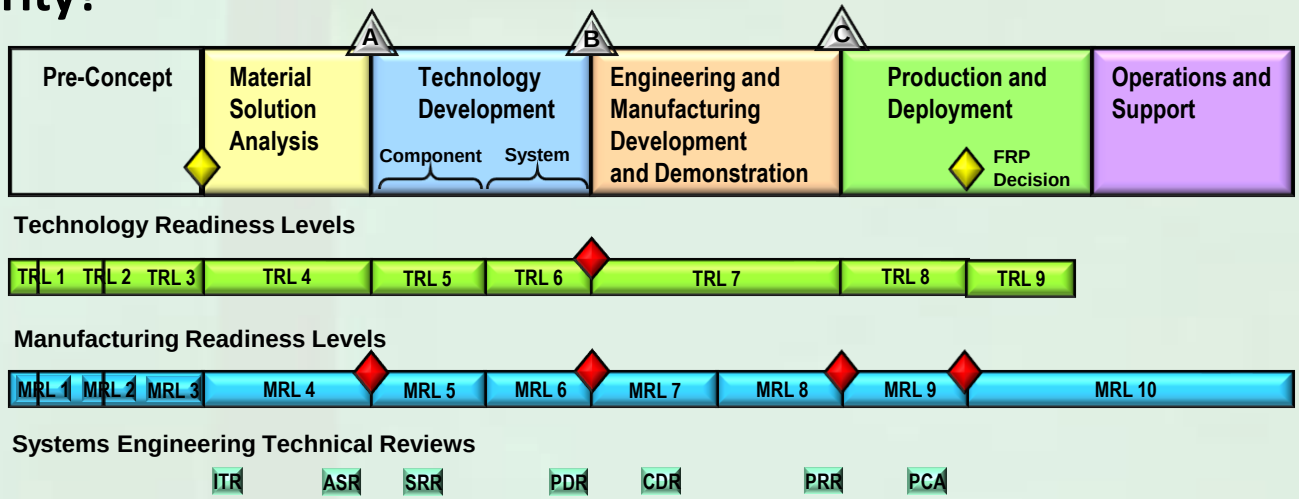
# Do You Know Your Risks?

**In your systems engineering process what knowledge do you have about Manufacturing Maturity?**





# Why use MRLs?

- Acquisition performance perceived as broken by users, Congress, and GAO
  - Numerous cost and schedule overruns
  - Not adequately addressing manufacturing issues early in the process is one of the key issues
- Addressing manufacturing earlier in the design/development process is being demanded
  - DoDI 5000.02
  - Congress (HR 6523 Section 812)
- Current performance in acquisition must be improved – MRLs just one tool to help

GAO
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# MRLs Recognized by Many

- NDIA Manufacturing Division endorses MRLs
- DoD ManTech Strategic Plan, March 2009
  - Thrust 3.1: Effective policies and practices to assess and improve manufacturing readiness
- DoDI 5000.02, Dec 2009
  - Moved manufacturing considerations to the left
  - Exit criteria based upon MRL definitions now required for all phases of acquisition
- GAO report 10-439, April 2010
  - In-depth assessment of MRL practices
  - Recommends requiring use of MRLs in DoD acquisition
- Congressional direction, Dec 2010
  - Requires MRLs on MDAPs

**MRLs provide a well developed tool to address manufacturing risk earlier in the acquisition process**

# National Defense Authorization Act

FY11 NDAA: SEC. 812. MANAGEMENT OF MANUFACTURING RISK IN MAJOR DEFENSE ACQUISITION PROGRAMS

Guidance Required- **the Secretary of Defense shall issue comprehensive guidance** on the management of manufacturing risk in major defense acquisition programs

The guidance issued under subsection (a) shall, at a minimum—

(1) **require the use of manufacturing readiness levels** as a basis for measuring, assessing, reporting, and communicating manufacturing readiness

(2) provide guidance on the **definition of manufacturing readiness levels and how manufacturing readiness levels should be used** to assess manufacturing risk and readiness

