

# Research Priorities of the Supporting Industries Program: Linking Industrial R&D Needs

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# Outline

- Project Objective and Role of SI Program
- Definitions of Analysis Elements and Links Between R&D Needs and Research Projects
- Database Characteristics and Analysis
- Powder Metallurgy and Particulate Materials (PM<sup>2</sup>) Example
- Database Navigator
- Analysis of Multiple-Industry Research Need (MIRN) Category Links
- Conclusions and Recommendations

# Project Objective

- Improve coordination between programs of projects and solicitations by identifying significant multiple-industry research challenges
  - Define and analyze *links* between Supporting Industries and other Industrial Technologies programs by creating and analyzing a database that incorporates:
    - Research needs and performance targets from Industries of the Future and Supporting Industries technical roadmaps
    - DOE-funded projects meeting research needs and/or performance targets

# Role of the Supporting Industries Program

**IOF Industries**

*Need Improved Components and Processes to Reduce Energy Use and Environmental Impact and Increase Productivity*



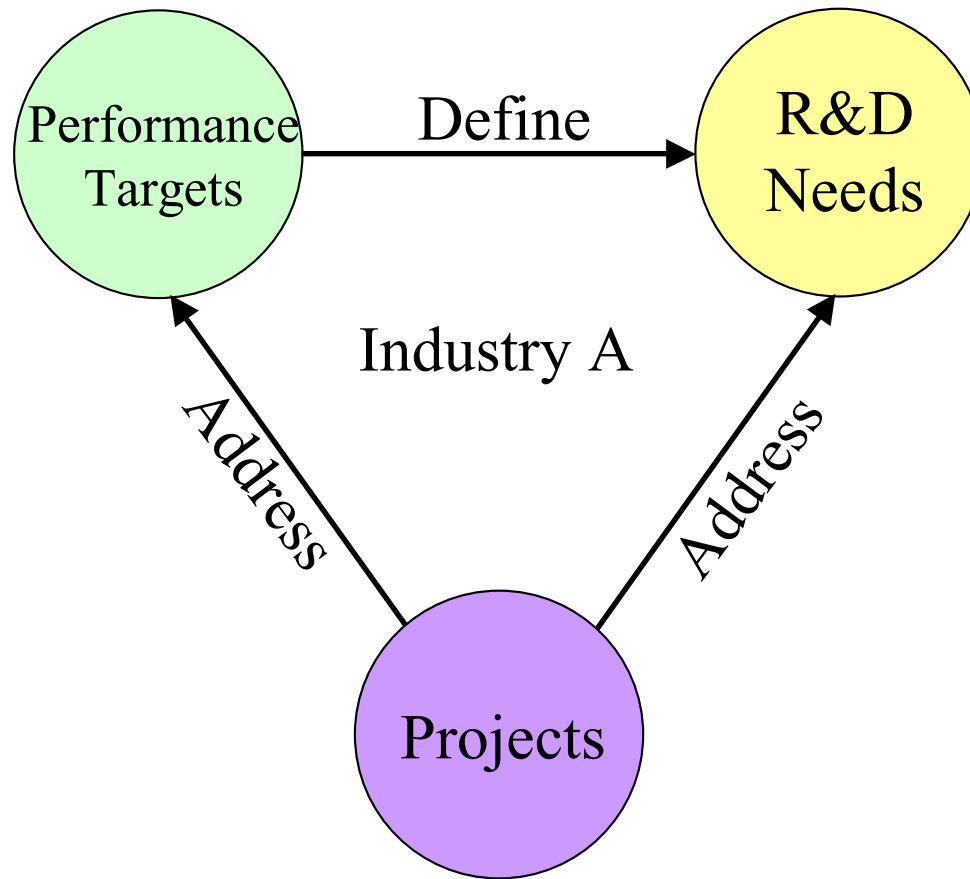
**SUPPORTING INDUSTRIES**

*Provide Improved Materials Properties, Process into Products, and Provide Components*



**DOE Office of Science, NSF, ONR, and other agencies**  
*Sponsor Basic Materials Research*

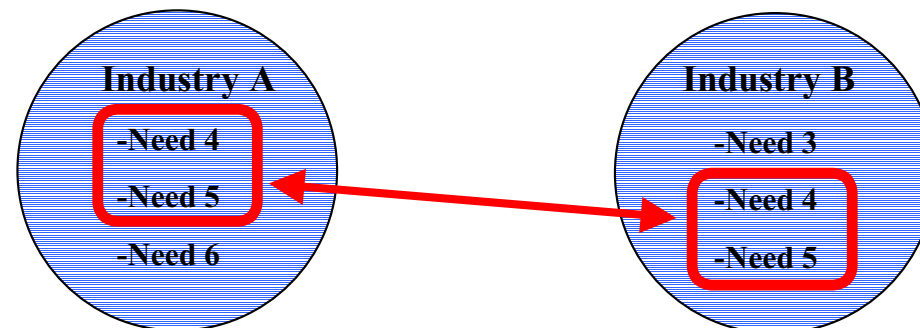
# Relationships Among Basic Elements of Analysis



# Description of Basic Elements of Analysis

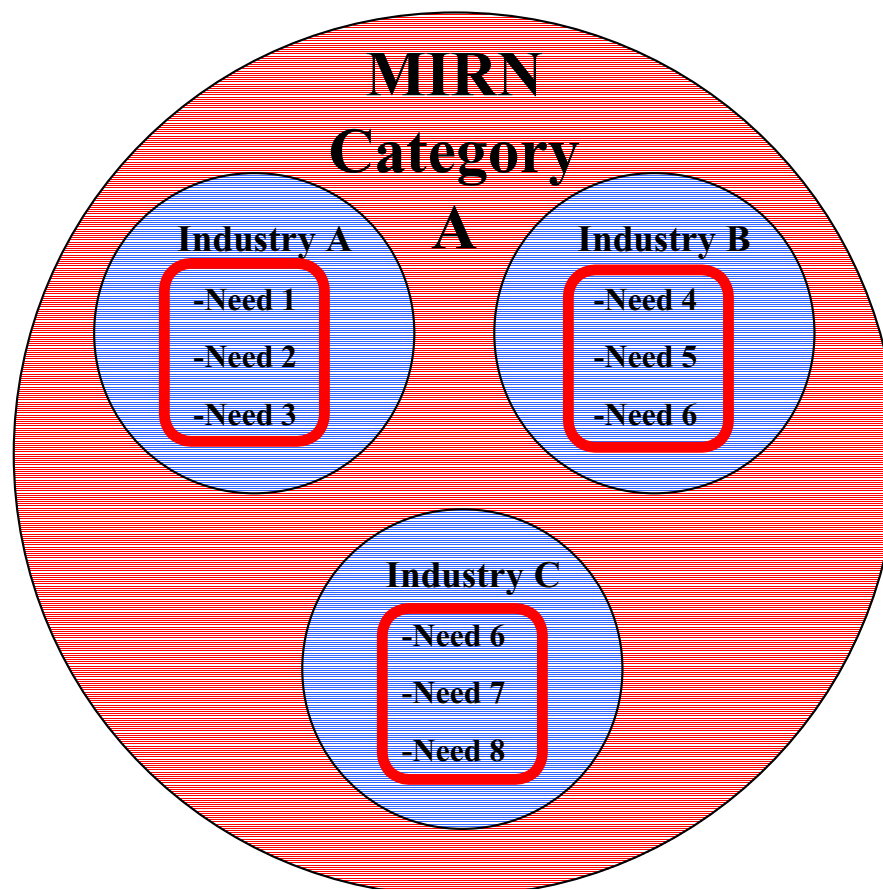
- Performance Targets:
  - Described in IOF and SI roadmaps
  - Goals of industry vision
- R&D Needs:
  - Described in IOF and SI roadmaps
  - Materials and/or process needs to achieve industry vision
- (DOE) Research Projects:
  - Described in DOE Industrial Technologies website, EMaCC reports, and BES project summaries
  - Address at least one need or performance target

# Some R&D Needs Appear in More Than One Industry Roadmap



These needs are defined as Multiple-Industry Research Needs (MIRNs). In this example, Needs 4 and 5 are MIRNs because they appear in both Industry A and Industry B roadmaps.

