"Roadmaps for Additive Manufacturing – Past, Present, Future"

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Outline for This Presentation

- Review Previous Roadmap Activities in RP/DDM/AM
- 1998 NCMS Roadmap Study
- 2009 NSF/ONR Roadmap Study
- 2010 NAVAIR DDM of Metals
- Where Are We Headed?

Previous Roadmap Activity in Additive Manufacturing

1994: “En Route to the Future: A Roadmap from Rapid Prototyping to Advanced Rapid Manufacturing”, 1994 Advanced Manufacturing Roadmap Working Group of the Department of Energy (DOE) Laboratories

Basic technology roadmap for three sectors deemed to be critical in the broad area of advanced rapid manufacturing:

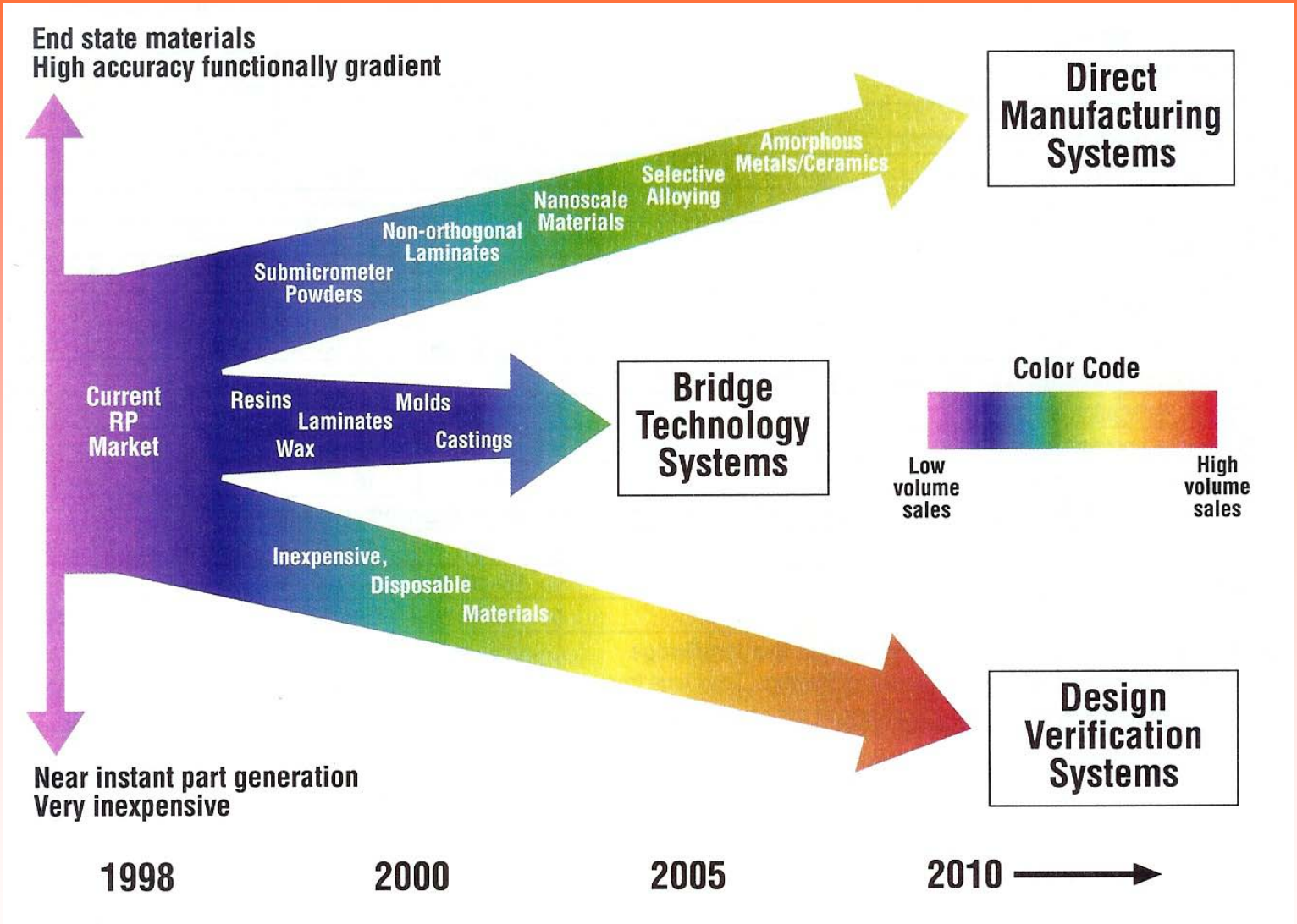
1. Rapid Prototyping/SFF/Additive Processes
2. Product Design and Visualization
3. High-speed Machining