(3) **specify manufacturing readiness levels that should be achieved** at key milestones and decision points for major defense acquisition programs

(4) **identify tools and models** that may be used to assess, manage, and reduce risks that are identified in the course of manufacturing readiness assessments

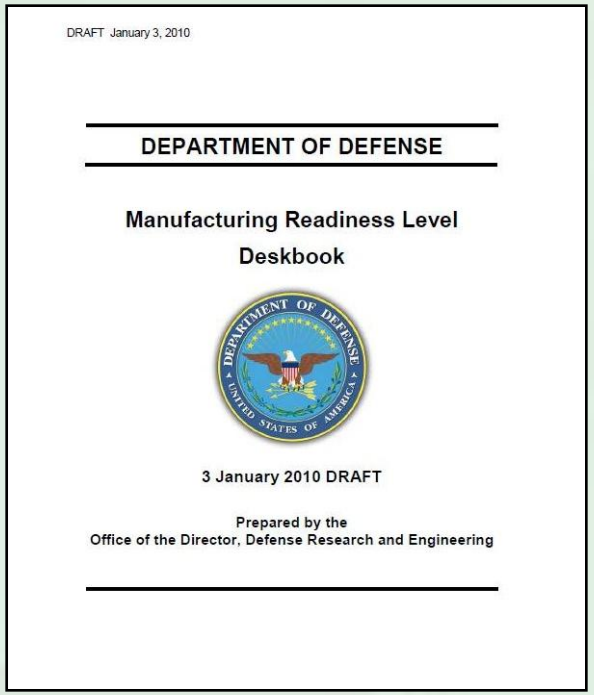
(5) **require appropriate consideration** of the manufacturing readiness and manufacturing readiness processes of potential contractors and subcontractors **as a part of the source selection process**

# MRL Process Defined in a Deskbook

Process well-defined – MRL Deskbook @ http://www.dodmrl.com

Deskbook has 6 chapters:

1. Introduction
2. Manufacturing Readiness Levels
3. MRLs and the Acquisition Management System
4. The Process for Conducting Assessments of Manufacturing Readiness
5. Manufacturing Maturation Plans and Risk Management
6. Applying MRLs in Contract Language


DRAFT January 3, 2010

DEPARTMENT OF DEFENSE

Manufacturing Readiness Level Deskbook

3 January 2010 DRAFT

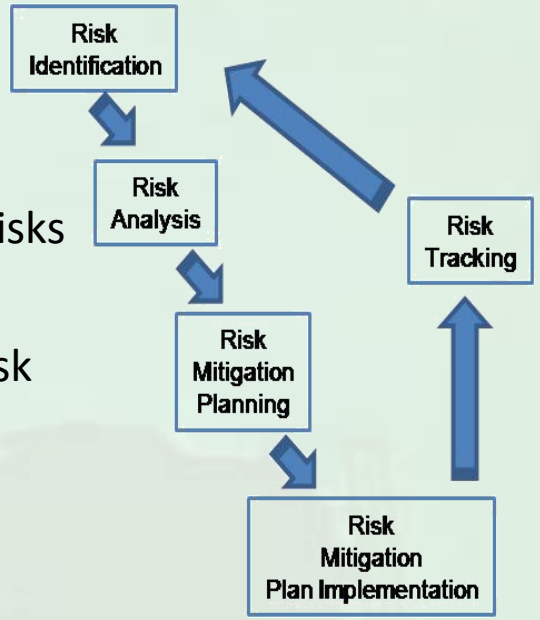
Prepared by the
Office of the Director, Defense Research and Engineering

# MRL Process Defined (continued)

MRLs designed to identify and manage manufacturing risk.

The key is the MRL Matrix – the maturity levels are defined by expected criteria at each step along the development/design process.