# Multiple-Industry Research Need (MIRN) Categories



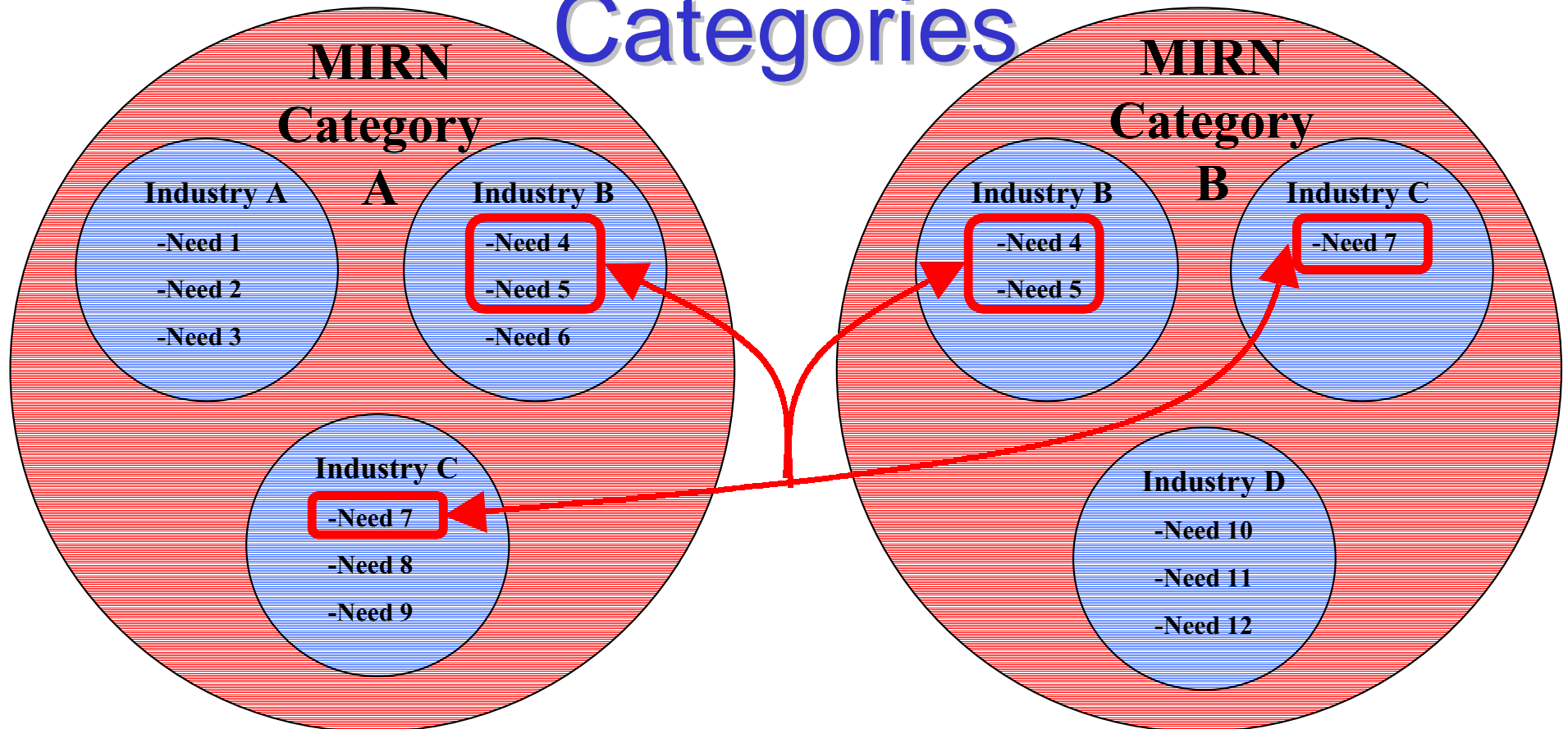
Related needs from more than one industry roadmap can be grouped together under a general heading called a Multiple-Industry Research Need (MIRN) Category.



# 25 MIRN Categories Describe All of the R&D Needs

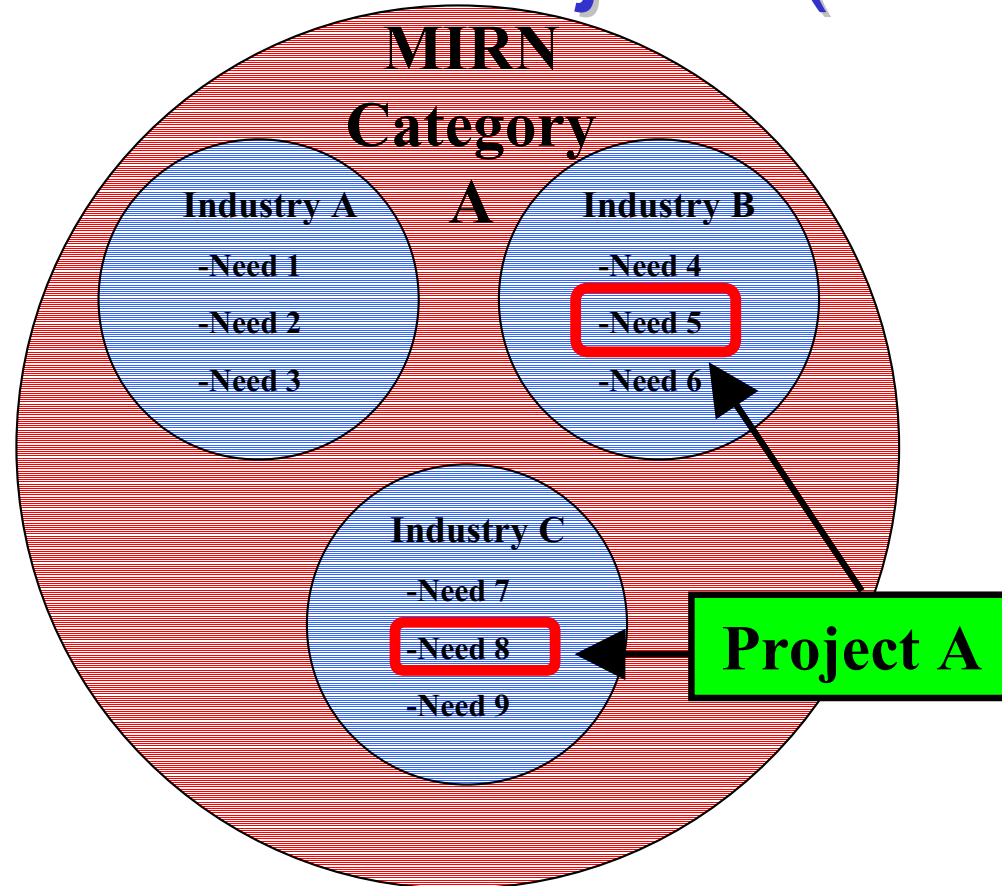
- Adhesives
- Advanced forming
- Casting
- Coatings
- Composites
- Corrosion-, erosion-, wear-resistant materials
- Databases and properties
- Design tools
- High-temperature materials and refractories
- Human and technical resources
- Joining and welding
- Low-friction/lubricants
- Magnetic materials
- Markets and applications
- Modeling and simulation
- Non-destructive evaluation (NDE) and inspection
- Process design and improvement
- Process monitoring and control
- Raw materials
- Sensors and sensor materials
- Separation technologies
- Standards, product quality, and testing
- Surfaces and interfaces
- Tools and dies
- Waste and byproduct treatment, recycling, and use

# Links Among MIRN Categories



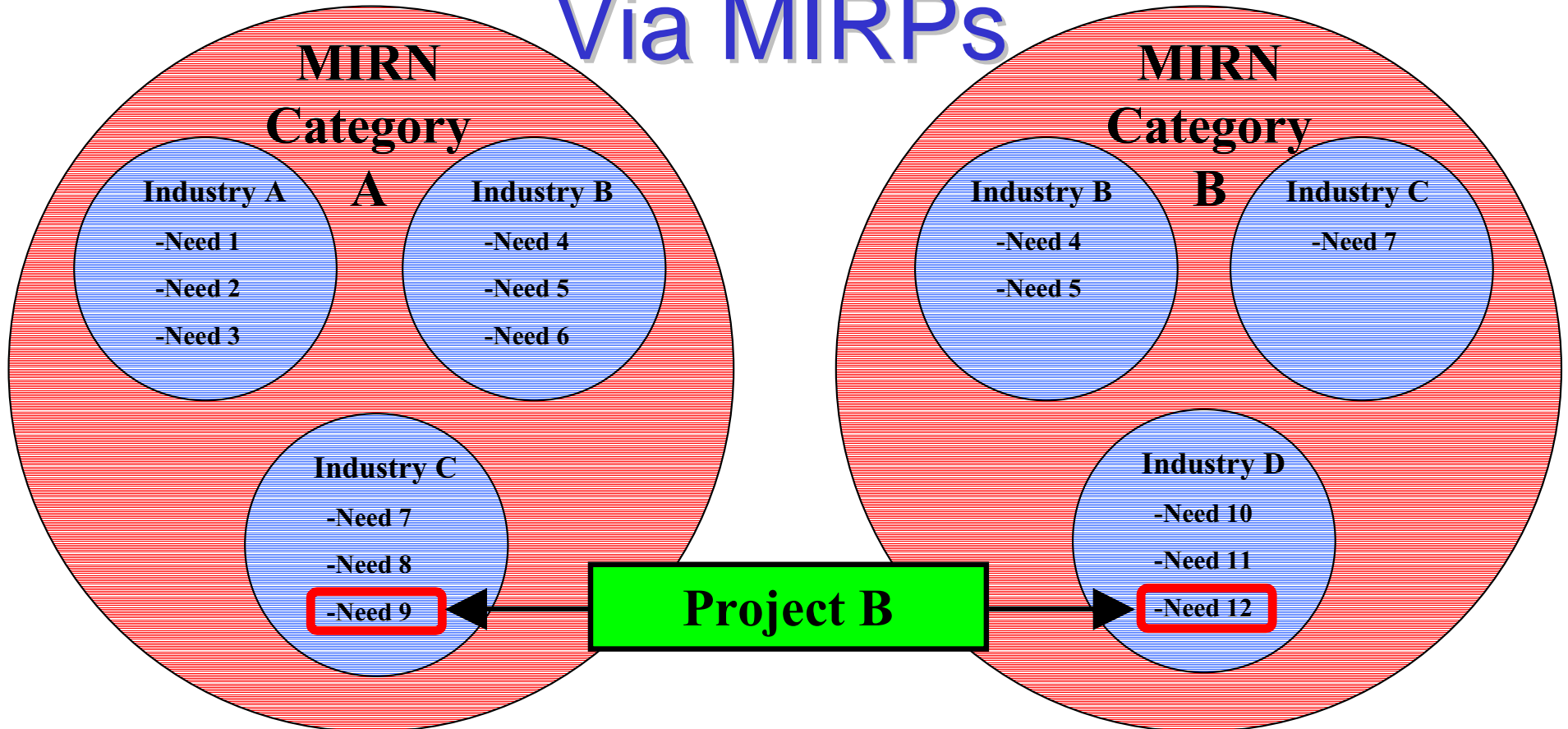
Some needs fit into more than one MIRN Category. These similar needs serve to link MIRN Categories. When several industries link the same MIRN Categories, it suggests a strong connection among the industries.

# Multiple-Industry Research Project (MIRP)



A project that addresses needs in more than one industry is called a Multiple-Industry Research Project (MIRP).

# Linking MIRN Categories Via MIRPs



Some projects address needs in more than one MIRN Category. These projects often identify underpinning research areas and problems that need to be solved to address the research needs of groups of industries. These underpinning research areas, or MIRAs, are significant because projects in these special research areas can greatly leverage R&D investments.

