GENERAL DYNAMICS
Armament and Technical Products

Ready or Not? Using Readiness Levels to Reduce Risk on the Path to Production

August, 2011

Are You Ready …

- To adopt a new technology?
- To incorporate a new technology into a design?
- To integrate subsystems?
- To transition to production?

The Answers to these Questions Have Critical Implications to the Product Developer, Acquirer and User

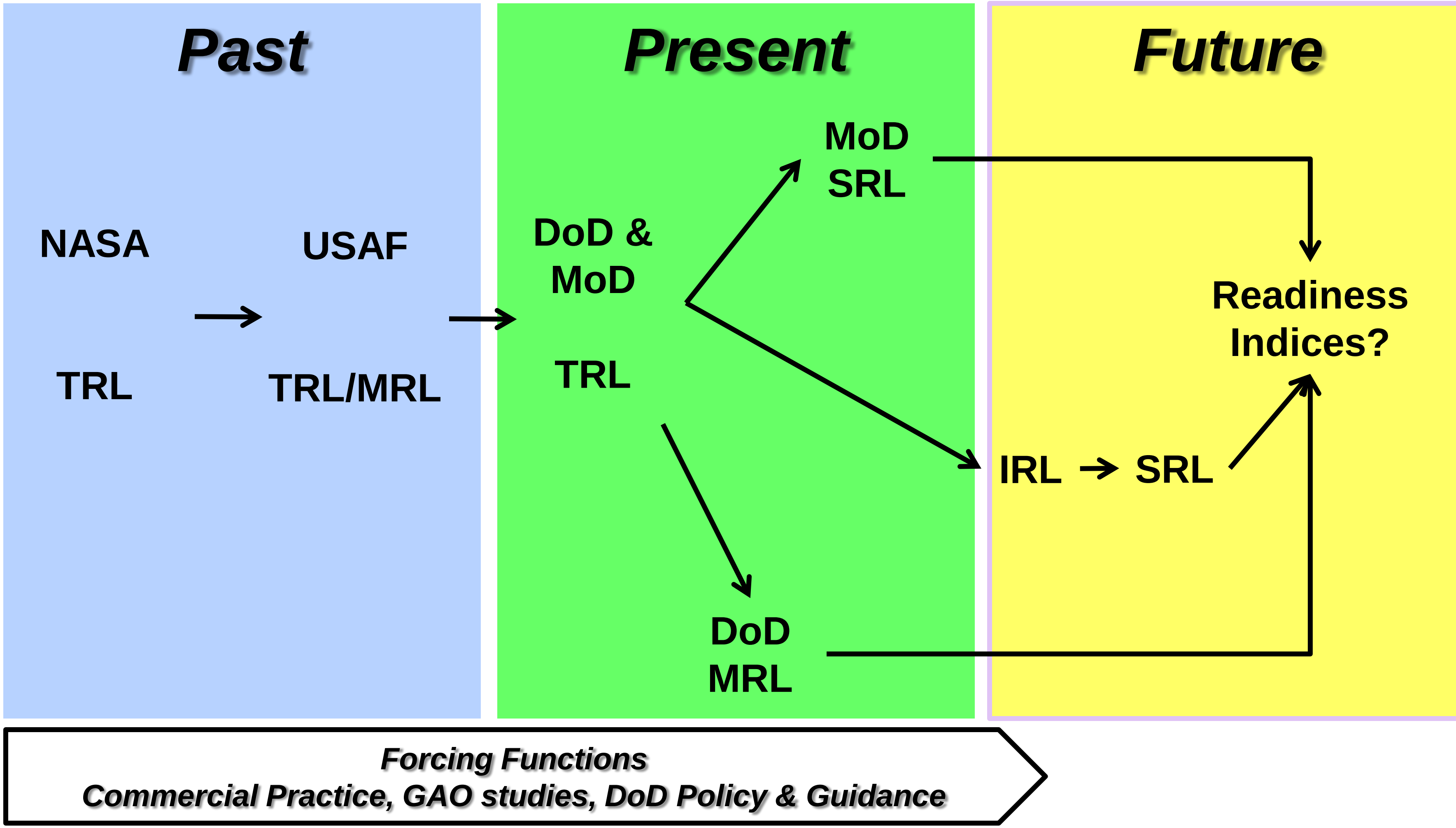
Agenda

- Introduction to Readiness Levels
- DoD Policy & Guidance
- Readiness Methods Survey
  - Technology Readiness
  - Manufacturing Readiness
  - Integration Readiness
  - System Readiness
- Implementation Suggestions