- Define current level of manufacturing maturity
- Identify maturity shortfalls and associated costs and risks
- Provide the basis for manufacturing maturation and risk management



# MRL Criteria – the Threads

**Technology and the Industrial Base**: Do you have the capability and capacity to produce?

**Design**: Is the design stable, mature and producible?

**Cost and Funding**: Is the cost realistic, affordable and is the funding in place for the system and for investments in maturing technologies and processes?

**Materials**: Are the materials available at all levels of the supply chain?

**Process Capability and Control**: Are your manufacturing processes proven, stable, capable and in control?

**Quality Management**: Is your QA program in place and effective throughout the supply chain?

**Manufacturing Workforce:** Is your manufacturing workforce trained and certified?

**Facilities**: Are your facilities in place, proven and capable throughout the supply chain?

**Manufacturing Management:** Is your manufacturing planning complete and ready for production?

# MRL Criteria – the Matrix

The MRL Matrix is an expansion of the "Definitions and Descriptions"

- Includes nine major threads and twenty sub-threads
- Evaluation criteria for each thread
- Plotted against every acquisition phase and milestone decision point

| Acquisition Phase | | MSA | Tech. | Dev. | Engr & Mfg Dev. | | LRIP | FRP |
|---|---|---|---|---|---|---|---|---|
| Thread | Sub-Thread | MRL 4 | MRL 5 | MRL 6 | MRL 7 | MRL 8 | MRL 9 | MRL 10 |
| Technology & the Industrial Base | Technology Maturity | | | | | | | |
| | Transition to Production | | | | | | | |
| | Mfg. Tech Development | | | | | | | |
| Design | Producibility Program | | | | | | | |
| | Design Maturity | | | | | | | |
| Cost & Funding | Production Cost | | | | | | | |
| | ManTech Investments | | | | | | | |
| Materials | Availability | | | | | | | |
| | Supply Chain | | | | | | | |