# Multiple-Industry Research Area (MIRA)

## MIRA : Wear-resistant die materials

### Steel

Need: Improve die and roll materials and coatings and lubricants used in die and roll systems

### Metal Casting

Need: Develop Improved Dies: (1) new die materials, (2) better coatings

### PM<sup>2</sup>

Need; Wear-resistant die materials or coatings

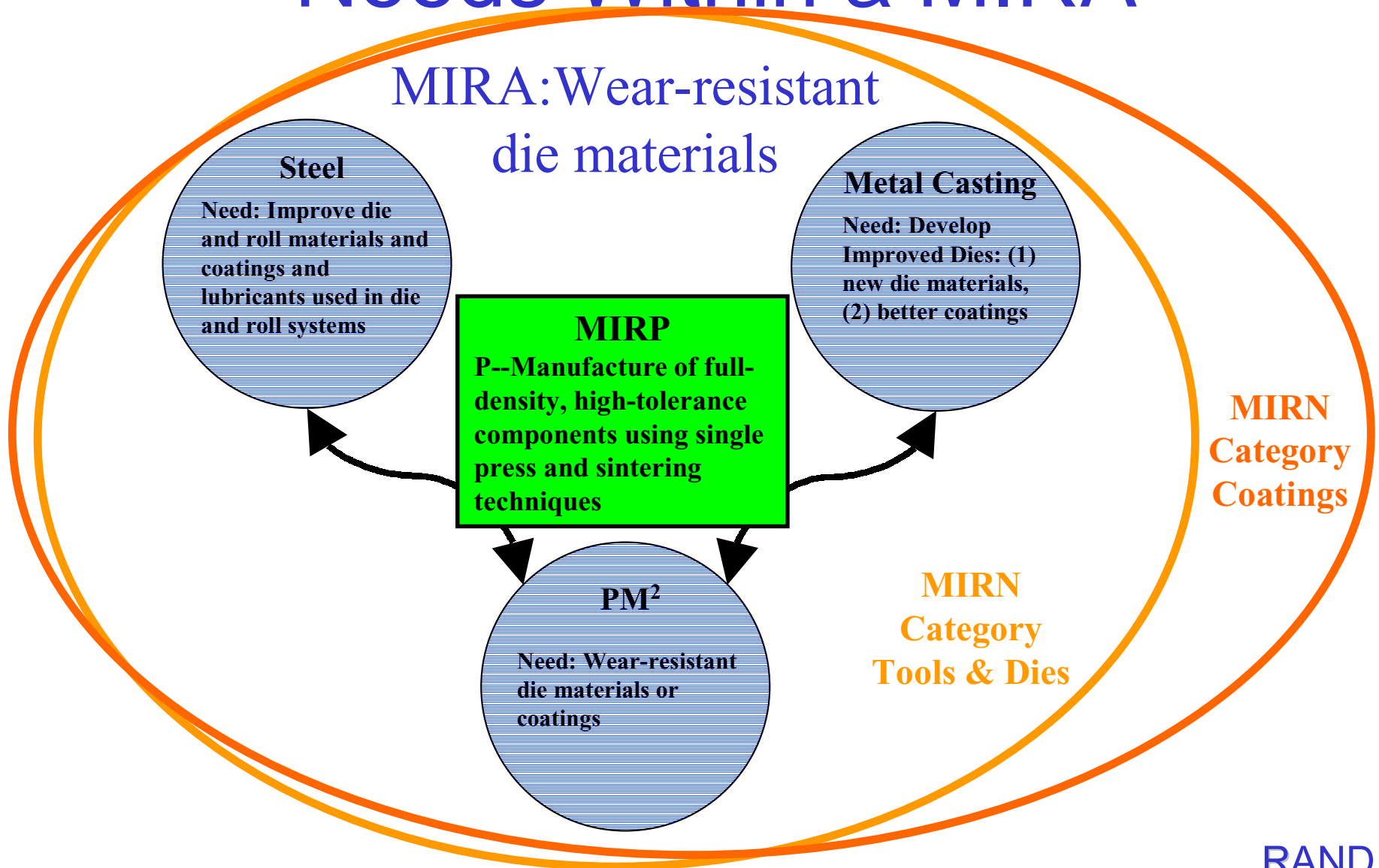
### Forging

Need: Develop models that can handle parametric studies for cost optimization: (1) die material, (2) coating, and (3) radius

MIRN  
Category  
Coatings

MIRN  
Category  
Tools & Dies

# MIRP Addressing Research Needs Within a MIRA



# Summary of Links Based on Needs and Projects

- 1) **Multiple-Industry Research Needs (MIRNs):**  
R&D needs that appear in more than one industry roadmap
- 2) **MIRN Categories:** Groups of related R&D needs in different industry roadmaps
- 3) **Multiple Industry Research Projects (MIRPs):**  
Projects that meet R&D needs in more than one industry roadmap
- 4) **Multiple Industry Research Areas (MIRAs):**  
Underpinning research areas with common needs of multiple industries across multiple MIRN Categories

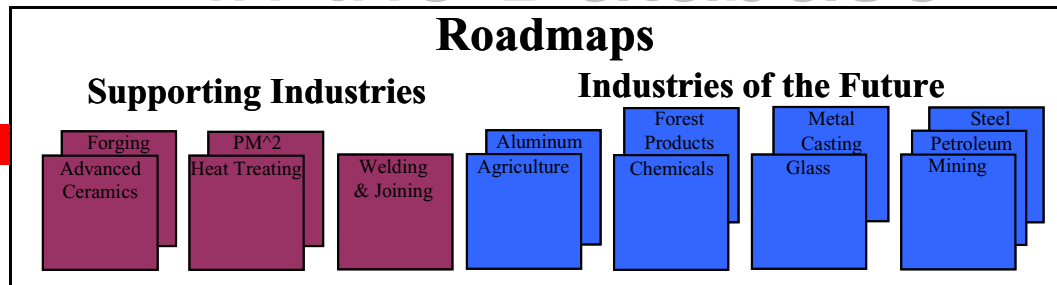
# RAND Compiled a Database Using the Basic Elements

## The Contents of the Database:

- **887 R&D needs** and **133 Performance targets** from 9 IOF and 5 SI roadmaps
- **309 DOE-funded or proposed projects** that address needs and/or performance targets
- **1206 MIRN Category Links** between related R&D needs in different roadmaps
- **48 MIRP Links** through projects meeting R&D needs in different roadmaps, including **44 projects that link different MIRN Categories**



# Performance Targets, Needs, and Projects Were Tabulated Separately in the Database

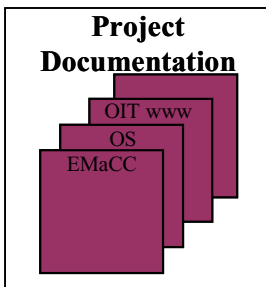


**Industry Performance Targets Table**

Performance Target	Performance Target Description	Roadmap
P.T. (k)	P.T.D. (k)	R. (k)
P.T. (k+1)	P.T.D. (k+1)	R. (k)
⋮	⋮	⋮
P.T. (133)	P.T.D. (133)	R. (k+p)

**Industry Research Needs Table**

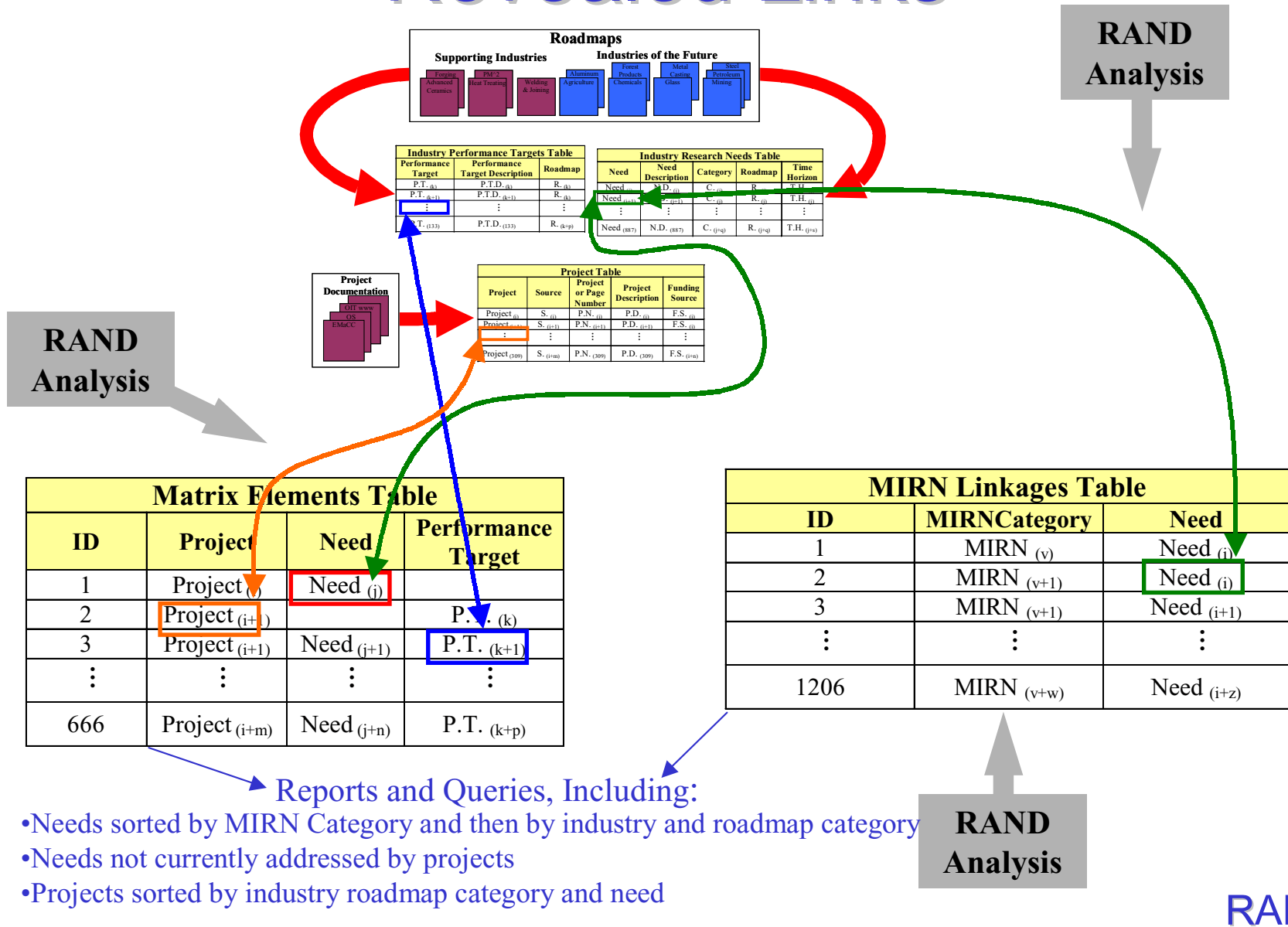
Need	Need Description	Category	Roadmap	Time Horizon
Need (i)	N.D. (i)	C. (i)	R. (i)	T.H. (i)
Need (i+1)	N.D. (i+1)	C. (i)	R. (i)	T.H. (i)
⋮	⋮	⋮	⋮	⋮
Need (887)	N.D. (887)	C. (j+q)	R. (j+q)	T.H. (j+s)