Introduction

- A management method
- Informs risk management
- A measurement scale and vocabulary
  - Technology Readiness
  - Manufacturing Readiness
  - Integration Readiness
  - System Readiness
  - And others…
- Used in various forms
  - Multiple Federal departments/agencies
  - Multiple industries

An Approximate History



DoD Policy – Technology Readiness Assessment, TRA

- Required by DoD 5000.01 (directive) and DoD 5000.02 (instruction)
- TRA are required for ALL MDAP at Milestone B (before EMD phase).
- TRA not required for non-MDAP or MAIS
- TRA should focus *on "technology maturity as opposed to engineering and integration risk"*…memo: Improving Technology Readiness Assessment Effectiveness; Ashton Carter, May 2011.

Technology Readiness

- Approximate measure of technical maturity
- Technology Readiness Assessment (TRA) Deskbook, July 2009
- Applicable to 'critical' hardware and software technology elements (CTEs)
  - Identified during material solution analysis
  - Depend on element to meet op requirements
  - New, novel or poses 'major technological risk'
  - Assessment criteria for hardware, software; aircraft, ground vehicles, missiles, ships…

Technology Readiness, Continued

Increasing Maturity, Decreasing Risk

Level	Definition
TRL 1	Basic principles observed and reported
TRL 2	Technology concept and/or application formulated
TRL 3	Analytical and experimental critical function and/or characteristic proof of concept
TRL 4	Component and/or breadboard validation in a laboratory environment
TRL 5	Component and/or breadboard validation in a relevant environment
TRL 6	System/subsystem model or prototype demonstration in a relevant environment(required to start EMD)
TRL 7	System prototype demonstration in an operational environment (required to start LRIP)
TRL 8	Actual system completed and qualified through test and demonstration
TRL 9	Actual system proven through successful mission operations

Source: Technology Readiness Assessment (TRA) Deskbook, July 2009

DoD Policy, Manufacturing Readiness

- Manufacturing Readiness Requirements
  - Implied by DoD 5000.02
    - Requires assessment of manufacturing capabilities and risks
  - Not institutionalized to degree TRLs are
    - Lack of consensus on use across services
    - Not currently required by DoD acquisition policy
  - Use growing in DoD and defense industry
  - Analogs used routinely in other industries

Manufacturing Readiness

- Approximate measure of manufacturing maturity
- Resource: Manufacturing Readiness Level Deskbook, July 2010 (OSD Mfg Tech Program)
- Threads used to assess risk areas
  - Technology & Industrial Base
  - Design
  - Cost and Funding
  - Materials
  - Process Capability and Control
  - Quality Management
  - Manufacturing Personnel
  - Facilities
  - Manufacturing Management