Previous Roadmap Activity in Additive Manufacturing

1998: “1998 Industrial Roadmap for the Rapid Prototyping Industry”, National Center for Manufacturing Sciences Report 0199RE98

- Driver: Upcoming NCMS Rapid Prototyping Technology Advancement (RPTA) Program which initiated in 1998.
- RPTA Mission: “…to advance the use and development of RP technologies through collaboration among RP users and technology suppliers”.
- The 1998 roadmap built on the 1994 roadmap by updating it and adding an industry perspective with a focus on RP/AM.

The Future According to the 1998 Industrial Roadmap



From “The Roadmap to Manufacturing: 1998 Industrial Roadmap for the Rapid Prototyping Industry”, NCMS Report 0199RE98, NCMS, Ann Arbor MI, 1998.

2009 Roadmap Activity

National Science Foundation CMMI-0906212
Office of Naval Research N00014-09-1-0558

Organizers: Dave Bourell, Ming Leu, Dave Rosen

Comparison of the 1998 and 2009 Roadmap Activities

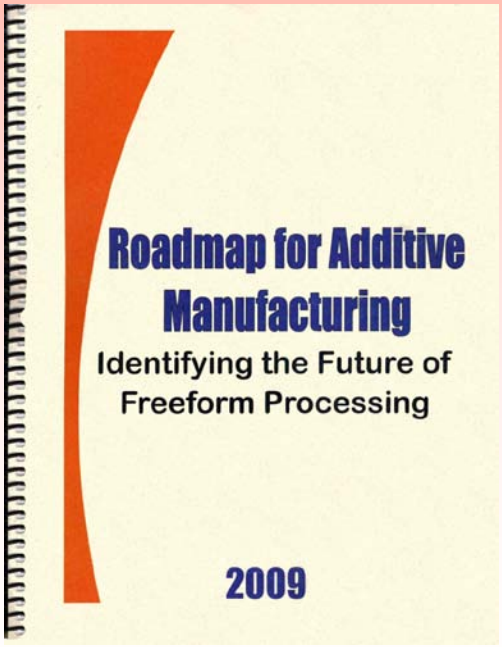
	1998	2009
Emphasis	Industry	Research Community
Motivation	RPTA II	Focus Research Activity
Players	EOM's/Customers	Researchers/Funding Agencies
Participation		
Industry	73% (8/11)	32% (21/65)
University	0% (1 on Ext Rev Comm)	45% (29/65)
Government/Non-Profits	27% (3/11)	23% (15/65)
Function	Roadmap	Define Research Topics
Predictability	Mostly Correct	Too Early to Tell
Headline	Trifurcation→Bifurcation	Research Agenda

