ACKNOWLEDGEMENTS

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# Table of Contents

Executive Summary .......................................................................................................................... 4

I. Overview ..................................................................................................................................... 8
   Introduction ................................................................................................................................. 8
   Vision .......................................................................................................................................... 8
   Driving forces ............................................................................................................................. 8
   Strategic Imperatives .................................................................................................................. 9

II. Challenges & Activities ........................................................................................................... 10
   Challenges ................................................................................................................................. 10
   Activities ................................................................................................................................... 10
   Highest Priorities ...................................................................................................................... 13

III. Strategic Imperatives .............................................................................................................. 14
   Four Strategic Imperatives ........................................................................................................ 14
   Summary ................................................................................................................................... 14

IV. Implementation ....................................................................................................................... 16
   Introduction ............................................................................................................................... 16
   Implementing the Current Roadmap ......................................................................................... 16
   Closing Words .......................................................................................................................... 17

Appendix A: Complete Set of Challenges Facing the Forging Industry ........................................ 18

Appendix B: Complete Set of Research, Education, and Other Activities
   Needed to Overcome the Challenges ....................................................................................... 20

Appendix C: Sample of Completed Projects .............................................................................. 23
EXECUTIVE SUMMARY

The forging industry has achieved an essential place in the U.S. industrial economy by producing components with unique benefits that are difficult to duplicate. The strength, reliability, and durability of forged components have made them the preferred choice in a variety of industries for applications where tension, stress, load, and human safety are critical considerations. Despite the fact that these industries have come to depend on it as a key supplier, the U.S. forging industry faces an increasingly dynamic and challenging business landscape.

In order to maintain a strategic, proactive approach to positioning the forging industry for the future, the Forging Industry Education and Research Foundation (FIERF), under the auspices of the Forging Industry Association (FIA), sponsored a workshop in May 2008 to update the Forging Industry Technology Roadmap. The workshop brought together key members of the forging industry and academia to identify major challenges facing the industry and to determine research, education, and other development priorities that are needed to overcome them. The results of that workshop formed the basis for this 2008 Forging Industry Technology Roadmap Update.

The 2008 Roadmap outlines a growth and development strategy to ensure that the forging industry is positioned to move into a future in which forging firms not only survive, but thrive and grow. Figure 1 presents a high-level picture of the structure and content of the 2008 Roadmap.

VISION

The forging industry first established its vision for the future in the original 1997 Forging Industry Technology Roadmap, and reiterated the same vision in the 2003 update. In 2008, the industry’s original vision remains: a future in which the forging industry is a world leader in customer-focused, efficient, and cost-effective supply of high-quality components.

MAJOR DRIVING FORCES

To achieve its vision, the forging industry must navigate a dynamic market and business landscape that has been and will continue to be shaped by a number of external driving forces. These forces create both obstacles and opportunities for the forging industry as it pursues its vision. They include:

- **Fluctuating economic & market conditions** – The forging business is sensitive to economic and market conditions that are notoriously unstable, such as energy costs, currency exchange rates, demand driven by financially vulnerable manufacturing sectors (automotive, aerospace, etc.), and metal supply. To cope with unpredictable changes, forging firms are pressured to be more lean, resilient, flexible and adaptable.

- **Accelerated technological change** – Forging is a technology-dependent business that can be drastically affected by scientific breakthroughs and innovation. New advancements can present new threats or new opportunities, making the future less predictable. While this increases the risk attached to R&D investments, obsolescence or simply falling behind remains a constant threat. Forging firms are pressured to be innovative and technologically up-to-date with limited capital resources.

- **Intensified global competition** – For the forging industry, global competition means more than the competition from forging firms in other countries. It refers to all firms and industries that seek to offer an alternative to forged components, including component manufacturers who employ different methods of metal processing (e.g., casting, high speed machining, additive manufacturing technologies, etc.) as well as those who use different materials (e.g., plastics).