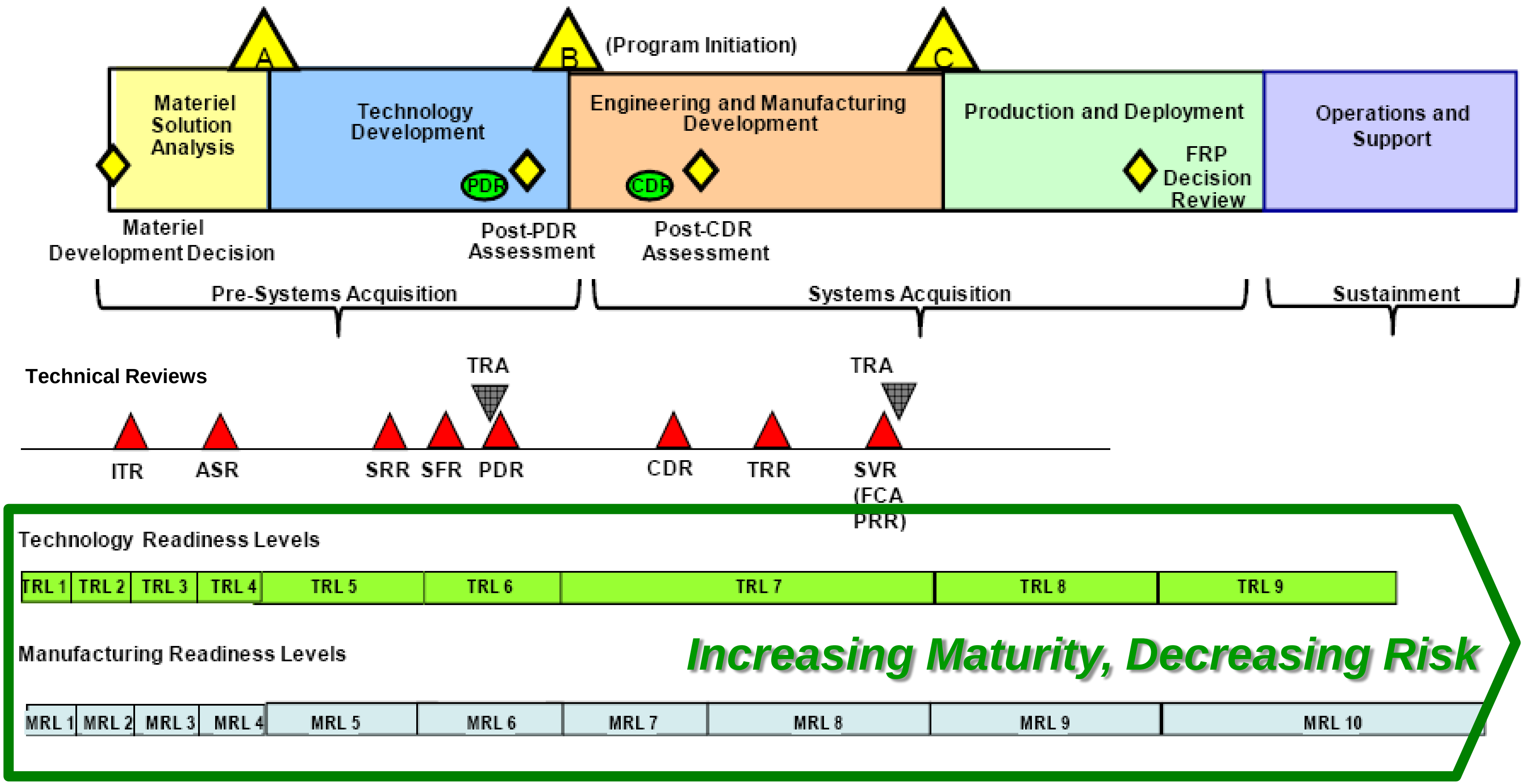
Manufacturing Readiness, Cont

Increasing Maturity, Decreasing Risk

Level	Definition
MRL 1	Basic Manufacturing Implications Identified
MRL 2	Manufacturing Concepts Identified
MRL 3	Manufacturing Proof of Concept Developed
MRL 4	Capability to Produce the Technology in a Laboratory Environment
MRL 5	Capability to produce prototype components in a production relevant environment
MRL 6	Capability to produce a prototype system or subsystem in a production relevant environment
MRL 7	Capability to produce systems, subsystems or components in a production representative environment
MRL 8	Pilot line capability demonstrated; Ready to begin low rate initial production
MRL 9	Low rate production demonstrated; Capability in place to begin full rate production
MRL 10	Full rate production demonstrated and lean production practices in place