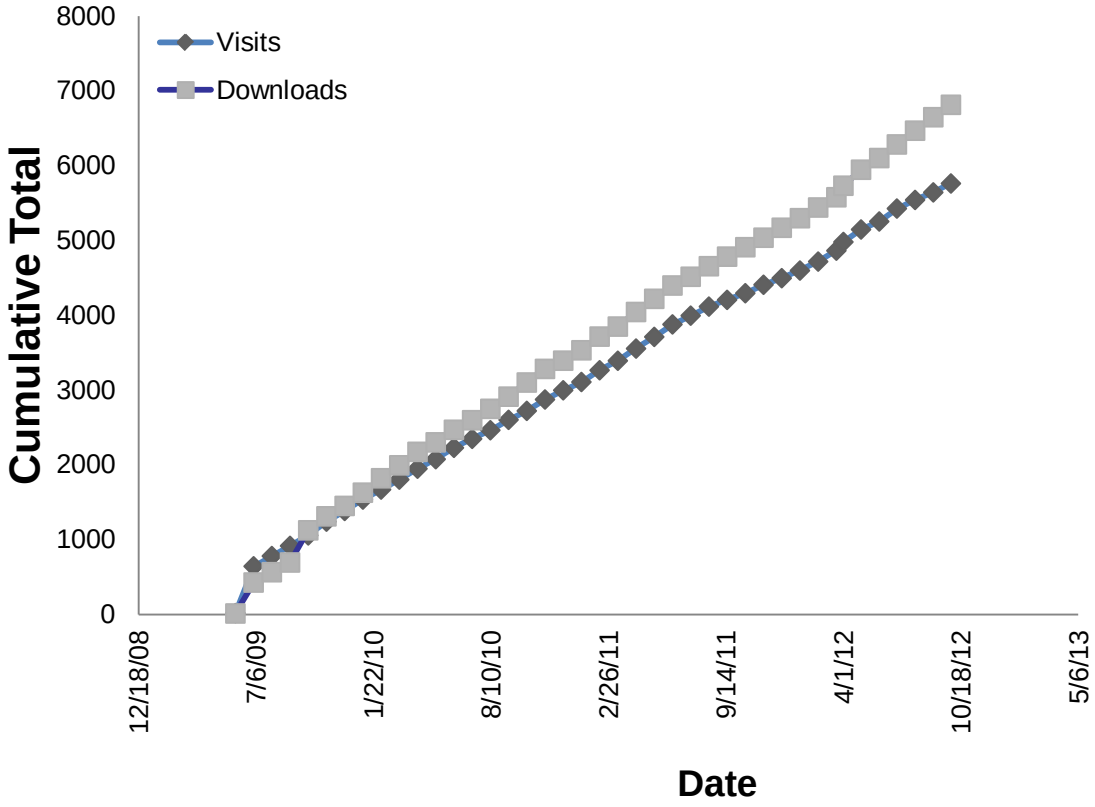
Breakout Topics

B1 - Industry Targets	Terry Wohlers
B2 - Technology Goals and Barriers	Richard Hague
B3 - Design and Analysis	David Rosen
B4 - Processes and Machines	Brent Stucker
B5 - Materials and Materials Processing	Dave Bourell
B6 - Biotechnology	Wei Sun/Ming Leu
B7 - Energy and Sustainability	Hong-Chao Zhang

Meeting Output: Roadmap Report (92 pages)

- Free download at Terry Wohlers' website: http://wohlersassociates.com/roadmap2009.html
- As of October 27, 2012, there have been 5759 views of the document and 6811 downloads