- **Increasing customer demand** – Increased customer demand puts a premium on both continuous improvement and continuous innovation. It pressures the industry to produce forged components
that maintain the traditional benefits of strength, reliability, durability, and affordability, while, at the same time, offering new benefits.

**STRATEGIC IMPERATIVES**

Individual forging companies not only compete among themselves, but also as an industry against alternatives to forged metal components. To reach its vision, the forging industry must become stronger and more competitive as an industry. Four strategic imperatives have emerged to meet this competitive challenge.

- **Operational excellence** – This imperative casts a critical eye on the current practices, methods, techniques, and processes of forging. It asks, “What do we currently do and how can we do it better?” The continuous enhancement of operational excellence is the starting place and foundation for becoming stronger and more competitive.

- **Capability development** – This imperative looks behind the activity to the skills, expertise, and know-how that enables the activity—from what we do to what we know. It asks, “What do we currently know and what else could we know in the future?” This is a critical next step in becoming stronger and more competitive, because it speaks to the industry’s ability to adapt and pursue new markets.

- **Collaborative partnerships** – This imperative recognizes that moving toward the vision will require the coordinated participation of multiple stakeholders. It asks, “What could we know and do together?” This imperative represents a shift from an inward to a more outward focus, and is a further step toward becoming stronger and more competitive.

- **Product and market innovation** – The final imperative casts a critical eye on the relationship with customers. It asks, “How well do we serve our customers, how might we serve them better, and who else might we be able to serve?” This imperative represents a more deliberate and systematic customer focus at an industry level; it is the capstone of becoming stronger and more competitive.

**MAJOR CHALLENGES**

Pursuing the strategic imperatives will require the industry to confront several major challenges. The challenges identified at the workshop are organized into seven areas that provide a useful overview of the nature and scope of the issues facing the industry. Consistent with the previous roadmaps, the forging industry faces a number of research and technical challenges involving materials, energy, and forging technology. The industry also faces broader business issues involving labor, government, and the environment, as well as, market issues. The challenges in these areas require the industry to move beyond technical problems and deal with matters of education, perception, and influence.

**ACTION PRIORITIES**

The most critical part of the roadmap is the determination of specific activities that address the major challenges and move the industry along the path toward its vision. The activities identified distinct action agendas in the following areas:

- **Improve market positioning** – Pursue a closer connection to customers; look for ways to collaborate, rather than compete, with forging firms in other countries; and develop business tools that help individual firms deal with market instability

- **Develop current and future workforce** – Continue building strong relationships with educational institutions; strengthen placement opportunities for graduates; develop better
programs to train current and future workers; and execute a serious and sustained recruitment effort to attract and retain talent within all facets of a forging enterprise.

- **Advocate public policy agendas** – Improve the industry’s public image; implement targeted lobbying efforts; and build political influence.

- **Establish industry guidelines and best practices** – Implement a worldwide data-gathering effort to compile a library of best practices; and establish a common set of guidelines around forging operations and outputs.

- **Enhance material options and usage** – Develop better ways to minimize and process material waste in the forging process; and work collaboratively to enhance the range of material options available to the forging industry.

- **Reduce energy costs and inefficiencies** – Find ways to reduce energy-related costs and inefficiency within the forging process.

- **Advance forging technology** – Pursue greater automation of the forging process; develop new lubricants that can improve die life; and generate innovations in the tools, equipment, and process of forging.