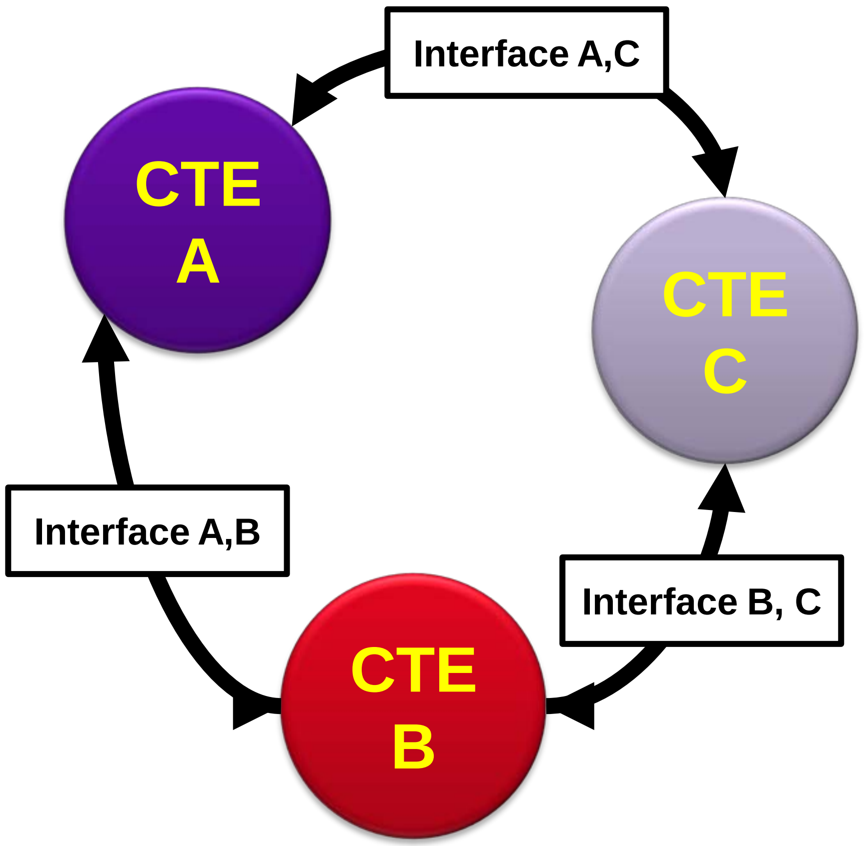
Source: Manufacturing Readiness Level Deskbook, July 2010

Role in DoD Acquisition



Source: Manufacturing Readiness Level Desk Book, July 2010

What About Interfaces?



Integration Readiness

- Approximate measure of integration maturity
  - Between two or more items or subsystems
- Work on integration measures, assessments and indices culminated in Integration Readiness Levels (IRLs) proposed by Gove et al., at Stevens Institute of Technology, School of Systems & Enterprises
- Resources: No deskbook equivalent, multiple papers and briefings on subject

