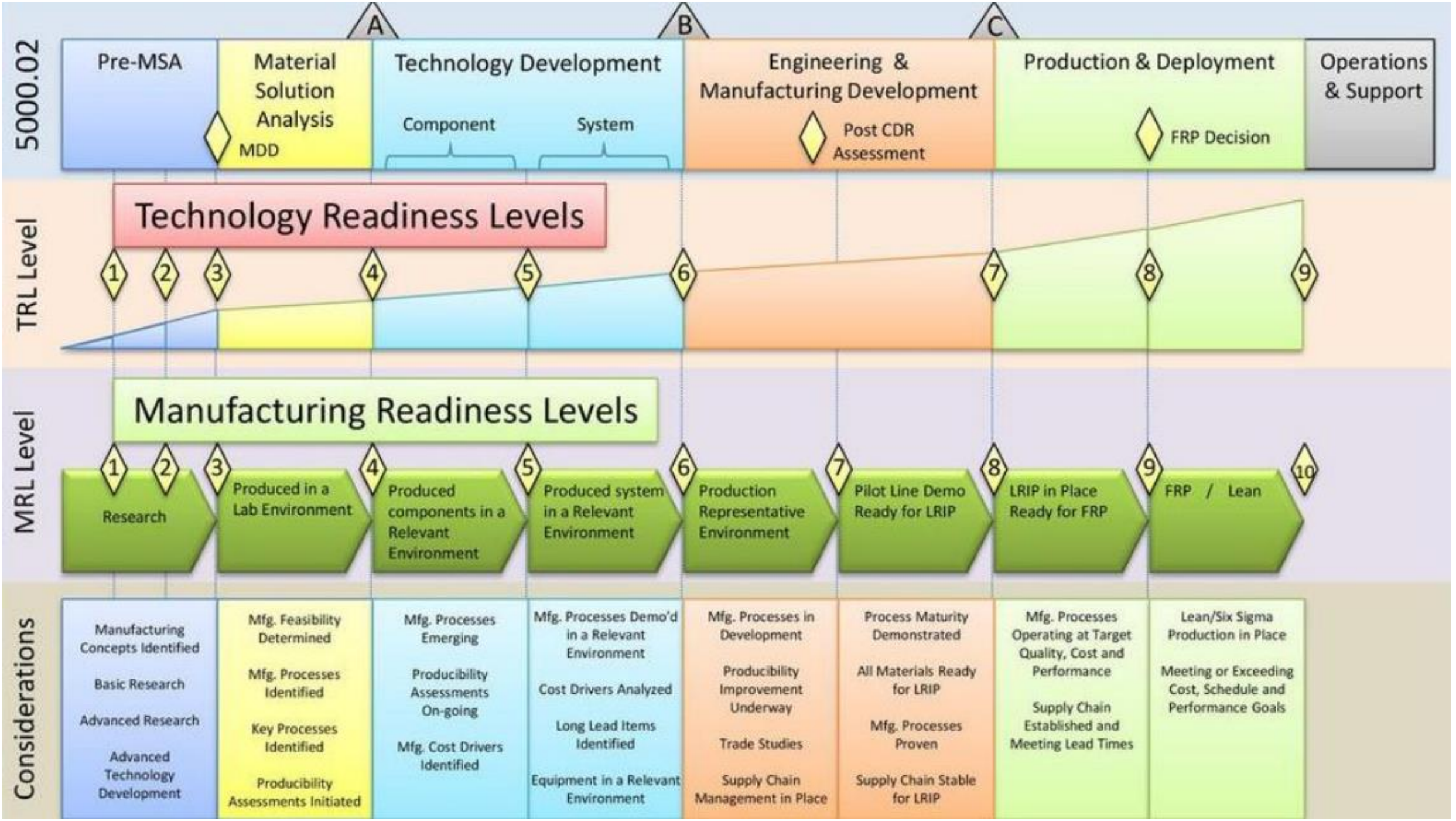
Manufacturing Readiness Level (MRL)