**PATH FORWARD**

The path to achieving the forging industry’s bold yet realistic vision is filled with competitive challenges as well as opportunities. Industry-level action that is decisive and strategic will enable the industry to move forward immediately and effectively. The industry has identified a diverse range of research, development, education, and other pursuits that could be undertaken as part of its strategic response. Six actionable items merit the highest priority in achieving the industry’s vision:

<table>
<thead>
<tr>
<th>Highest Priority Activities</th>
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</thead>
<tbody>
<tr>
<td>Build real relationships with high schools, technical colleges, and local communities to develop skilled workers for all facets of the forging enterprise</td>
</tr>
<tr>
<td>Seek government support for energy-saving investments</td>
</tr>
<tr>
<td>Develop a low-cost, highly thermally efficient, environmentally friendly heating source</td>
</tr>
<tr>
<td>Challenge equipment suppliers to bring new technology to industry and FIA/FIERF to identify the most successful</td>
</tr>
<tr>
<td>Benchmark the global industry and competing industries for best practices in enterprise and technological innovation</td>
</tr>
<tr>
<td>Develop improved automation in process sensors</td>
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</tbody>
</table>
For the 2008 Forging Industry Technology Roadmap Update, the vision is to become "a world leader in customer-focused, efficient, and cost-effective supply of high quality components." The roadmap identifies "stronger and more competitive as an industry" as a strategic imperative, focusing on capability development, operational excellence, collaborative partnerships, and product and market innovation.

Key challenges include material issues, energy issues, technology issues, government issues, environment issues, and labor issues.

Action priorities are set to address these challenges, including improving market positioning, advocating public policy agendas, developing current and future workforce, establishing industry guidelines and best practices, enhancing materials options and usage, reducing energy costs and inefficiency, and advancing forging technology.
I. OVERVIEW

INTRODUCTION

In 1997, the Forging Industry Association (FIA) and FIERF worked with the U.S. Department of Energy’s Office of Industrial Technologies (now the Industrial Technologies Program, or ITP) to create the Forging Industry Technology Roadmap. The Roadmap outlined a collaborative industry-wide vision of the future forging industry and presented R&D priorities needed to achieve that vision. In 2003, FIA/FIERF led an effort to update the Roadmap in light of new market realities and the progress that the industry had made toward its vision. To ensure that the industry maintains an up-to-date, proactive, and forward-looking strategy for the future, FIA/FIERF initiated a second update effort in May of 2008. The results of that update effort are presented in this 2008 Forging Industry Roadmap.

VISION

The 1997 roadmap was based on a vision of the future in which the forging industry is a world leader in customer-focused, efficient, and cost-effective supply of high-quality components. This vision was reiterated in the 2003 update of the Forging Industry Technology Roadmap. In 2008, this vision remains as compelling and relevant a destination as it was ten years ago.

DRIVING FORCES

To achieve its vision, the forging industry must navigate a dynamic market and business landscape that has been, and will continue to be, shaped by a number of external driving forces. These driving forces create both obstacles and opportunities for the forging industry as it pursues its vision. They include:

- **Fluctuating economic & market conditions** – The forging business is sensitive to economic and market conditions that are notoriously unstable, such as energy costs, currency exchange rates, demand driven by financially vulnerable manufacturing sectors (automotive, aerospace, etc.), and metal supply. To cope with unpredictable changes and market instability, forging firms are pressured to be more resilient, flexible and adaptable, while maintaining their traditional qualities of reliability, unwavering quality, and cost efficiency.

- **Accelerated technological change** – Forging is a technology-dependent business that can be drastically affected by scientific breakthroughs and innovation. New advancements can present new threats or new opportunities, making the future less predictable. Technological change has a disruptive influence that increases the risk attached to R&D investments, and makes obsolescence or simply falling behind a constant threat. Forging firms are pressured to be innovative, and technologically up-to-date with limited capital resources.

- **Intensified global competition** – For the forging industry, global competition refers to more than the competition from foreign firms—it refers to all firms and industries that seek to offer an alternative to forged components. This includes component manufacturers who employ different methods of metal processing as well as those who use different materials (e.g., plastics). As
traditional competitive advantages erode, the forging industry will experience increasing price pressure and a greater risk of commoditization.