# MRL Criteria – the Matrix

| DoD Manufacturing Readiness Levels (MRLs) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Acq Phase** | | **Pre CR** | **Pre CR** | **Pre CR** | **CR - MS A** → | **TD** | **MS B** → | **SDD** | **MS C** → | ← **LRIP - FRP** → | **FRP** |
| **Thread** | **Sub-Thread** | **MRL 1** | **MRL 2** | **MRL 3** | **MRL 4** | **MRL 5** | **MRL 6** | **MRL 7** | **MRL 8** | **MRL 9** | **MRL 10** |
| Technology & Industrial Base | **Technology Maturity** | Should be assessed at TRL 1. | Should be assessed at TRL 2. | Should be assessed at TRL 3. | Should be assessed at TRL 4. | Should be assessed at TRL 5. | Should be assessed at TRL 6. | Should be assessed at TRL 7 | Should be assessed at TRL 7. | Should be assessed at TRL 8. | Should be assessed at TRL 9. |
| | **Technology Transition to Production** | | | Potential sources identified for technology needs. (Understand state of the art). | Industrial Base capabilities and gaps/risks identified for key technologies, components, and/or key processes. | Industrial Base assessed to identify potential manufacturing sources. | Industrial Capability Assessment (ICA) for MS B has been completed. Industrial capability in place to support mfg of development articles. Plans to minimize sole/foreign sources complete. Need for sole/foreign sources justified. Potential alternative sources identified. | Industrial capability to support production has been analyzed. Sole/foreign sources stability is assessed/monitored. Developing potential alternate sources as necessary. | Industrial Capability Assessment (ICA) for MS C has been completed. Industrial capability is in place to support LRIP. Sources are available, multi-sourcing where cost-effective or necessary to mitigate risk. | Industrial capability is in place to support start of FRP. | Industrial capability supports FRP. Industrial capability assessed to support mods, upgrades, surge and other potential manufacturing requirements. |
| | **Manufacturing Technology Development** | | New manufacturing concepts and potential solutions identified. | Manufacturing technology concepts identified through experiments / models. | Mfg science & advanced mfg technology requirements identified. | Required manufacturing technology development efforts initiated. | Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production relevant environment. | Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production representative environment. | Manufacturing technology efforts continuing. Required manufacturing technology solutions validated on a pilot line. | Manufacturing technology efforts continuing. Manufacturing technology process improvement efforts initiated for FRP. | Manufacturing technology efforts continuing. Manufacturing technology continuous process improvements ongoing. |
| Design | **Producibility Program** | | | Relevant materials/processes evaluated for manufacturability using experimental results. | Producibility & Manufacturability assessment of design concepts completed. Results guide selection of design concepts and key components/technologies for Technology Development Strategy. Required Test Evaluation Strategy (TES) includes Design for Test during production. | Producibility & Manufacturability assessments of key technologies and components initiated. Systems Engineering Plan (SEP) requires validation of design choices against manufacturing process and industrial base capability constraints. Manufacturing processes assessed for capability to test and verify in production, and influence on Operations & Support (O&S). | Producibility assessments of key technologies/components and producibility trade studies (performance vs. producibility) completed. Results used to shape System Development Strategy and plans for SDD or technology insertion programs phase. | Detailed producibility trade studies using knowledge of key design characteristics and related manufacturing process capability completed. Producibility enhancement efforts (e.g. Design For Mfg Assembly) initiated. | Producibility improvements implemented on system. Known producibility issues have been resolved and pose no significant risk for LRIP. | Prior producibility improvements analyzed for effectiveness during LRIP. Producibility issues/risks discovered in LRIP have been mitigated and pose no significant risk for FRP. | On-going producibility improvements analyzed for effectiveness. Producibility refinements continue. All mods, upgrades, Diminishing Mfg Sources & Material Shortages (DMSMS) and other changes assessed for producibility. |
| | **Design Maturity** | Manufacturing opportunities identified. | Applications defined. Broad performance goals identified that may drive manufacturing options. | Top level performance requirements defined. Trade-offs in design options assessed based on experiments. Product lifecycle and technical requirements evaluated. | Initial Systems Engineering Plan and Test and Evaluation Strategy recognize the need for the establishment/validation of manufacturing capability and management of manufacturing risk for the product lifecycle. Initial Key Performance Parameters (KPPs) identified. | Identification of enabling/critical technologies and components is complete and includes the product lifecycle. Evaluation of design Key Characteristics (KC) initiated. | Basic system design requirements defined. All enabling/critical technologies/components have been tested and validated. Product data required for prototype manufacturing released. A preliminary performance as well as focused logistics specification is in place. Key Characteristics and tolerances have been established. | Product requirements and features are well enough defined to support detailed systems design. All product data essential for manufacturing of component design demonstration released. Potential KC risk issues have been identified and mitigation plan is in place. Design change traffic may be significant. | Detailed design of product features and interfaces is complete. All product data essential for system manufacturing released. Major product design features are sufficiently stable such that key LRIP manufacturing processes will be representative of those used in FRP. Design change traffic does not significantly impact LRIP. Key characteristics are stable and have been demonstrated in SDD or technology insertion program. | Major product design features are stable and LRIP produced items are proven in product testing. Design change traffic is limited to minor configuration changes. All KCs are controlled in production to 3-sigma or other appropriate quality levels. | Product design is stable. Design changes are few and generally limited to those required for continuous improvement or in reaction to obsolescence. All KCs are controlled to 6-sigma or other appropriate quality levels. |
| | **Production Cost Knowledge (Cost modeling)** | | Cost model approach defined. | Technology cost models developed for new process steps and materials based on experiments. | Detailed process chart cost models driven by key characteristics and process variables. Manufacturing, material and specialized reqt. cost drivers identified. | Detailed end-to-end value stream map cost model for major system components includes materials, labor, equipment, tooling/STE, setup, yield/scrap/rework, Work In Progress (WIP), and capability/capacity constraints. Component simulations drive | Cost model inputs include design requirements, material specifications, tolerances, integrated master schedule, results of system/subsystem simulations and production relevant demonstrations. | Cost models updated with detailed designs and features, collected quality data, plant layouts and designs, and obsolescence solutions. | Engineering cost model driven by detailed design and validated with data from relevant environment. | Actual cost model developed for FRP environment. Variability experiments conducted to show FRP impact and potential for continuous improvement. | Cost model validated against actual FRP cost. |