**Project Table**

Project	Source	Project or Page Number	Project Description	Funding Source
Project (i)	S. (i)	P.N. (i)	P.D. (i)	F.S. (i)
Project (i+1)	S. (i+1)	P.N. (i+1)	P.D. (i+1)	F.S. (i)
⋮	⋮	⋮	⋮	⋮
Project (309)	S. (i+m)	P.N. (309)	P.D. (309)	F.S. (i+n)

# Analysis of the Database Revealed Links



# Summary of MIRN Category Links

MIRN Category	# of Roadmaps	# of R&D Needs	MIRN Category	# of Roadmaps	# of R&D Needs	MIRN Category	# of Roadmaps	# of R&D Needs
1) Adhesives	3	5	10) Human and technical resources	5	33	19) Raw materials	9	44
2) Advanced forming	6	37	<b>11) Joining and welding</b>	<b>8</b>	<b>164</b>	<b>20) Sensors and Sensor materials</b>	<b>11</b>	<b>53</b>
3) Casting	3	13	12) Low-friction/Lubricants	5	10	21) Separation technologies	5	21
<b>4) Coatings</b>	<b>8</b>	<b>73</b>	13) Magnetic materials	2	2	<b>22) Standards, product quality, and testing</b>	<b>13</b>	<b>74</b>
5) Composites	3	43	14) Markets and applications	6	9			
<b>6) Corrosion-, erosion-, wear-resistant materials</b>	<b>12</b>	<b>44</b>	<b>15) Modeling and simulation</b>	<b>12</b>	<b>110</b>	<b>23) Surfaces and interfaces</b>	<b>8</b>	<b>16</b>
<b>7) Databases and properties</b>	<b>13</b>	<b>59</b>	16) NDE and inspection	7	38	24) Tools and dies	6	29
8) Design tools	10	31	<b>17) Process design and improvement</b>	<b>12</b>	<b>160</b>	<b>25) Waste and byproduct treatment, recycling, and use</b>	<b>12</b>	<b>50</b>
9) High-temperature materials and refractories	11	43	18) Process monitoring and control	9	48			

**MIRN Categories in black cover more than half of the industry roadmaps**

MIRN Categories in grey cover half or less than half of the industry roadmaps

# MIRN Categories Encompassing Many Industries Identify Common Research Needs

- 14 MIRN Categories include research needs in more than half of the industry roadmaps
- Common research needs in these MIRN Categories can be addressed through joint workshops, solicitations, partnerships, etc.
  - Research to achieve desirable suites of properties
  - Surface- and interface-related processing issues
  - Development of common databases, models, design tools
  - Industrial process issues that span related industries

# The Same MIRN Categories That Encompass Many IOFs Also Encompass Many SIs

(SI Research Provides Materials for IOF Products/Components)

		Supporting Industries					Industries Of The Future								
		Advanced Ceramics	Forging	Heat Treating	PM^2	Welding & Joining	Agriculture	Aluminum	Chemicals	Forest Products	Glass	Metal Casting	Mining	Petroleum	Steel
<b>MIRN Categories</b>	Adhesives	1.6%							2.6%					3.3%	
	Advanced forming	6.0%	2.6%		15.7%	2.0%		4.4%			3.7%				
	Casting							17.4%			18.5%			13.3%	
	<b>Coatings</b>	30.4%	4.4%		0.9%				3.0%		3.2%	7.4%		2.8%	20.0%
	Composites	20.7%			3.7%	0.7%									
	<b>Corrosion-, erosion-, wear-resistant materials</b>	8.2%	2.6%	1.9%	1.9%	1.3%		4.4%	33.3%	2.6%	3.2%		10.0%	5.6%	6.7%
	<b>Databases and properties</b>	7.1%	4.4%	1.9%	9.3%	2.7%	35.7%	26.1%	6.1%	5.1%	3.2%	7.4%	6.7%		3.3%
	<b>Design tools</b>	6.5%	1.7%		2.8%	4.0%	3.6%	3.5%		2.6%		11.1%	3.3%	2.8%	
	<b>High-temperature materials and refractories</b>	4.9%	2.6%	7.4%	3.7%	2.0%		4.4%	9.1%		19.4%	3.7%		2.8%	26.7%
	Human and technical resources		7.0%		11.1%	6.7%			3.0%			7.4%			
	<b>Joining and welding</b>	3.8%			0.9%	100.0%		4.4%	6.1%	2.6%		3.7%			3.3%
	Low-friction/lubricants	1.1%	2.6%		2.8%						3.2%				3.3%
	Magnetic materials				0.9%	0.7%									
	Markets and applications	0.5%			2.8%	0.7%	7.1%			2.6%		3.7%			
	<b>Modeling and simulation</b>	8.7%	24.4%	24.1%	7.4%	12.7%		13.0%	21.2%	7.7%	12.9%	3.7%	13.3%	11.1%	
	NDE and inspection	4.9%	6.1%			8.0%		4.4%	12.1%			3.7%		11.1%	
	<b>Process design and improvement</b>	19.0%	15.7%	38.9%	2.8%	20.7%	39.3%	30.4%		10.3%	16.1%		33.3%	25.0%	20.0%
	<b>Process monitoring and control</b>	3.8%	9.6%	5.6%		12.7%					3.2%	3.7%	3.3%	11.1%	3.3%
	<b>Raw materials</b>	6.0%	1.7%	3.7%	7.4%	4.0%	7.1%			28.2%		3.7%			3.3%
	<b>Sensors and sensor materials</b>	2.2%	4.4%	9.3%	8.3%	10.0%		8.7%	3.0%	2.6%	22.6%	7.4%	6.7%		
	Separation technologies						3.6%			5.1%	3.2%		46.7%	8.3%	
	<b>Standards, product quality, testing</b>	12.0%	7.8%	1.9%	12.0%	9.3%	3.6%	17.4%	6.1%	2.6%	9.7%	7.4%	3.3%	2.8%	
	<b>Surfaces and interfaces</b>		2.6%		1.9%	1.3%		13.0%		2.6%	3.2%		6.7%		6.7%
Tools and dies	0.5%	14.8%		3.7%			8.7%				11.1%			6.7%	
<b>Waste and by-product treatment recycling and use</b>	1.1%	2.6%	11.1%	3.7%	2.7%		4.4%		30.8%	6.5%	7.4%	13.3%	16.7%	13.3%	

Key

0
0 < X < 10
10 ≤ X < 20
20 ≤ X

# MIRN Categories Share Many Identical Research Needs

(These MIRN Category Links Can Be Used To Identify MIRAs, Especially When They Involve Multiple Industries)

		MIRN Categories																									
		Adhesives	Advanced forming	Casting	Coatings	Composites	Corrosion-, erosion-, wear-resistant materials	Databases and properties	Design tools	High-temperature materials and refractories	Human and technical resources	Joining and welding	Low-friction/lubricants	Magnetic materials	Markets and applications	Modeling and simulation	NDE and inspection	Process design and improvement	Process monitoring and control	Raw materials	Sensors and sensor materials	Separation technologies	Standards, product quality, testing	Surfaces and interfaces	Tools and dies	Waste and by-product treatment recycling and use	
MIRN Categories	Number of R&D Needs that appear in both MIRN Categories	5			4		1					2															
	Adhesives		37		3	2					3																
	Advanced forming			13				1							1							1		1	2	2	
	Casting	4	3		73	9	13	3	1	6		2	2			6	3	6	4	2	2		4	2	5	1	
	Coatings		2		9	43	2			5		1					6	4		4							
	Composites	1			13	2	44	1		4		2				2								2	2		
	Corrosion-, erosion-, wear-resistant materials			1	3		1	59	2			4				8	1	4				1	2	1	1	1	
	Databases and properties				1			2	31			7				5		3				1					
	Design tools				6	5	4			43		3	1					3					1				
	High-temperature materials and refractories										33	10															
	Human and technical resources	2	3		2	1	2	4	7	3	10	164		1	1	19	12	32	19	6	15		14	2		4	
	Joining and welding				2						1		10										1		2		
	Low-friction/lubricants													2													
	Magnetic materials												1		2												
	Markets and applications														9												
	Modeling and simulation			1	6		2	8	5		19					110		4	1	1		2	1	3	3		
	NDE and inspection				3			1			12						38	1	1		1		1				
	Process design and improvement				6	6		4	3	3	32					4	1	160	3	2		4	1		1		
	Process monitoring and control				4						19					1	1	3	48	2	9						
	Raw materials				2	4				2	6					1		2	2	44							
Sensors and sensor materials			1	2						15						1		9		53		1		1	1		
Separation technologies							1	1							2		4				21	1					
Standards, product quality, testing			1	4			2		1	14	1				1	1	1			1	1	74	2				
Surfaces and interfaces			2	2		2	1			2					3							2	16	3	1		
Tools and dies			2	5		2	1				2				3		1			1			3	29			
Waste and by-product treatment recycling and use				1			1			4										1	1		1		50		