- **Increasing customer demand** – The forging industry must deal with a customer who is more demanding, in terms of price and quality and of new functionalities and applications. Increased customer demand puts a premium on both continuous improvement and continuous innovation. Forgers are pressured to provide components that maintain the traditional benefits of strength, reliability, durability, and at the same time offer new benefits and new functionality.

**STRATEGIC IMPERATIVES**

Attaining the vision amid a landscape shaped by these driving forces is an undertaking that must be pursued by the forging industry as a strategic whole. In today’s globalized business landscape, individual forging companies not only compete among themselves, but also as an industry against alternatives to forged metal components.

To reach its vision, the forging industry must become stronger and more competitive as an industry. Four strategic imperatives have emerged to meet this competitive challenge: operational excellence, capability development, collaborative partnerships, and product and market innovation. These imperatives provide an organizing framework for aligning and cross-leveraging separate action initiatives, and are the subject of Chapter 3.
II. CHALLENGES & ACTIVITIES

This Roadmap informs and facilitates the industry’s path forward by identifying the particular challenges facing the forging industry and determining the range of research, education, and other activities needed to overcome those challenges.

CHALLENGES

Workshop participants identified many challenges the forging industry faces today. A content analysis of these items revealed seven overall challenge areas that provide a useful overview of the nature and scope of the issues facing the industry. The challenge areas, along with the corresponding challenge items, are displayed in Appendix A. These results indicate that the forging industry is facing a broader range of challenges. Consistent with the results of previous roadmaps, the forging industry continues to face specific research and technical challenges involving materials, energy, and the forging process itself. However, the industry also faces broader business matters involving labor, government, and the environment, as well as critical customer and market issues. The challenges in these areas require the industry to move beyond technical problems and deal with matters of education, perception, and influence.

ACTIVITIES

The workshop participants also generated an extensive list of the activities needed to overcome the challenges and move the industry along the path toward its vision. These results are presented in Appendix B. Just as the challenge results show the broad range of issues facing the forging industry, the list of needed activities indicates the diverse range of research, development, education, and other pursuits that could be part of the industry’s strategic response. In particular, the activities identify specific action agendas in the areas listed below. While all of the action agendas represent important priorities for action, six were indicated as having the highest priority. These six appear in italics.

- **Improve market positioning** – How well the forging industry is positioned in the marketplace affects its ability to adapt to changing market conditions and capitalize on new market opportunities. More importantly, market positioning is about expanding the depth and breadth of the demand for forged components. The activities to improve market positioning in the forging industry identify four key action agendas for the forging industry:
  - Pursue a closer connection to customers, including maintaining a better understanding of changing customer needs and actively managing/shaping customer perceptions and understanding of the benefit and role of forged components in the customer’s business.
  - Develop industry capacity to pursue the nuclear power plant construction market.
  - Pursue connections with forging firms in other countries and examine ways to maximize opportunities for collaboration and mutual learning while minimizing the occurrence of direct competitive battles.
  - Develop business tools that help individual firms deal with market instability.

- **Develop future workforce** – The development of the future workforce is an investment in the long-term future of the industry. It is directly related to the industry’s ability to remain technologically current and ensures the capacity and capability to meet future customer demand. It also provides the foundation for developing new and more robust capabilities that enable the industry to expand its market by serving a wider range of customer needs, and determines the quality of technological and product innovation within the industry. The activities to develop the future workforce identify three key action agendas for the forging industry:
➤ *Pursue collaborative relationships with educational institutions.*
- Implement sustained recruitment efforts (especially in schools and universities) designed to attract talent to the industry.
- Work with universities to establish internships and apprentice programs.

- **Develop current workforce** – The development of the current workforce is an investment in the near-term capacity and capability of the industry. It is directly related to the industry’s ability to remain competitive and technologically current over the near-term. It also ensures that the industry is able to maintain quality and productivity standards and meet shifting levels of demand. The activities to develop the current workforce identify two key action agendas for the forging industry:
  - Develop the programs and resources to retrain employees to use new technology and to support improved or redesigned manufacturing processes.
  - Find ways to better retain talented people and expand the labor pool for new hires.