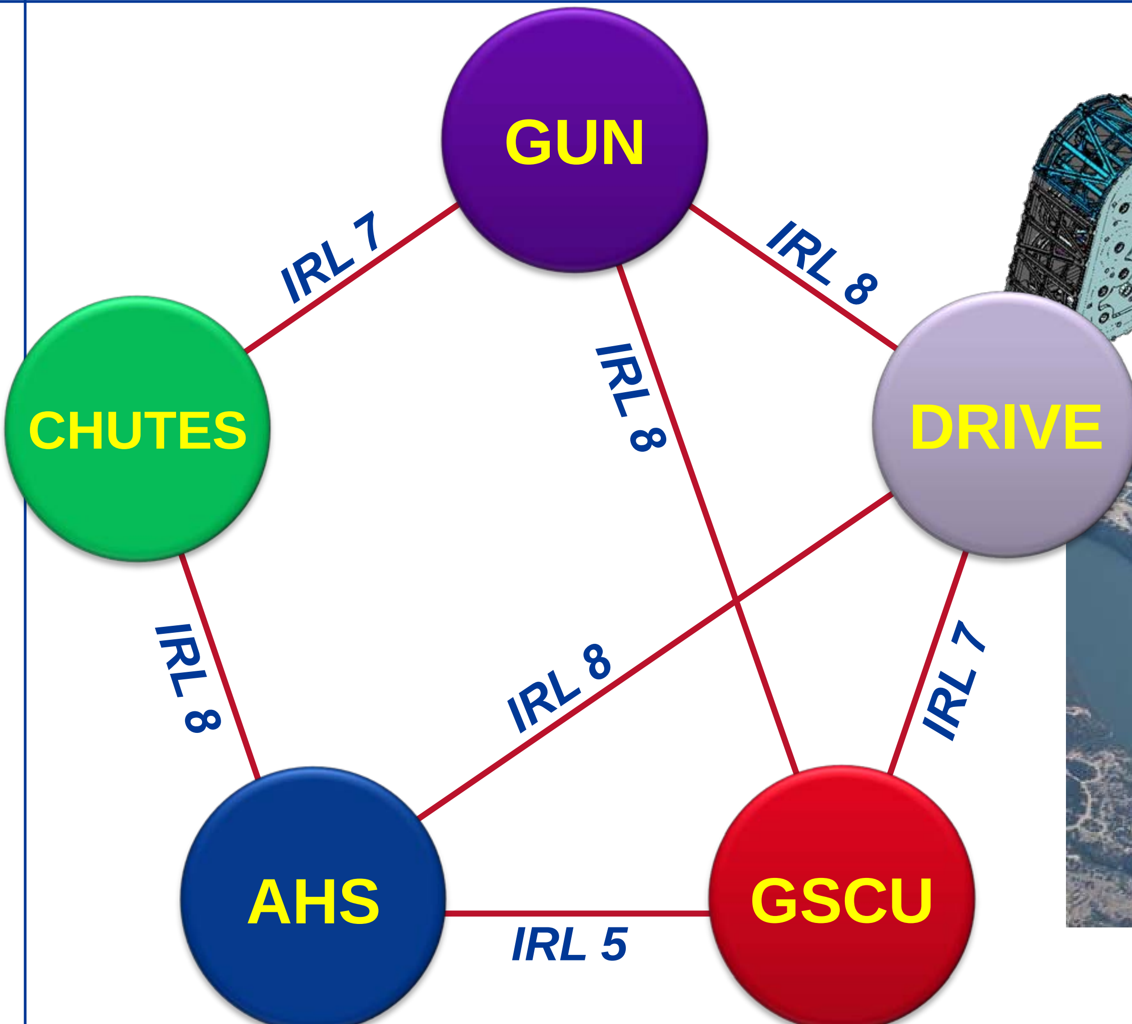
Integration Readiness, Continued

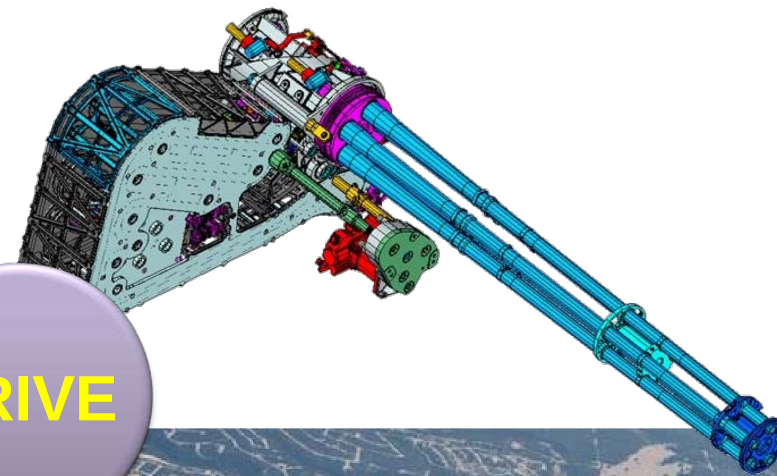
Increasing Maturity, Decreasing Risk

Level	Definition
IRL 1	An interface between technologies has been identified with sufficient detail to allow characterization of the relationship
IRL 2	There is some level of specificity to characterize the interaction between technologies through their interface
IRL 3	There is compatibility between technologies to orderly and efficiently integrate and interact
IRL 4	There is sufficient detail in the quality and assurance of the integration between technologies
IRL 5	There is sufficient control between technologies necessary to establish, manage, and terminate the integration
IRL 6	The integrating technologies can accept, translate, and structure information for its intended application
IRL 7	The integration of technologies has been verified and validated with sufficient detail to be actionable
IRL 8	Actual integration completed and Mission Qualified through test and demonstration, in the system environment
IRL 9	Integration is Mission Proven through successful mission operations

Source: A Systems Approach to Expanding the Technology Readiness Level within Defense Acquisition, International Journal of Defense Acquisition Management, Volume 1 2008

Example: F35JSF and Gun System





IRL values are arbitrary and for illustrative purposes only.