Key

0
1 ≤ X ≤ 3
4 ≤ X ≤ 6
6 < X

# Several DOE Programs Fund Projects That Address IOF Needs

(The SI and IMF Programs Address Many IOF Needs Per Project)

		Project Funding Source					
		IOF	SI	IMF	OIT Financial Assistance Program	OS	Total
<b>Sum over all projects funded by each source of the needs addressed by each project</b>							
<b>Industries Of The Future</b>	Agriculture	16		1		2	19
	Aluminum	19	12	7	6	15	59
	Chemicals	7	6	12	5	19	49
	Forest Products	53	3	17	6	3	82
	Glass	6	5	37	16	7	71
	Metal Casting	13	7	10	5	3	38
	Mining	4	1	4	3	18	30
	Petroleum	1	2	2	7	11	23
	Steel	40	8	18	5	12	83
	<b>IOF Subtotal</b>	<b>159</b>	<b>44</b>	<b>108</b>	<b>53</b>	<b>90</b>	<b>454</b>
<b>Supporting Industries</b>	Advanced Ceramics	4	8	*	1	*	13
	Forging	2	11	*	2	*	15
	Heat Treating		10	*		*	10
	PM^2	12	24	7	6	19	68
	Welding & Joining		10	*		*	10
	<b>SI Subtotal</b>	<b>18</b>	<b>63</b>	<b>7</b>	<b>9</b>	<b>19</b>	<b>116</b>
<b>Grand Total</b>		<b>177</b>	<b>107</b>	<b>115</b>	<b>62</b>	<b>109</b>	<b>570</b>

<b>Total # of Projects</b>	169	12	17	25	80	303
<b>Average # of Needs Addressed per Project</b>	1.05	8.92	6.76	2.48	1.36	1.88

\* Note: RAND did not review projects funded by these sources with respect to these SI needs.

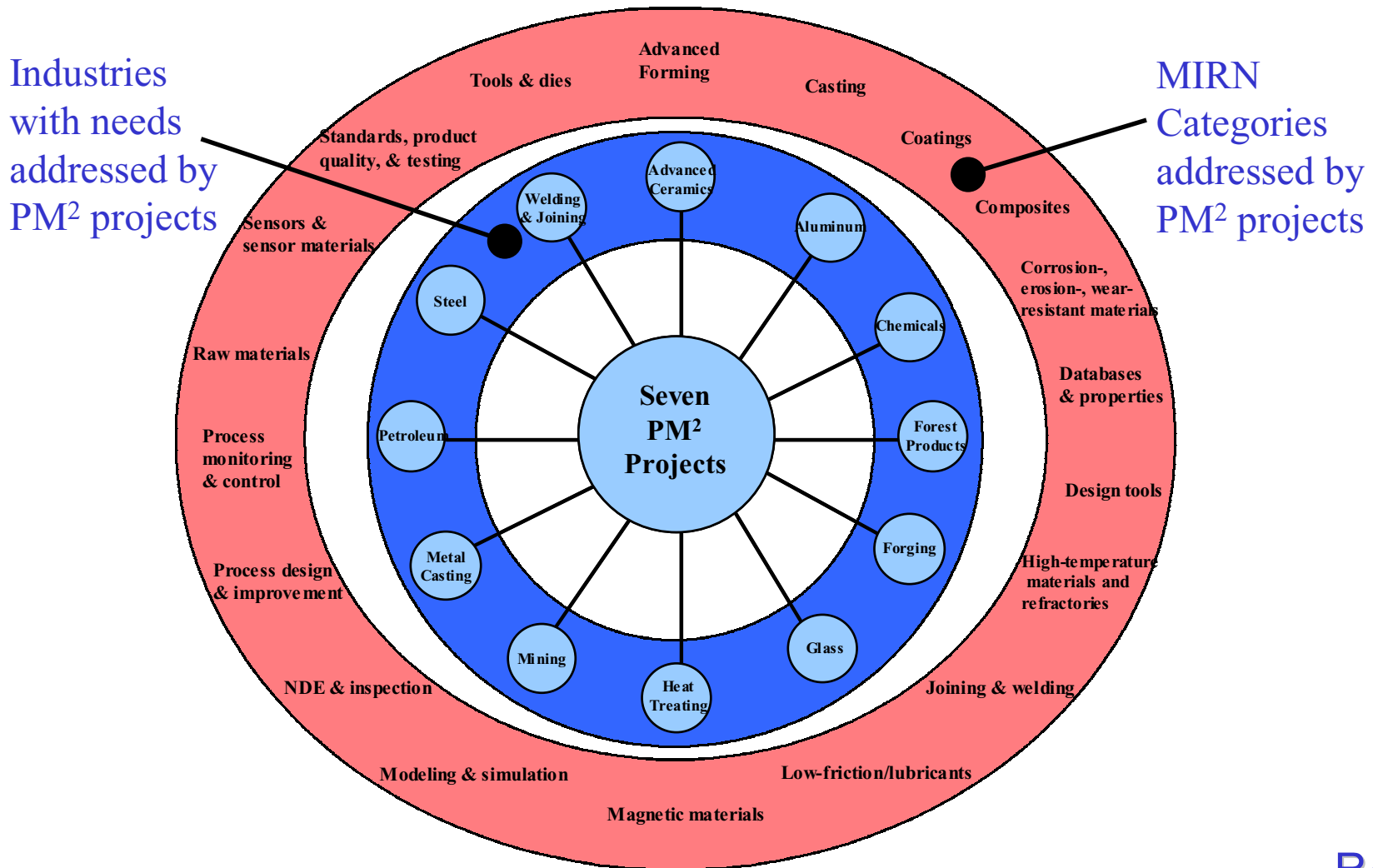
# The SI and IMF Programs Are Strong Sources of Project-MIRN Category Links

(For Projects Involving Multiple Industries (MIRPs), These Links Can Also Identify MIRAs)

Funding Source	# of Industries in which Projects Address Needs	# of Projects	# of Projects Addressing 2 or more MIRN Categories		# of Projects Addressing 3 or more MIRN Categories		# of Projects Addressing 4 or more MIRN Categories		# of Projects Addressing 5 or more MIRN Categories		# of Projects Addressing 6 or more MIRN Categories		# of Projects Addressing 10 or more MIRN Categories	
			#	%	#	%	#	%	#	%	#	%	#	%
<b>IOF</b>	12	169	26	15.38%	8	4.73%	6	3.55%	4	2.37%		0.00%		0.00%
<b>SI</b>	13	12	10	83.33%	10	83.33%	9	75.00%	5	41.67%	3	25.00%	1	8.33%
<b>IMF</b>	10	17	14	82.35%	8	47.06%	8	47.06%	7	41.18%	5	29.41%	2	11.76%
<b>OIT Financial Assistance Program</b>	11	25	10	40.00%	7	28.00%	3	12.00%	3	12.00%	2	8.00%		0.00%
<b>OS</b>	10	80	28	35.00%	18	22.50%	7	8.75%	2	2.50%	1	1.25%		0.00%
<b>Grand Total</b>		<b>303</b>	<b>88</b>	<b>29.04%</b>	<b>51</b>	<b>16.83%</b>	<b>33</b>	<b>10.89%</b>	<b>21</b>	<b>6.93%</b>	<b>11</b>	<b>3.63%</b>	<b>3</b>	<b>0.99%</b>



# PM<sup>2</sup> Projects Address Many Industries' Needs and MIRN Categories



# P--Advanced material manufacture using novel nanophase materials (Part I of II)

(This project links 10 MIRN Categories, 4 SI and 8 IOF industries)

MIRN Category	Roadmap	Need
Advanced forming	Advanced Ceramics (SI)	Expand functionally gradient materials component fabrication R&D; consider bulk and surface gradation
Casting	Aluminum (VT)	Develop better tool and die materials with improved heat extraction capabilities (NMAB)
Coatings	Metal Casting (NMAB)	Develop Improved Dies: (1) new die materials, (2) better coatings
Coatings	Steel (VT)	Improve die and roll materials and coatings and lubricants used in die and roll systems
Composites	PM <sup>2</sup> (SI)	Co-sintering composites with different materials
Composites	PM <sup>2</sup> (SI)	Custom composite powders of different materials (biological, plastics, etc.)
Corrosion-, erosion-, wear-resistant materials	Advanced Ceramics (SI)	Improve resistance to the use environment (e.g., oxidation, corrosion)
Corrosion-, erosion-, wear-resistant materials	Chemicals (VT)	Develop new materials
Corrosion-, erosion-, wear-resistant materials	Forest Products (VT)	Develop new material for the industry's processing equipment which are cheaper to use, less expensive to maintain, and stand up to the nature of chemical processes
Corrosion-, erosion-, wear-resistant materials	Heat Treating (SI)	Improved alloys that extend the life and operating temperature range of furnace hardware and fixtures
Corrosion-, erosion-, wear-resistant materials	Mining (VT)	Develop new materials to improve wear resistance
High-temperature materials and refractories	Aluminum (VT)	Develop more durable refractory materials (NMAB)
High-temperature materials and refractories	Chemicals (VT)	Develop longer life refractories that are field repairable and ductile
High-temperature materials and refractories	Glass (VT)	Develop longer lasting materials in addition to refractories
High-temperature materials and refractories	Glass (VT)	Develop new refractories
High-temperature materials and refractories	Glass (VT)	Develop refractories that do not introduce defects

## P--Advanced material manufacture using novel nanophase materials (Part II of II)

(This project links 10 MIRN Categories, 4 SI and 8 IOF industries)