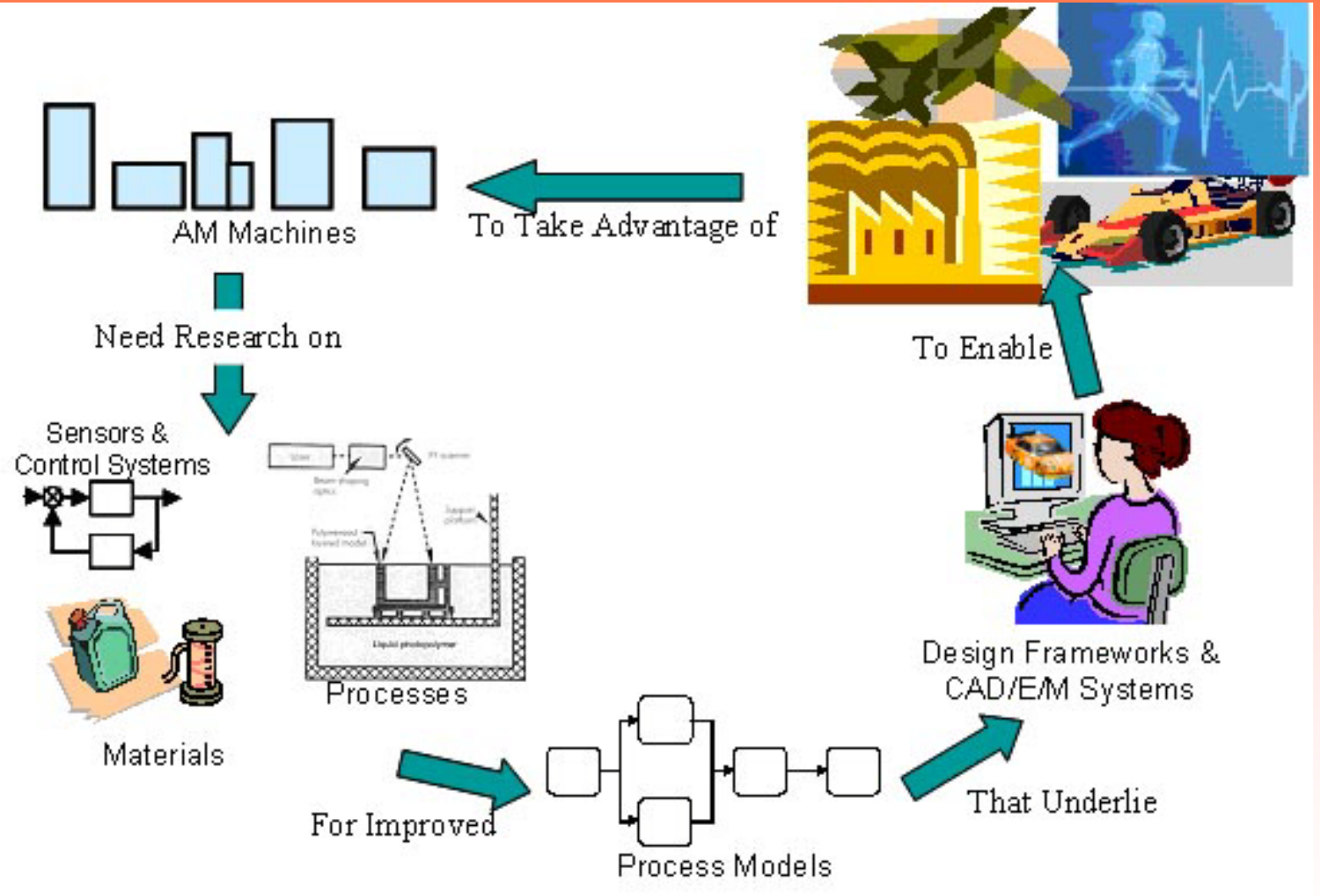


Common AM Themes

Issues Crossing Over Several Topic Areas

- Consistency, Repeatability
- Process Standards
- Closed Loop Feedback Control
- Predictive Analysis and Modeling
- Material Property Data Generation
- Exploitation of Unique Features of AM
- Design Rules/Tools
- In-Build Considerations (Inspection, Sensors)
- Education

National Testbed Center



Expected Outcomes of the 2009 Roadmap

- Acceleration of integration of AM into the marketplace
- Identification of fruitful area of AM research
- Networking of leading experts in AM across the discipline
- Systematic plan for AM research for the next 10-15 years
- “White paper” guide for government and other research funding organizations

Direct Digital Manufacturing of Metallic Components: Affordable, Durable, and Structurally Efficient Airframes

NAVAIR, ONR (Bill Frazier)

11-12 May 2010

Solomons Island, MD

Broad Motivation

- Reducing the Total Ownership Cost of weapon systems, both in platform design and construction
- Following Presidential guidance to pursue transformational solutions and support visionary thinkers proposing high-risk, high-payoff research

William E. Frazier, “Direct Digital Manufacturing of Metallic Components: Vision and Roadmap”, SFF Symposium Proceedings, Bourell, et al., eds., Austin TX 2010, pp. 717-32.

Direct Digital Manufacturing of Metallic Components

Organizations Represented

Government	Industry	Industry	Academia
• NAVAIR (4.1, 4.3, 4.4, 4.5, 4.7, 4.8, 5.2, 6.7) • FRC • NASA • Air Force • OPNAV • OSD • ONR • PEOs	• Bell Helicopter • Boeing • CalRam • CTC • GE Aviation • Lockheed Martin •Morris Technology • NAVMAR • Navy Metalworking Center	•Northrop Grumman •Sikorsky •Stratasys •TRI •Wyle •Honeywell •Sciaky •Innovati •Pratt & Whitney	• University of Texas, Austin • North Carolina State University • University of Michigan • California Institute of Technology • Penn State University • National Center for Manufacturing Science