- **Advocate public policy agendas** – Advancement of the industry’s public policy agendas affects the degree to which public policy supports or inhibits the industry’s competitiveness and operational freedom. In particular, it influences the level of regulatory control and administrative bureaucracy with which forging firms must contend. It also affects the level of government support and funding directed to R&D efforts that could benefit the forging industry. The activities to advance public policy agendas identify two key action agendas for the forging industry:
  - *Develop a focused political strategy to build influence and execute targeted lobbying efforts.*
  - Implement a public relations effort to raise awareness and improve the industry’s public image.

- **Establish industry guidelines and best practices** – The establishment of industry guidelines and best practices will enhance the industry’s overall level of performance, and in turn its reputation for both quality and efficiency. Established guidelines and best practices also provide a basis for improving communication, collaboration, and trust with both suppliers and customers. Equally important, they are a necessary requisite for developing robust, world-class capabilities that can sustain a competitive advantage in the global marketplace. The activities to establish industry guidelines and best practices identify two key action agendas for the forging industry:
  - *Implement a worldwide data gathering effort to compile a library of best practices for selected issues or operations (e.g., automation).*
  - Establish, communicate, and build buy-in for a common set of guidelines around forging operations and outputs.

- **Enhance material options and usage** – Materials represent a significant cost factor in forging operations and have a direct link to the bottom line profitability of the forging industry. At the same time, materials are a significant factor in determining the properties and functionality of forged components. Material options and usage, therefore, also affect the industry’s potential for product innovation and its ability to provide new benefits to customers and pursue new markets. The activities to enhance material options and usage identify three key action agendas for the forging industry:
  - Develop better ways to minimize and process material waste in the forging process.
  - Work within the supply chain to improve efficiency in material logistics.
  - Work through partnerships and collaborative efforts to enhance the range of material options available to the forging industry.
- **Reduce Energy Costs & Inefficiencies** – Energy, particularly as it is used in heating material for forged components, is another significant cost factor in forging operations. Energy inefficiencies adversely affect bottom-line profitability and make the industry more vulnerable to unstable energy prices. Efficient energy usage could help reduce the industry’s adverse environmental impact. The activities in this area expressed a single agenda:
  - *Find ways to reduce costs and inefficiency around the use of energy within the forging process, including developing better heating systems, using alternative energy sources, maintaining better control, and improving energy management of forging operations themselves.*

- **Advance Forging Technology** – The technological enhancement of the forging process itself continues to be an important part of the industry’s path into the future. On the one hand, it is an avenue by which the industry may pursue continuous improvement in quality and productivity, and achieve cost reduction goals. On the other hand, technological enhancement of the forging process may also lead to new capabilities and the ability to meet new customer needs. The activities in this area identify three key technology agendas for the forging industry:
  - *Pursue greater automation of the forging process.*
  - *Pursue innovations in the tools, equipment, and process of forging.*
  - Develop new tool materials and invoke process modeling to extend die life.
  - Develop new lubricants that can improve die life.
HIGHEST PRIORITIES

As stated above, each action agenda represents an important priority for action, although six were identified as having the highest priority. For each of these six action agendas, there is a single activity item that stands out as a more specific focus and starting place for implementation. The top priority action agendas with the corresponding activity items are shown below (see Appendix B for the complete list of activity items).