System Readiness

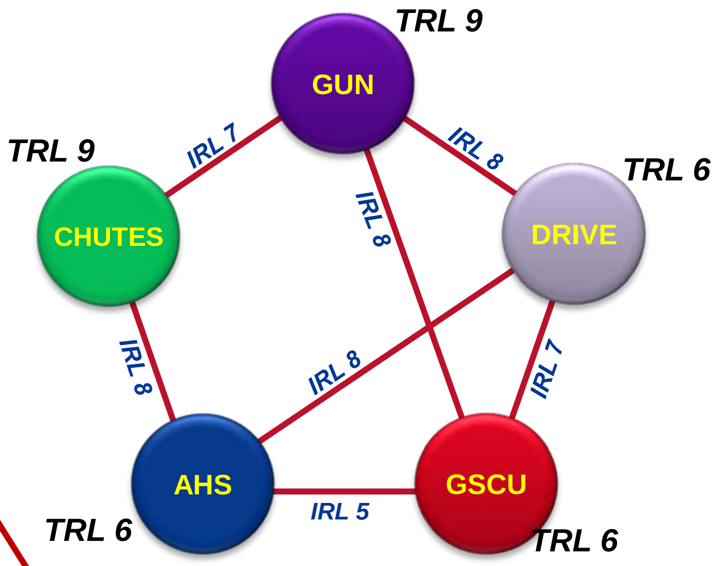
- Approximate measure of system maturity
- Aggregated measure of technology and integration readiness across elements and interfaces of a product/system
- Based on the outcome of TRL and IRL assessments
  - SRL = f(technology readiness, integration readiness)
- Matrix of pair wise comparisons of IRLs & TRLs
  - $[SRL]_{nx1} = [IRL]_{nxn} \times [TRL]_{nx1}$; IRL & TRL normalized
  - SRL composite = f(SRLn)
- Resources: No deskbook equivalent, many papers

Source: A Systems Approach to Expanding the Technology Readiness Level within Defense Acquisition, International Journal of Defense Acquisition Management, Volume 1 2008

Sample SRL Analysis

Normalized IRL Matrix

	Gun	Drive	GSCU	AHS	Chutes	TRL Matrix	SRL Matrix
Gun	1.00	0.89	0.89	0.00	0.78	1.00	2.96
Drive	0.89	1.00	0.78	0.89	0.00	0.67	2.67
GSCU	0.89	0.78	1.00	0.56	0.00	0.67	2.44
AHS	0.00	0.89	0.56	1.00	0.89	0.67	2.52
Chutes	0.78	0.00	0.00	0.89	1.00	1.00	2.37
						Average	2.59