# MRL Guidance

MRLs are an information tool for managers and engineers to identify, manage and mitigate manufacturing risk throughout the systems engineering process

- **A common language used to assess manufacturing maturity**
- **Provide insight, not oversight**

MRLs are not pass/fail – they identify risks!

- **MRL 7 might not be good**
- **MRL 3 might not be bad**

# MRL Benefits

- Well-documented roadmap to achieve manufacturing maturity effectively and efficiently
  - Developed by Industry and Government manufacturing and systems engineering SMEs
- A tool that provides/requires fact-based information on a program's manufacturing maturity
  - Essential for risk management
- A forcing function to get manufacturing considerations addressed earlier in the design & development process
- Provides process for managing & communicating manufacturing maturity across the supply chain and customer base
- Excellent tool to identify systemic manufacturing problems across programs/contractors/industrial base

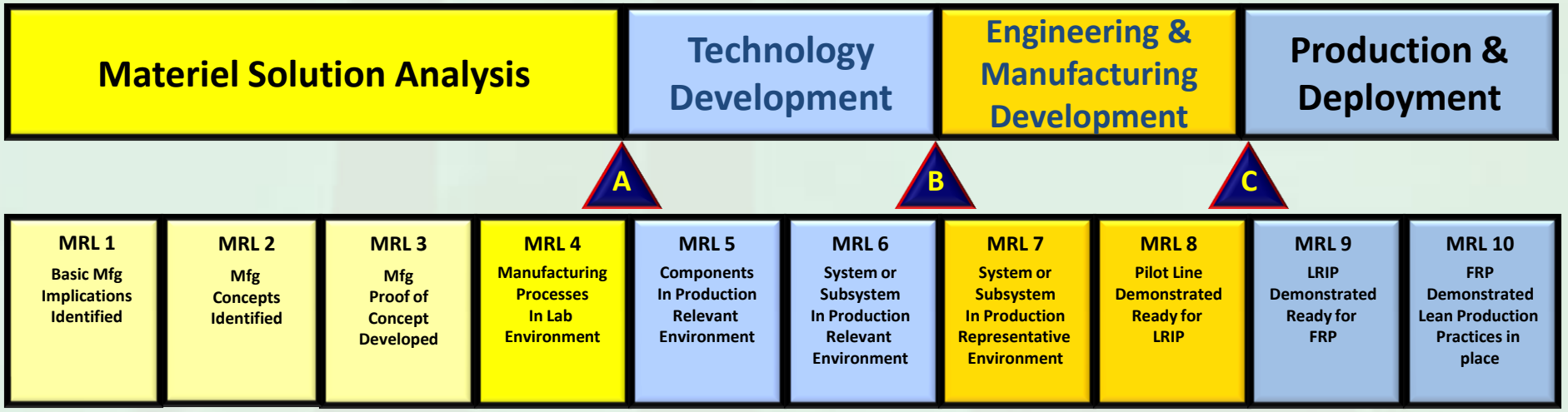
# Implementation Status

- MRL Deskbook at http://www.dodmrl.com
- Training available
  - AFIT course (SYS 213)
  - Some DAU courses
- Is a "Standard Operating Procedure" at many prime contractors
  - Raytheon, Honeywell, GE, Lockheed, etc
- DoD implementation mixed
  - OSD: DAG Chapter 4 provides manufacturing assessment criteria
  - Air Force: Firm guidance to use MRLs at SAF, AFMC, AFRL, ASC, and AAC
  - Army: Firm guidance on ManTech programs and significant use in acquisition
  - Navy: Used on some acquisition programs (NAVAIR is implementing MRLs)
  - MDA: Mixed use of EMRLs and MRLs
- Other Government agencies that have used or are using MRLs
  - DCMA, DOE, DOC, NASA, DHS