<table>
<thead>
<tr>
<th>Top Priority Action Agenda</th>
<th>Specific Activity Item</th>
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<tbody>
<tr>
<td>Pursue collaborative relationships with educational institutions</td>
<td>➔ Build real relationships with high schools, technical colleges, and local communities</td>
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<tr>
<td>Develop a focused political strategy to build influence and execute targeted lobbying efforts</td>
<td>➔ Seek government support for energy-saving investments</td>
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<tr>
<td>Find ways to reduce costs &amp; inefficiency around the use of energy within the forging process</td>
<td>➔ Develop a low-cost, highly thermally efficient, environmentally friendly heating source</td>
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<tr>
<td>Pursue innovations in the tools, equipment, and process of forging</td>
<td>➔ Challenge equipment suppliers to bring new technology to industry and FIA/FIERF to identify the most successful</td>
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<tr>
<td>Implement a worldwide data gathering effort to compile a library of best practices</td>
<td>➔ Benchmark the global industry and competing industries for best practices in enterprise and technological innovation</td>
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<tr>
<td>Pursue greater automation of the forging process</td>
<td>➔ Develop improved automation in process sensors</td>
</tr>
</tbody>
</table>
III. STRATEGIC IMPERATIVES

Examination of the identified priority activities reveals four strategic imperatives that cut across the different categories. These imperatives provide an organizing structure that can guide action initiatives to directly aid in achieving the Roadmap vision. Together, the imperatives define a strategy to become stronger and more competitive as an industry.

FOUR STRATEGIC IMPERATIVES

- **Operational Excellence** – Action items show a push toward higher levels of operational excellence by improving productivity and efficiency, and reducing costs, waste, and environmental impact. Operational excellence reflects a strategic mindset in which the industry casts a critical eye on the current practices, methods, techniques, and processes of forging. It asks “What do we currently do and how can we do it better?” To meet the competitive challenge, operational excellence must be pursued at the industry level as well as the firm level. The continuous enhancement of operational excellence is the starting place and foundation for becoming stronger and more competitive.

- **Capability Development** – Action items also indicate a need to develop and expand capability, both at the industry and firm levels, through workforce development, best practices, technology development, and the pursuit of new markets. Capability development reflects a strategic mindset in which the industry looks behind the activity to the skills, expertise, and know-how that enable the activity. It asks “What do we currently know and what else could we know in the future?” This is a critical next step in becoming stronger and more competitive because it speaks to the industry’s ability to adapt and pursue new markets. New capabilities that are hard to imitate enable a sustainable competitive advantage.

- **Collaborative Partnerships** – Action items reveal a need to engage in more collaborative partnerships. Moving toward the vision will require the coordinated participation of multiple stakeholders, including government agencies, academic institutions, customers, suppliers, and even competitors. With both operational excellence and capability development, the focus tends to be inward, with the industry examining itself. Collaborative partnership, on the other hand, reflects a strategic mindset that is more outward looking. It asks “What could we know and do together?” This is another critical step toward becoming stronger and more competitive because it allows for more than a purely adversarial conception of business. Government is seen as a research partner rather than indifferent regulator. Foreign firms are seen as potential allies rather than just potential threats.

- **Product & Market Innovation** – Action items show a push toward developing a more deliberate and systematic customer focus at an industry level. Product and market innovation reflects a strategic mindset in which the industry casts a critical eye on the relationship with customers. It asks “How well do we serve our customers, how might we serve them better, and who else might we be able to serve?” This is the capstone of becoming stronger and more competitive. It recognizes that value is defined by the customer and that what customers desire is always subject to change. To understand and serve migrating customer needs, an industry must be able to reinvent both its product and the relationship it has with its customers.

SUMMARY

The four strategic imperatives provide a dynamic guide to align industry efforts. Operational excellence and capability development establish the competitive identity of the industry. This, in turn, provides the
basis for building collaborate partnerships that leverage what the industry knows and can do. Competence, capability, and partnerships are deployed with and through product and market innovation to enhance the strength and competitiveness of the forging industry in meeting the needs of current and future customers.

**Stronger and more competitive as an industry**

Together, these imperatives elaborate and clarify what it will take for the forging industry to become stronger and more competitive as an industry. They also provide an organizing framework that shows how different activities fit together.
IV. IMPLEMENTATION

INTRODUCTION
An industry roadmap is an organizing framework for strategic action at an industry level. It is designed to stimulate and focus industry action, enroll and engage stakeholders and potential partners, attract resources, and facilitate the recognition and realization of emergent opportunities. Good roadmaps are both practical and inspiring.

IMPLEMENTING THE CURRENT ROADMAP
There is no one right way to implement a roadmap and no two roadmaps are ever implemented in exactly the same way. Roadmaps are designed to be robust documents that offer a wide range of options for implementation. In fact, any activity, project, or event; any new learning, discovery, or innovation; and any new relationship, meeting of the minds, or deepening of mutual understanding, may be considered implementation if it moves the industry along the path toward the vision.

Below is a list of different ways in which this Roadmap may be used or implemented. It is not an exhaustive list, nor is it a to-do list. Effective implementation may involve any of these options, but certainly not all. This list is offered to stimulate ideas and facilitate the recognition of opportunity when it presents itself.

Reframing & refocusing industry – The results suggest that moving toward the industry vision will require new ideas, new ways of thinking, and new frames of reference. Such a change is likely to come against traditions, implicit assumptions, and entrenched ways of thinking that have developed over a long period of time. This roadmap could be used to enable dialogues—especially among industry leaders—that help the industry to question assumptions and discover new insights.

Building coalitions, relationships, etc., with stakeholders – Collaboration and partnerships are important to achieving the Roadmap vision. This Roadmap presents a clear and practical picture of the industry’s vision and path forward. It could be used to establish common understanding and alignment of interests that is the basis for effective partnerships.

Communication & promotion of industry value and needs – Past experience has shown that opportunities and support can come from unexpected sources. Beyond building relationships with specific stakeholders, the industry may also want to promote and market itself in a more general way in order to attract resources. This Roadmap presents a message that is both practical and inspiring; it could be a valuable addition to any promotional effort.

Decision-making – Moving forward will require decisive choices about allocation of resources, the priorities for action, and so on. Conversely, action can be stalled if such decisions fail to get made. Industry-level action cannot occur without industry-level decisions. This Roadmap offers frameworks, insights, and concrete information that can used to enable dialogues and facilitate common understanding that lead to concrete decisions.

Establishing metrics – It is difficult to manage what you cannot measure. Action is always more likely to occur and be effective when it is supported by metrics. This Roadmap presents a cogent framework that links concrete action items to the industry vision. It therefore provides a basis by which to identify success criteria and develop metrics to evaluate and guide industry-level action.

Implementing specific projects – This Roadmap is, first and foremost, an action planning tool. The activities, action priorities, and strategic imperatives provide an effective basis for designing and executing individual projects, programs, or action initiatives.
It is important to keep in mind that steps forward can be the product of both intention and serendipity. Implementation should strike a balance between stimulating action via a prescriptive action plan and stimulating action via attracting resources and facilitating emergent opportunities.

**CLOSING WORDS**

The forging industry has a bold and promising vision of the future. Although the journey may currently seem particularly uncertain and difficult, this roadmap suggests that a “circling of the wagons” is not the path forward. Rather, the time is right for the industry to step up to the competitive challenge and move forward with decisive and strategic action.
## APPENDIX A: COMPLETE SET OF CHALLENGES FACING THE FORGING INDUSTRY

### MARKET ISSUES
- Increasing global competition; increasing gap on skilled labor (very lean technical staff relative to Japan/Germany); advancing worldwide technology; and loss of technology leadership (equipment, automation, maintenance)
- Eroding customer perceptions (e.g., perception of forgings as commodities, not solutions; industry lacks vision and solutions, especially for large forgings; perception of high cost; etc.)
- Slow down of market and potential over capacity (domestic and global)
- Increasing competition from other product forms (e.g., casting, machining, machined parts from plate, etc.) as they close the gap on strengths of forging process
- Changes in strength of U.S. dollar
- