Manufacturing Readiness Level (MRL) Guidance Document

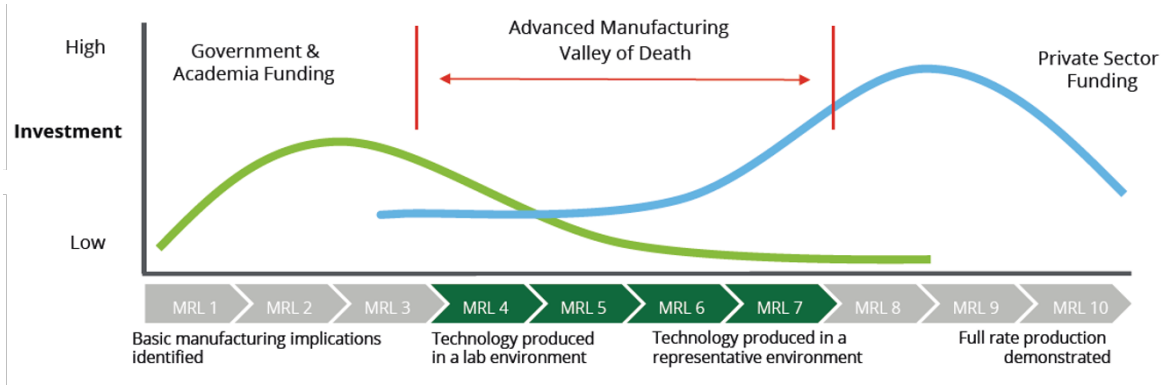
Purpose

The purpose of this document is to provide guidance on manufacturing readiness level (MRL) as it applies to NIIMBL projects. As a member of the Manufacturing USA Network, NIIMBL's Technology Development Projects will fall within MRL 4-7. The goal of NIIMBL funded projects is to advance technology in a measurable way. At the completion of a successful project, the final MRL will have advanced from the starting MRL.

This document provides a set of MRLs that describe development of a technology and its readiness for manufacture. The MRL scale has been adapted from similar scales defined by the DOD and includes elements specific to manufacturing biopharmaceuticals.

NIIMBL Scope

NIIMBL's mission is to accelerate biopharmaceutical manufacturing innovation, support the development of standards that enable more efficient and rapid manufacturing capabilities, and educate and train a world-leading biopharmaceutical manufacturing workforce. As a Manufacturing USA Institute, NIIMBL aims to fill the gap in manufacturing innovation between government and university research and the private sector. This gap occurs between MRL 4-7.



What is MRL?

The MRL scale was developed by the United States Department of Defense (DOD) to assess manufacturing readiness. The MRL is a measure of manufacturing maturity and is complementary to the technology readiness level (TRL). The MRL scale helps businesses manage cost, scheduling and performance risk through examination of the maturity of manufacturing. Key areas of consideration that are particularly relevant include:

Producibility – How easy is it to manufacture? Have key design characteristics been identified?

Materials – Are materials available? Have materials been characterized? Are there any special handling requirements?

Processes – Have critical processes/parameters been identified? Have processes been demonstrated? Are processes stable and well-controlled?

Workforce skills & training – Are there any special skills required? Are personnel trained and certified? Is the workforce stable?

Supply chain capabilities – Is the supply chain integrated into the manufacturing plan? Have long lead items been identified?

There are also considerations of predictability of scheduling, predictability of cost, and facility availability and readiness.

The MRL Scale

MRL 4-7 occurs ***after proof of concept*** studies have been completed. MRL 4-7 is a space where technology is de-risked and studies are carried out to demonstrate the reliability and robustness of the technology in an industrially-relevant environment. A technology falls within an MRL when it meets the requirements of that MRL (e.g. a new sensor used in the manufacturing process of a clinical batch of a therapeutic protein in a GMP facility would be at MRL 7).

MRL	Definition	Activities
N/A	Pre-MRL scale	Basic technology development, scientific research and translation into applied research and development, exploration into key principles. *Technologies at TRL 1-2*
1	Basic manufacturing implications identified	**Basic research** to address manufacturing shortfalls and program objectives *Technologies at TRL 3*
2	Manufacturing concepts identified	**Applied research** to translate basic research into specific solutions; understanding of feasibility and risk emerging; materials and process approaches defined; producibility assessments commenced *Technologies at TRL 4*
3	Manufacturing **proof of concept** developed	Advanced development to validate manufacturing concepts through analytical or lab experiments; materials and processes characterized and defined, but further demonstration required; prototypes may have been developed but are limited *Technologies at TRL 5*
4	Capability to produce the technology in a **laboratory environment** (*e.g. GLP*)	Manufacturing feasibility assessed, key processes identified, producibility of key concepts assessed, risks identified, target cost objectives established, cost drivers identified, key performance parameters identified *Technologies at TRL 6*
5	Capability to produce technology **components in a production-relevant environment** (*e.g. elements of GMP*)	Manufacturing process emerging, critical components identified, producibility assessment ongoing, cost model constructed *Technologies at TRL 7*
6	Capability to produce technology **system in a production-relevant**	Process and equipment demonstrated in a relevant environment, initial manufacturing approach developed,

	environment (*e.g. elements of GMP*)	producibility assessment complete, materials, processes and personnel skills demonstrated, cost analysis complete *Technologies at TRL 8*
7	Capability to produce technology in a **production-representative environment** (*e.g. GMP*)	Manufacturing process developed, producibility improvement ongoing, supply chain management in place *Technologies at TRL 9*
8	**Pilot capability** demonstrated; ready to begin low rate production	Manufacturing process mature, all materials ready, supply chain stable, ready to begin low rate initial production
9	**Low rate production** demonstrated; capability in place to begin full rate production	Manufacturing process operating at target quality, cost & performance, technologies should be TRL 9, ready for full rate production
10	**Full rate production** demonstrated and lean production practices in place	Lean/Six Sigma, meeting or exceeding quality, cost, schedule & performance, production sustainment phase

A *production-relevant environment* incorporates key elements of production realism such as production personnel, materials, equipment, processes, or work instructions, and may occur in a laboratory or model facility if key elements of production realism are added.

A *production-representative environment* is typically found on the manufacturing floor and contains most of the key elements of production realism such as production personnel, materials, equipment, processes, work instructions, cleanliness, etc.

A *pilot environment* is typically on the manufacturing floor and incorporates all key elements of production realism and is required to generate product that meets design requirements in low rate production.

Additional Information

DOD MRL Training PowerPoint	http://www.dodmrl.com/DCMA_training_SEP_26_16.pdf
DOD MRL Guidance Document	http://www.dodmrl.com/MRL_Deskbook_2016.pdf
NIH Biomedical Technologies TRLs	https://ncai.nhlbi.nih.gov/ncai/resources/techreadylevels
Automotive TRL/MRL Alignment	[Draft pdf]