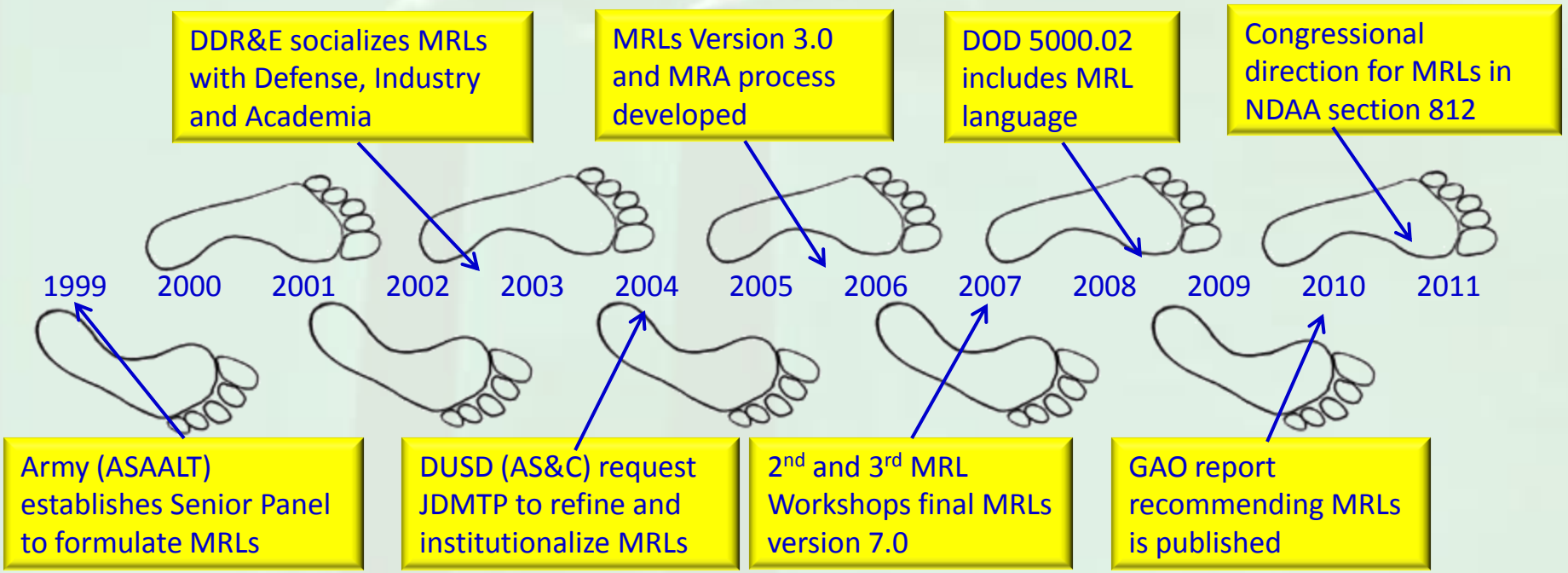
# MRLs Integrated

MRLs have been integrated into the Acquisition process and the Systems Engineering process

- MRL criteria has been incorporated into DAG language for Design Reviews
- Language consistent with DoDI 5000.02 requirements
- MRL criteria are used in Program Support Reviews (PSRs)



# How We Got Here – A Timeline

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# Summary

- MRLs developed by SMEs from Industry, Government and Academia – continuously refined and improved by
  - Numerous joint workshops and pilot studies
- Process well defined – MRL Deskbook (http://www.dodmrl.com)
- Recognized process by manufacturing and systems engineering SMEs to reduce risk
  - Industry, Services, GAO, Congress & other Government agencies
- Integrated into Acquisition and Systems Engineering Process

**MRLs are a tool that can reduce manufacturing risk!**

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