MIRN Category	Roadmap	Need
High-temperature materials and refractories	Heat Treating (SI)	Improved alloys that extend the life and operating temperature range of furnace hardware and fixtures
High-temperature materials and refractories	PM^2 (SI)	Low-creep, high-temperature materials
High-temperature materials and refractories	Steel (VT)	Develop improved refractories for walls, or better ways to seal existing leaking through walls
Low-friction/lubricants	Steel (VT)	Improve die and roll materials and coatings and lubricants used in die and roll systems
Process design and improvement	Forging (SI)	New materials to reduce needs for processing: (1) colder working temperature, (2) no heat treating, (3) no conditioning
Process design and improvement	Heat Treating (SI)	Alloys that enable some heat treating operations to be eliminated (to shorten cycle and/or save energy)
Process design and improvement	Petroleum (VT)	Catalysts:(1) Develop >5 new chemical catalysts for low-temp environments, (2) increase catalyst life by 2-fold through new sulfur and nitrogen-tolerant catalysts, (3) single, non-energy requiring biocatalyst for hydrocarbon and heteroatom conversion
Process design and improvement	Petroleum (VT)	Develop improved catalysts for deep diesel desulfurization
Raw materials	PM^2 (SI)	Economic manufacture of sub-micron particles at production scale
Raw materials	PM^2 (SI)	Fine particle technology and nanocrystalline powders: 1) compaction, 2) material properties, 3) sintering
Raw materials	PM^2 (SI)	Self-sintering powders
Tools and dies	Aluminum (VT)	Develop better tool and die materials with improved heat extraction capabilities (NMAB)
Tools and dies	Forging (SI)	Develop improved die materials
Tools and dies	Metal Casting (NMAB)	Develop Improved Dies: (1) new die materials, (2) better coatings
Tools and dies	Steel (VT)	Improve die and roll materials and coatings and lubricants used in die and roll systems

P--Development of predictive tools for compression of time to describe properties (performance) at the component level (Math-based component design, processing and validation)  
 (This project links 5 MIRN Categories, 2 SI and 3 IOF industries)

MIRN Category	Roadmap	Need
Advanced forming	PM^2 (SI)	Understanding of basic process phenomena
Databases and properties	Aluminum (VT)	Develop integrated numerical methods for analysis and robust design of product process, and material
Design tools	Aluminum (VT)	Develop integrated numerical methods for analysis and robust design of product process, and material
Design tools	Metal Casting (VT)	Develop computer design tools to move from design concept to a design for manufacturing
Modeling and simulation	Aluminum (VT)	Develop integrated numerical methods for analysis and robust design of product process, and material
Modeling and simulation	Aluminum (VT)	Understand relationship of aluminum alloy composition & processing & its effect on microstructure and properties (zero earring, high strength formability can sheet product, develop 3000 series alloys for end stock beverage)
Modeling and simulation	Chemicals (VT)	Develop means to predict materials performance without empirical tests
Modeling and simulation	Heat Treating (SI)	Enhanced computer modeling of processes, which includes composition, distortion, resultant microstructure, and final properties
Modeling and simulation	Heat Treating (SI)	Integrated process model - mechanical
Modeling and simulation	PM^2 (SI)	Modeling of complete forming and strengthening processes for a component
Modeling and simulation	PM^2 (SI)	Process modeling for pressing, sintering, gas flow in furnaces, and other processes
Modeling and simulation	PM^2 (SI)	Widely available user-friendly, math-based process models with realistic constraints
Process design and improvement	Aluminum (VT)	Develop integrated numerical methods for analysis and robust design of product process, and material

# P--Development of sensor-based feedback control techniques to reduce process variation

(This project links 4 MIRN Categories, 4 SI and 3 IOF industries)

MIRN Category	Roadmap	Need
NDE and inspection	Advanced Ceramics (SI)	Develop intelligent processing (automated or semi-automated with sensors, NDE, etc.)
Process design and improvement	Advanced Ceramics (SI)	Develop intelligent processing (automated or semi-automated with sensors, NDE, etc.)
Process monitoring and control	Advanced Ceramics (SI)	Develop intelligent processing (automated or semi-automated with sensors, NDE, etc.)
Process monitoring and control	Forging (SI)	Develop closed-loop process controls for hot forging (requires sensors)
Process monitoring and control	Forging (SI)	Develop PC-based machine controllers
Process monitoring and control	Glass (VT)	Improve intelligent control of production and fabrication process
Process monitoring and control	Heat Treating (SI)	Improved process sensors, including those for carbon content, residual stress, and cleanliness. Also, more advanced controls that can fully exploit these and other sensors.
Sensors and sensor materials	Forest Products (VT)	Develop sophisticated real-time measurement and control systems for: (1) enviro-related, (2) process-related, (3) product quality, (4) large system controls, (5) expert systems
Sensors and sensor materials	Heat Treating (SI)	Improved process sensors, including those for carbon content, residual stress, and cleanliness. Also, more advanced controls that can fully exploit these and other sensors.
Sensors and sensor materials	Metal Casting (VT)	Develop smart controls and sensors for automation supervision
Sensors and sensor materials	PM <sup>2</sup> (SI)	Advanced controls for more accurate green compacting and sintering
Sensors and sensor materials	PM <sup>2</sup> (SI)	Non-intrusive, stable sensor materials for process control
Sensors and sensor materials	PM <sup>2</sup> (SI)	Novel use of new or existing sensor technology to monitor particle size, particle size distribution, flow rates, and furnace conditions
Sensors and sensor materials	PM <sup>2</sup> (SI)	System-based, closed-loop feedback controls (sintering problem feeds back to earlier process)

**P--Electromagnetic circuit design with three-dimensional P/M magnets and core components**  
**(This project links 3 MIRN Categories, 3 SI and 1 IOF industries)**

<b>MIRN Category</b>	<b>Roadmap</b>	<b>Need</b>
High-temperature materials and refractories	Forging (SI)	Develop induction heating system with higher efficiency (e.g. reshapable coils) or improved materials or insulation
Magnetic materials	PM^2 (SI)	Innovative magnetic materials
Process design and improvement	Forging (SI)	Develop induction heating system with higher efficiency (e.g. reshapable coils) or improved materials or insulation
Process design and improvement	Heat Treating (SI)	Induction coils that make optimum use of the electromagnetic field distribution for heating
Process design and improvement	Steel (VT)	Energy Use: Develop superconducting electrodes, higher power induction melting, economic microwave applications

# P--Joining of P/M components for greater functionality (Part I of II)

(This project links 5 MIRN Categories, 3 SI and 5 IOF industries)

MIRN Category	Roadmap	Need
Corrosion-, erosion-, wear-resistant materials	Welding & Joining (SI)	Development of more weldable corrosion-resistant materials (Very high priority)
High-temperature materials and refractories	Welding & Joining (SI)	Weldable materials sustainable of higher temperatures
Joining and welding	Advanced Ceramics (SI)	Develop field joining techniques (offsite)
Joining and welding	Advanced Ceramics (SI)	Develop joining techniques to reduce stresses (ceramic/metal, ceramic/plastic, ceramic/ceramic)
Joining and welding	Aluminum (VT)	Eliminate pre-treatment for joining (bonding, spot welding) /Non-mechanical joining methods for non-weldable alloys
Joining and welding	Chemicals (VT)	Explore joining methods for ODS alloys
Joining and welding	Chemicals (VT)	Investigate joining/fabrication techniques for ceramics and other brittle materials for chemical processing
Joining and welding	Forest Products (VT)	Improved welding techniques for system fabrication and construction
Joining and welding	Metal Casting (VT)	Demonstrate effective joining techniques for new and dissimilar cast materials - to join new alloys (especially for automotive applications)
Joining and welding	PM <sup>2</sup> (SI)	Improved welding and joining techniques
Joining and welding	Steel (VT)	Develop and optimize alternative joining methods
Joining and welding	Welding & Joining (SI)	Development of more weldable corrosion-resistant materials (Very high priority)
Joining and welding	Welding & Joining (SI)	Improvements in dissimilar materials joining (High priority)
Joining and welding	Welding & Joining (SI)	Inclusion of weldability and manufacturability in new material development (Top priority)
Joining and welding	Welding & Joining (SI)	Joining processes for dissimilar materials (Very high priority)

## P--Joining of P/M components for greater functionality (Part II of II)

(This project links 5 MIRN Categories, 3 SI and 5 IOF industries)

MIRN Category	Roadmap	Need
Joining and welding	Welding & Joining (SI)	Materials and/or process developments to enable aluminum alloys to be welded with minimal material property degradation
Joining and welding	Welding & Joining (SI)	More alloy development in general
Joining and welding	Welding & Joining (SI)	Weldable alloys that reduce need for pre and post heat treatment (Very high priority)
Joining and welding	Welding & Joining (SI)	Weldable materials sustainable of higher temperatures
Joining and welding	Welding & Joining (SI)	Weldable, cost-effective materials that met performance requirements of future automotive structures --- good strength-to-weight ratios, corrosion resistance, and/or high-temperature strength (Top priority)
Joining and welding	Welding & Joining (SI)	Welding of lighter-weight materials used in low-emission vehicles (Top priority)
Process design and improvement	Welding & Joining (SI)	Improvements in dissimilar materials joining (High priority)
Process design and improvement	Welding & Joining (SI)	Joining processes for dissimilar materials (Very high priority)
Process design and improvement	Welding & Joining (SI)	Materials and/or process developments to enable aluminum alloys to be welded with minimal material property degradation
Process design and improvement	Welding & Joining (SI)	Weldable alloys that reduce need for pre and post heat treatment (Very high priority)
Raw materials	Welding & Joining (SI)	More alloy development in general



**P--Manufacture of full-density, high-tolerance components using  
single press and sintering techniques  
(Part I of II)  
(This project links 9 MIRN Categories, 4 SI and 5 IOF industries)**