- MRLs are a method for understanding the maturity of a manufacturing process readiness, similar to how Technology Readiness Levels (TRLs) are used to understand technology maturity.
- MRLs allow innovators to have a consistent datum of reference for understanding manufacturing maturity evolution.
- The MRL concept was developed by the United States Department of Defence (DoD) to assess the maturity of a manufacturing process throughout its conception, development, deployment and support progression phases.
- MRLs are based on a scale from 1 - 10, with 10 being the most mature.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A
B
C
Pre-MSA
Material Solution Analysis
MDD
Technology Development
Component
System
Engineering & Manufacturing Development
Post CDR Assessment
Production & Deployment
FRP Decision
Operations & Support
TRL Level
Technology Readiness Levels
1
2
3
4
5
6
7
8
9
MRL Level
Manufacturing Readiness Levels
1 Research
2
3 Produced in a Lab Environment
4 Produced components in a Relevant Environment
5 Produced system in a Relevant Environment
6 Production Representative Environment
7 Pilot Line Demo Ready for LRIP
8 LRIP in Place Ready for FRP
9 FRP / Lean
10
Considerations
Manufacturing Concepts Identified
Basic Research
Advanced Research
Advanced Technology Development
Mfg. Feasibility Determined
Mfg. Processes Identified
Key Processes Identified
Producibility Assessments Initiated
Mfg. Processes Emerging
Producibility Assessments On-going
Mfg. Cost Drivers Identified
Mfg. Processes Demo'd in a Relevant Environment
Cost Drivers Analyzed
Long Lead Items Identified
Equipment in a Relevant Environment
Mfg. Processes in Development
Producibility Improvement Underway
Trade Studies
Supply Chain Management in Place
Process Maturity Demonstrated
All Materials Ready for LRIP
Mfg. Processes Proven
Supply Chain Stable for LRIP
Mfg. Processes Operating at Target Quality, Cost and Performance
Supply Chain Established and Meeting Lead Times
Lean/Six Sigma Production in Place
Meeting or Exceeding Cost, Schedule and Performance Goals

Manufacturing Readiness Level

Phase	Leading to	MRL	Definition	Description
Material solutions analysis	Material development decision review	1	Basic manufacturing implications identified	• Basic research expands scientific principles that may have manufacturing implications. The focus is on a high-level assessment of manufacturing opportunities. The research is unfettered.
		2	Manufacturing concepts identified	• Invention begins. Manufacturing science and/or concept described in application context. Identification of material and process approaches are limited to paper studies and analysis. Initial manufacturing feasibility and issues are emerging.
		3	Manufacturing proof of concept developed	• Conduct analytical or laboratory experiments 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.
	A: Milestone decision	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 design performance parameters identified. Special needs identified for tooling, facilities, material handling and skills.

Manufacturing Readiness Level

Phase	Leading to	MRL	Definition	Description
Technology maturation and risk reduction	B: Milestone decision	5	Capability to produce prototype components in a production relevant environment	• Manufacturing strategy refined and integrated with Risk Management 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. Manufacturing 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.
		6	Capability to produce a prototype system or subsystem in a production relevant environment	• Initial manufacturing 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 analysis include design trades. Cost targets allocated. Producibility considerations shape system development plans. Long lead and key supply chain elements identified. Industrial Capabilities Assessment for Milestone B completed.

Manufacturing Readiness Level

Phase	Leading to	MRL	Definition	Description
Engineering and manufacturing development	Post-CDR (Critical Design Review) Assessment	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 Quality Assurance assessed. Long lead procurement plans in place. Production tooling and test equipment design and development initiated.
	C: Milestone Decision	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. Industrial Capabilities Assessment for Milestone C.

Manufacturing Readiness Level

Phase	Leading to	MRL	Definition	Description
Production and deployment	Full rate production 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. Low Rate Initial Production (LRIP) cost goals met, learning curve validated. Actual cost model developed for Full Rate Production environment, with impact of Continuous improvement.
Operations and support	N/A	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. Full rate production unit cost meets goal, and funding is sufficient for production at required rates. Lean practices well-established and continuous process improvements ongoing.