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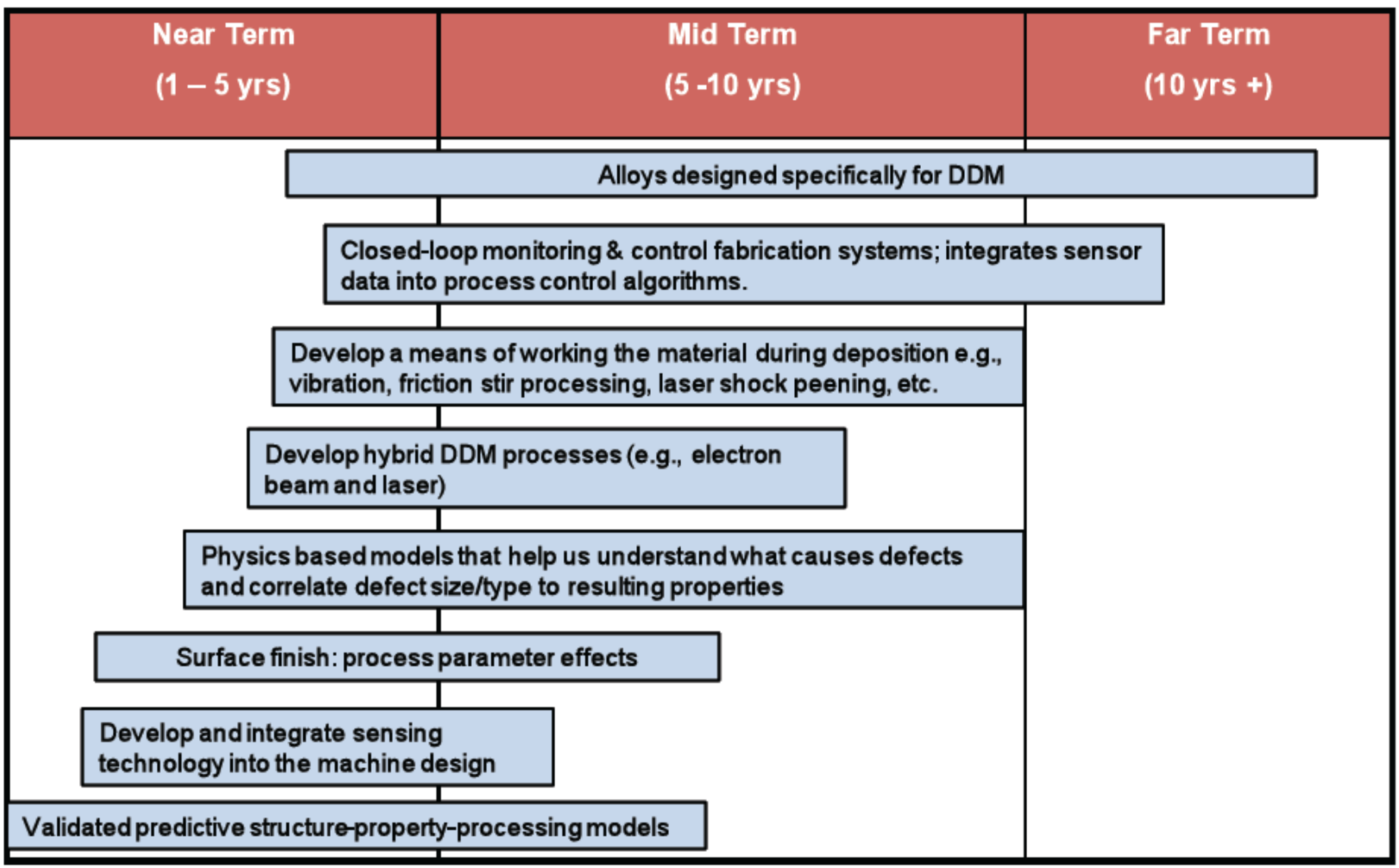
Direct Digital Manufacturing of Metallic Components