<b>MIRN Category</b>	<b>Roadmap</b>	<b>Need</b>
Advanced forming	Advanced Ceramics (SI)	Improve fabrication processes and reduce equipment costs
Advanced forming	Aluminum (VT)	Advanced forming and net-shape/near net-shape technology (semi-solid casting, casting spay forming, spray forming, physical vapor deposition, PM technology, rapid solidification)
Advanced forming	PM^2 (SI)	Form and sinter in one process
Advanced forming	PM^2 (SI)	Non-traditional processing techniques
Casting	Aluminum (VT)	Develop better tool and die materials with improved heat extraction capabilities (NMAB)
Coatings	Metal Casting (NMAB)	Develop Improved Dies: (1) new die materials, (2) better coatings
Coatings	PM^2 (SI)	Wear-resistant die materials or coatings
Coatings	Steel (VT)	Improve die and roll materials and coatings and lubricants used in die and roll systems
Corrosion-, erosion-, wear-resistant materials	Chemicals (VT)	Develop new materials
Corrosion-, erosion-, wear-resistant materials	Chemicals (VT)	Develop new materials
Corrosion-, erosion-, wear-resistant materials	Heat Treating (SI)	Improved alloys that extend the life and operating temperature range of furnace hardware and fixtures
Corrosion-, erosion-, wear-resistant materials	PM^2 (SI)	Wear-resistant die materials or coatings
High-temperature materials and refractories	Glass (VT)	Develop longer lasting materials in addition to refractories
High-temperature materials and refractories	Heat Treating (SI)	Improved alloys that extend the life and operating temperature range of furnace hardware and fixtures
High-temperature materials and refractories	Steel (VT)	Maintain the good properties achieved by newer refractories, while minimizing cost and consumption and ensuring safety
Low-friction/lubricants	Steel (VT)	Improve die and roll materials and coatings and lubricants used in die and roll systems

# P--Manufacture of full-density, high-tolerance components using single press and sintering techniques (Part II of II)

(This project links 9 MIRN Categories, 4 SI and 5 IOF industries)

MIRN Category	Roadmap	Need
Process design and improvement	Advanced Ceramics (SI)	Establish reliable fabrication capability for large-volume components
Process design and improvement	Advanced Ceramics (SI)	Improve sintering processes to near-100% uniformity (Top priority)
Process design and improvement	Heat Treating (SI)	Lower cost heat treatable alloys
Process design and improvement	PM <sup>2</sup> (SI)	Manufacturing process flexibility
Standards, product quality, testing	PM <sup>2</sup> (SI)	Materials single-pressed to full density
Tools and dies	Aluminum (VT)	Develop better tool and die materials with improved heat extraction capabilities (NMAB)
Tools and dies	Forging (SI)	Develop improved die materials
Tools and dies	Forging (SI)	Develop next-generation die manufacturing technology
Tools and dies	Metal Casting (NMAB)	Develop Improved Dies: (1) new die materials, (2) better coatings
Tools and dies	PM <sup>2</sup> (SI)	Wear-resistant die materials or coatings
Tools and dies	Steel (VT)	Improve die and roll materials and coatings and lubricants used in die and roll systems

## P--Three-dimensional forming techniques for complex shapes (This project links 4 MIRN Categories, 2 SI and 2 IOF industries)

MIRN Category	Roadmap	Need
Advanced forming	Aluminum (VT)	Advanced forming and net-shape/near net-shape technology (semi-solid casting, casting spray forming, spray forming, physical vapor deposition, PM technology, rapid solidification)
Advanced forming	Metal Casting (VT)	Improve the ability to produce size/dimension
Advanced forming	PM^2 (SI)	New techniques for large 3-D components
Advanced forming	PM^2 (SI)	Rapid formation of complex 3-D components with high density and tight dimensional control - as fast as current 2-D technology
Low-friction/lubricants	PM^2 (SI)	Research factors critical to 3-D forming: 1) filling, pressing and tooling, 2) low-friction materials, improved lubricants
Modeling and simulation	Forging (SI)	Develop 3-D simulation technology for deformation process
Modeling and simulation	Forging (SI)	Develop coupled 3-D models of forging process (die and piece) on massively parallel machines
Process design and improvement	PM^2 (SI)	Manufacturing process flexibility

# A Database Navigator Is Available To Facilitate Browsing

Browse by:

**MIRN Category**

**Industry**

# Navigation by MIRC Category Page

Adhesives	Markets & Applications
Advanced Forming	Modeling & Simulation
Casting	NDE & Inspection
Coatings	Process Design & Improvement
Composites	Process Monitoring & Control
Corrosion-, Erosion-, Wear-resistant Materials	Raw Materials
Databases & Properties	Sensors & Sensor Materials
Design Tools	Separations Technologies
High-temperature Materials & Refractories	Standards, Product Quality, & Testing
Human & Technical Resources	Surfaces & Interfaces
Joining & Welding	Tools & Dies
Low-friction/lubricants	Waste & By-product Treatment, Recycling, & Use
Magnetic Materials	

# Navigation by Industry Page

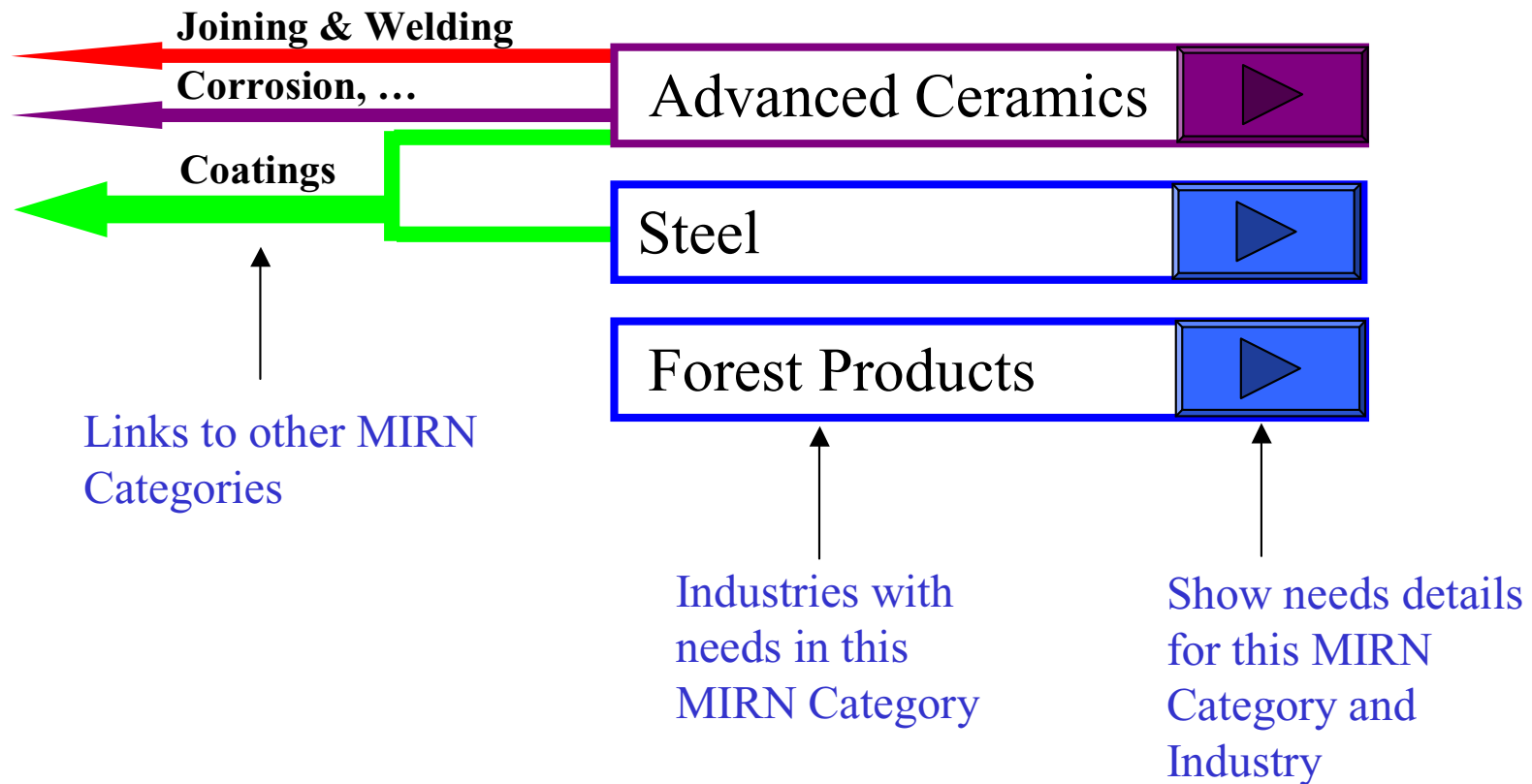
Supporting Industries	Industries of the Future
<a href="#">Advanced Ceramics</a>	<a href="#">Agriculture</a>
<a href="#">Forging</a>	<a href="#">Aluminum</a>
<a href="#">Heat Treating</a>	<a href="#">Chemicals</a>
<a href="#">PM<sup>2</sup></a>	<a href="#">Forest Products</a>
<a href="#">Welding &amp; Joining</a>	<a href="#">Glass</a>
	<a href="#">Metal Casting</a>
	<a href="#">Mining</a>
	<a href="#">Petroleum</a>
	<a href="#">Steel</a>