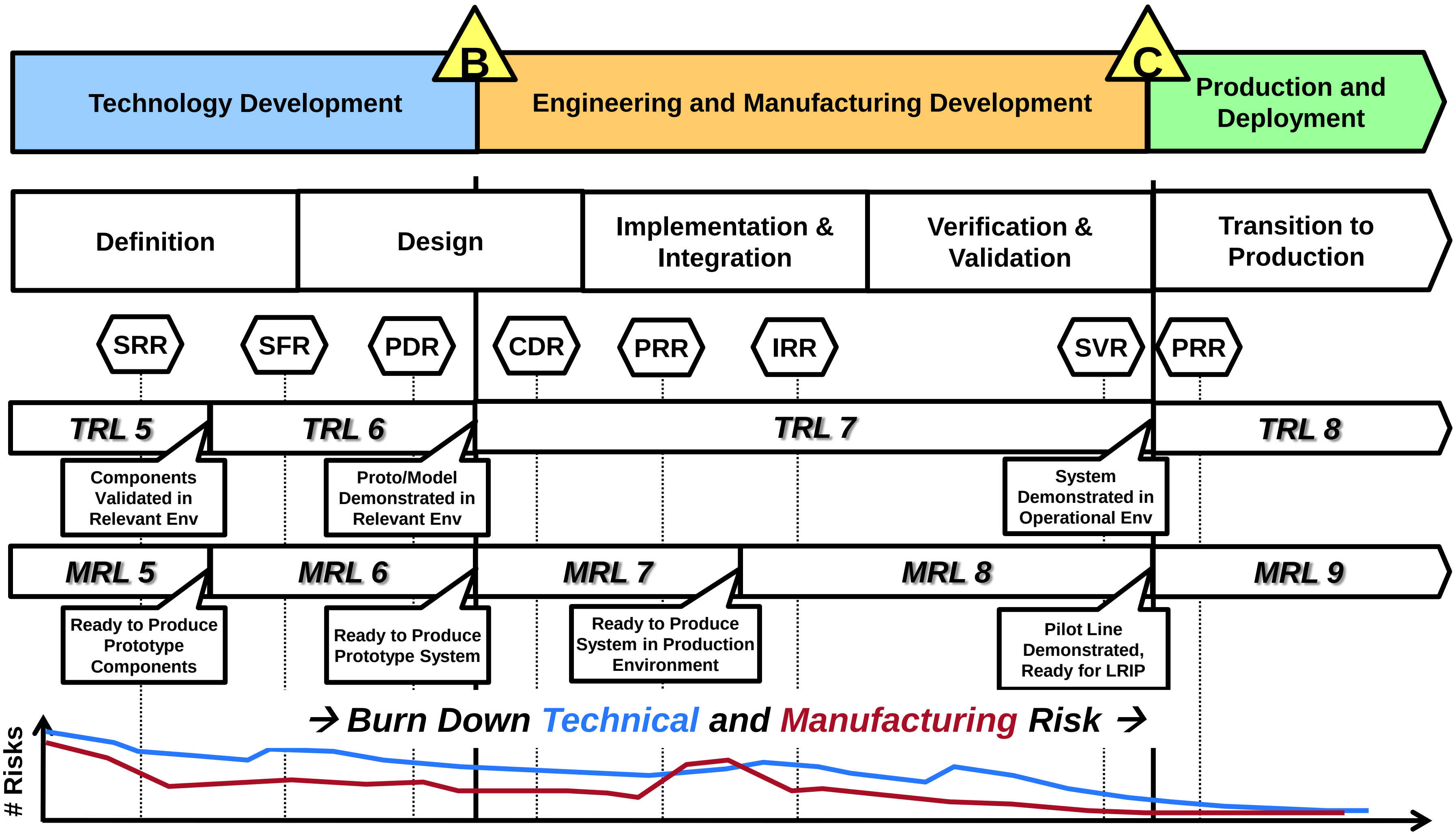
Normalized IRL Matrix

	Gun	Drive	GSCU	AHS	Chutes	TRL Matrix	SRL Matrix
Gun	1.00	0.89	0.89	0.00	0.78	1.00	2.96
Drive	0.89	1.00	0.78	0.89	0.00	0.67	2.67
GSCU	0.89	0.78	1.00	0.89	0.00	0.67	2.67
AHS	0.00	0.89	0.89	1.00	0.89	0.67	2.74
Chutes	0.78	0.00	0.00	0.89	1.00	1.00	2.37
						Average	2.68

Changing the Gun System Control Unit - Ammunition Handling System (GSCU - AHS) IRL from 5 to 8 impacts the SRL of both Line Replaceable Units (LRUs) and the overall SRL.

Implementation Model

One Perspective



Implementation Methods

- Concurrent product & mfg process development
- Engineering & manufacturing professionals working together closely and early
- Risk management
- Standard but tailorable work products
- Work product check lists
- Gate exit criteria
- Lessons learned
- Product & process prototyping
- Assessment & risk management tools

Conclusion

- Readiness assessments can reduce risk and improve program outcomes
- Technology & manufacturing readiness assessment methods are most mature
- Integration and system readiness assessment methods hold potential for use in future
- Meaningful assessments and relevant actions depend on experience and judgment
- Best used with concurrent development of product and manufacturing process

Select Resources

- Motivation for Readiness Assessments
  - GAO/NSIAD-99-162 Better Management of Technology Development Can Improve Weapon System Outcomes, July 1999
  - GAO-10-439 DOD Can Achieve Better Outcomes by Standardizing the Way Manufacturing Risks Are Managed, April 2010
- Assessment Methods & Guidance
  - DoD Technology Readiness Assessment Deskbook
  - DoD Manufacturing Readiness Level Deskbook, July 2010
- Papers on Advanced Assessment Methods
  - Fernandez (2010) Contextual Role of TRLs and MRLs in Technology Management, Sandia Report SAND2010-7595
  - Sauser, et all (2008) A Systems Approach to Expanding the Technology Readiness Level within Defense Acquisition, International Journal of Defense Acquisition Management, Volume 1, 2008
  - Other references identified in the papers above

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