DDM Science and Technology



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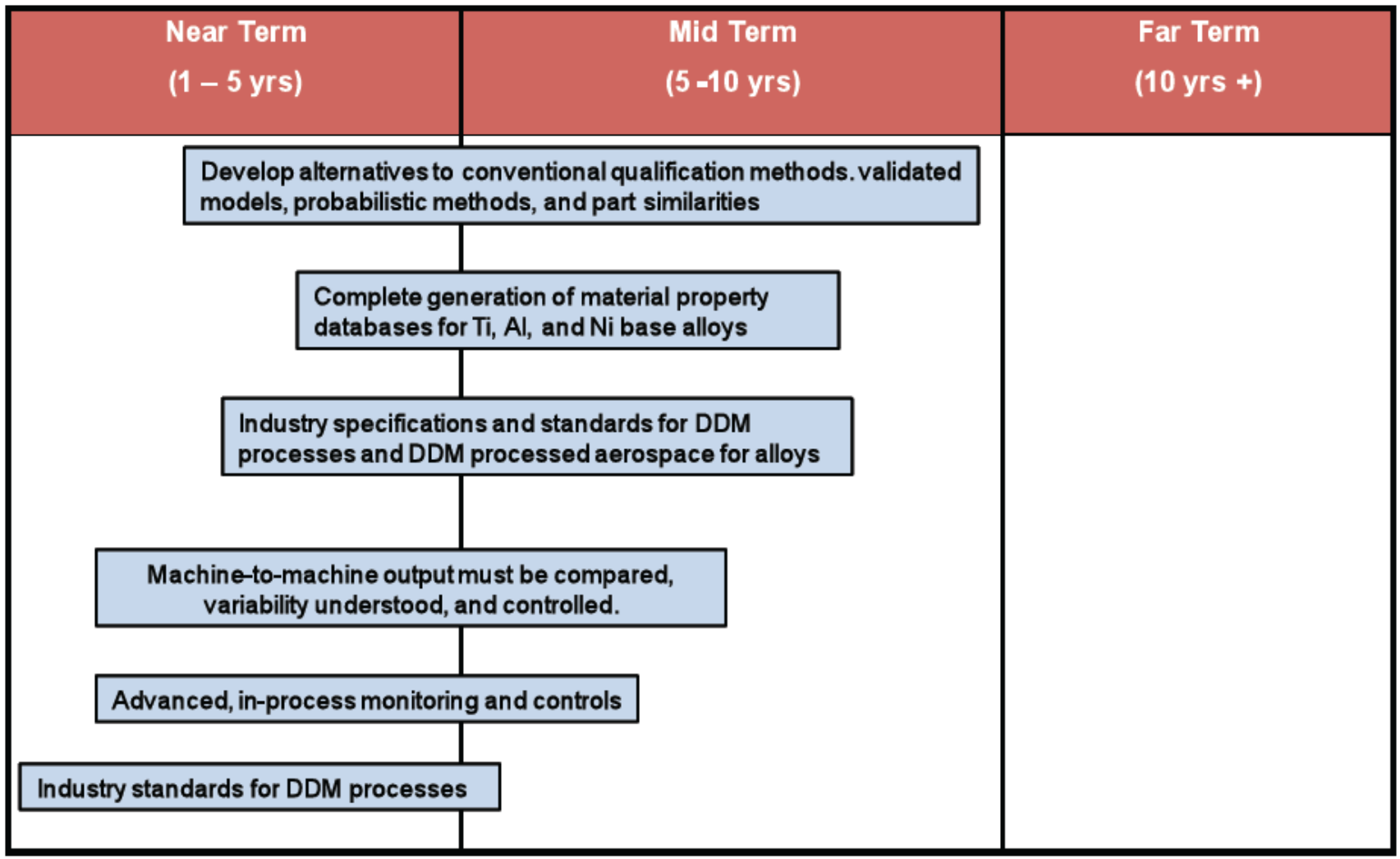
Direct Digital Manufacturing of Metallic Components

Qualification and Certification



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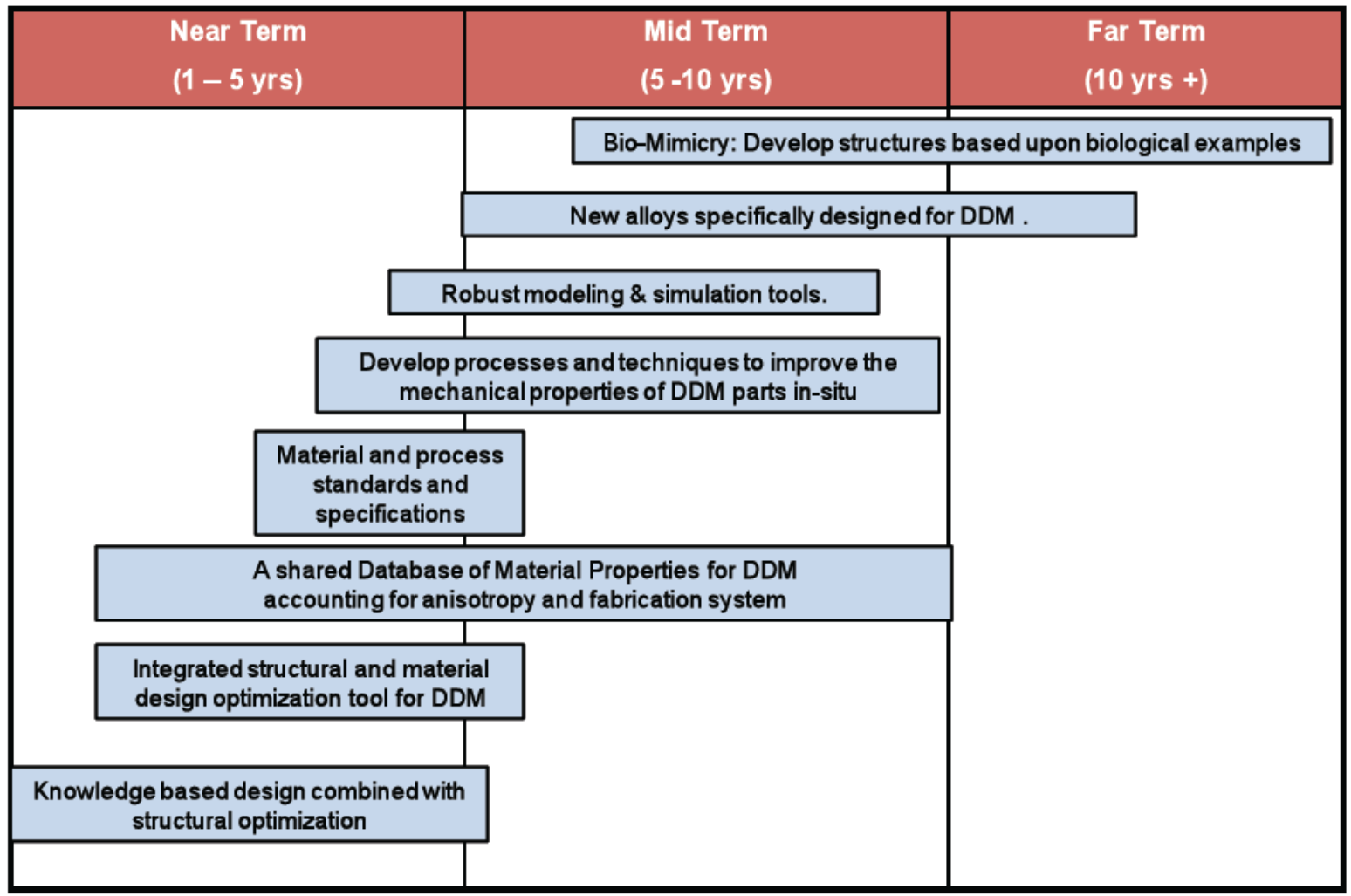
Direct Digital Manufacturing of Metallic Components