# Advanced Ceramics Industry Page

## Listing the Industry's MIRN Categories

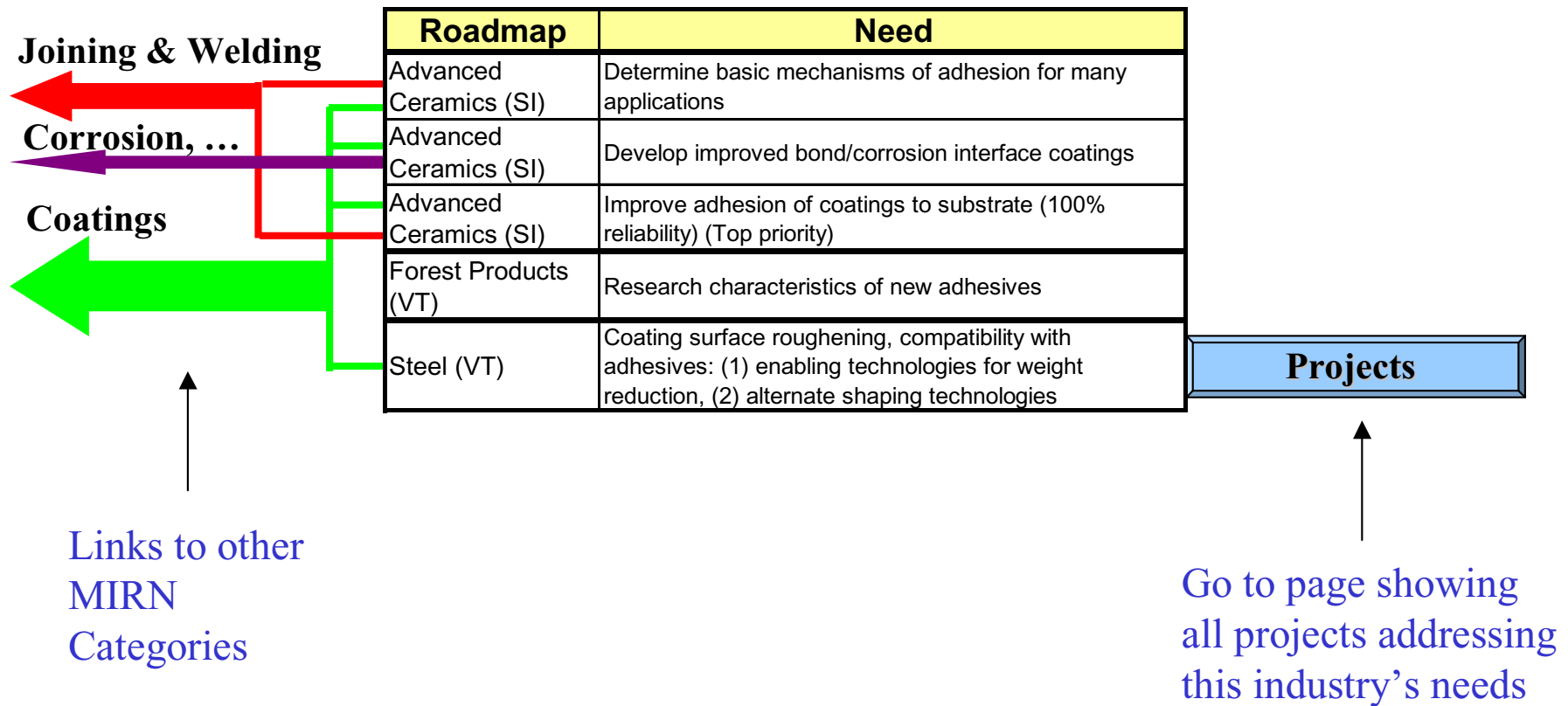
Adhesives	Markets & Applications
Advanced Forming	Modeling & Simulation
Coatings	NDE & Inspection
Composites	Process Design & Improvement
Corrosion-, Erosion-, Wear-resistant Materials	Process Monitoring & Control
Databases & Properties	Raw Materials
Design Tools	Sensors & Sensor Materials
High-temperature Materials & Refractories	Standards, Product Quality, & Testing
Joining & Welding	Tools & Dies
Low-friction/lubricants	Waste & By-product Treatment, Recycling, & Use

# Adhesives MIRN Category Example (Links Page)





# Adhesives MIRN Category Example (R&D Needs Detail Page)



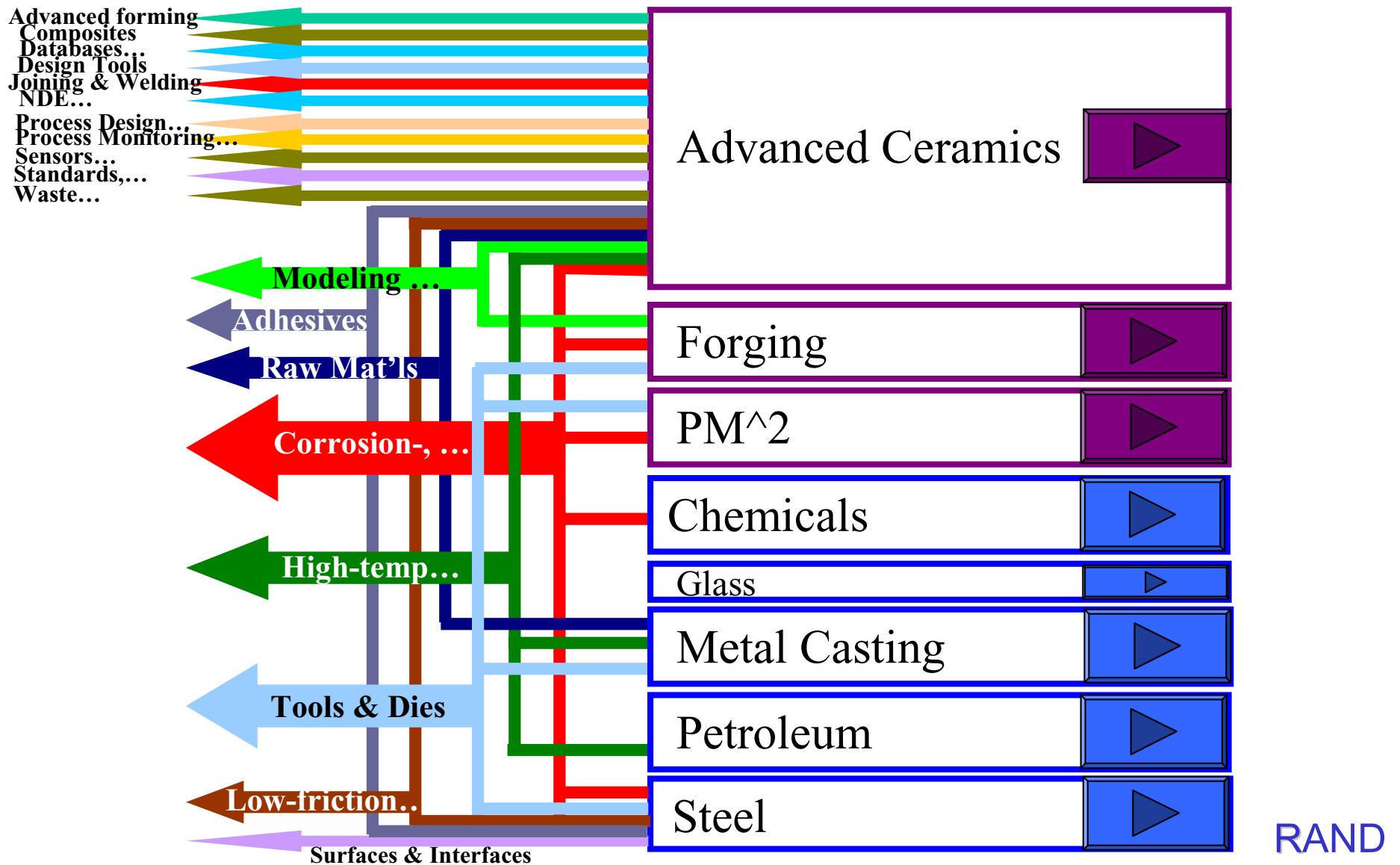
# Adhesives MIRN Category Example

## (Research Projects Addressing Steel Industry Needs in the MIRN Category)

Roadmap	Project	Funding Source	Need	Performance Target
Steel (VT)	Generic approach to improved semi-solid forming of metals	OS	Coating surface roughening, compatibility with adhesives: (1) enabling technologies for weight reduction, (2) alternate shaping technologies	Improve Product Development
Steel (VT)	Semi-solid metal freeform fabrication	OS	Coating surface roughening, compatibility with adhesives: (1) enabling technologies for weight reduction, (2) alternate shaping technologies	Improve Product Development
Steel (VT)	Surface quality of automotive sheet steels	VT	Coating surface roughening, compatibility with adhesives: (1) enabling technologies for weight reduction, (2) alternate shaping technologies	Improve Product Development
Steel (VT)	Uniform droplet processing	IMF	Coating surface roughening, compatibility with adhesives: (1) enabling technologies for weight reduction, (2) alternate shaping technologies	Improve Product Development

# Coatings MIRN Category Example

## (MIRN Category Links Page)



# MIRN Category Links Analysis (Common Research Needs)

- Analysis of MIRN Category links shows that SI/IOF have strong overlapping research needs in:
  - Coatings for resistance to severe environments (e.g., tools and dies) 3 SI/5 IOF
  - Databases and models for process design and quality control/standards 5 SI/8 IOF
  - Joining and Welding (links to 20 other MIRN Categories) 3 SI/5 IOF

**These common research needs represent opportunities for joint efforts between the industries concerned to maximize the effectiveness of their R&D funds.**

# MIRN Category Links Analysis (MIRP Identification)

- Analysis of MIRN Category links identified the following SI MIRPs:
  - P-Advanced material manufacture using novel nanophase materials (coatings)
  - P-Manufacture of full-density, high-tolerance components using single press and sintering techniques (coatings)
  - P-Development of predictive tools for compression of time to describe properties (performance) at the component level (databases and models)
  - P-Joining of P/M components for greater flexibility (joining and welding)

# MIRN Category Links Analysis (Identification of MIRAs)

- Addressing needs in the common research areas requires progress in MIRAs that are underpinnings for achieving the goals of more than one industry, including:
  - Understanding and control of surface and interface properties
  - Materials property databases and models that allow design for specific performance
  - Near net-shape manufacturing methods that retain phases and properties

# Conclusions

- The R&D needs from the SI and IOF roadmaps are strongly linked through multiple common MIRN Categories
- Most SI research projects are MIRPs, addressing on average 9 needs
- The same MIRAs serve to underpin the fulfillment of SI and IOF R&D needs

# Recommendations

- We recommend that the DOE/IT programs:
  - Sponsor multiple-industry workshops, e.g., in coatings for severe environments, modeling and databases, and joining and welding
  - Coordinate solicitations and undertake joint research projects to address common R&D needs in these areas, as well as in the MIRAs that underpin them
  - Use the database to facilitate further discussions of linkages to identify additional common research areas