Innovative Structural Design



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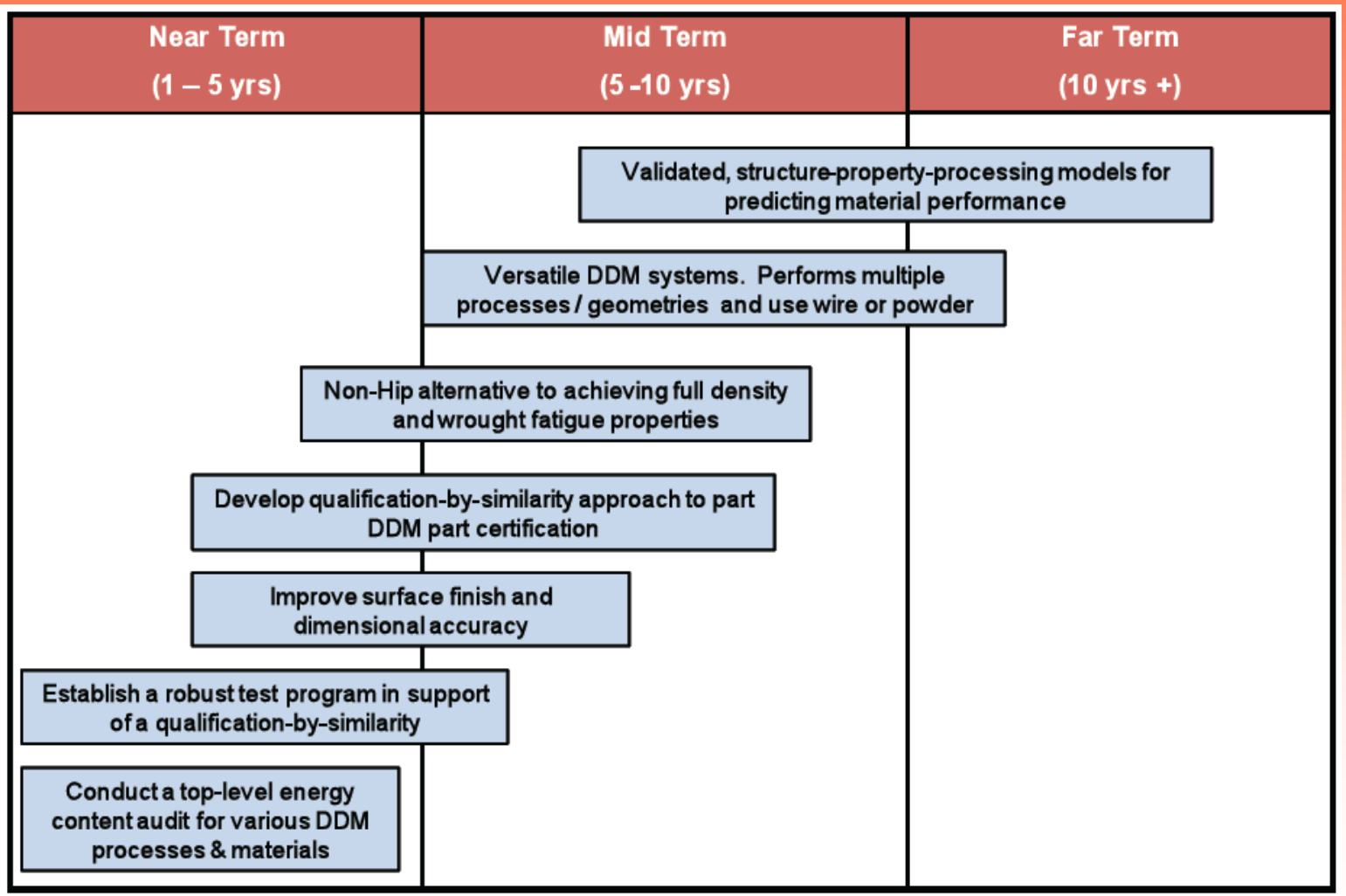
Direct Digital Manufacturing of Metallic Components

Maintenance and Repair



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Where Are We Headed?

Short Term (<5 Years)

- Research funding emphasis on manufacturing in general and advanced manufacturing/AM specifically (e.g., NAMII)
- Explosion of low-cost 3D printers by DIY
- Consumer acceptance through standards development efforts
- Development of easy to use, low cost 3D modeling software
- Easy to access libraries of parts

Medium Term (>5 Years)

- Explosion of 3D printers as low cost consumer goods driven by a need to “print” 3D objects
- Regional “Kinko’s” AM Capability
- The low-cost print capability will push high-cost AM technology
- Expanding experience base will foster new applications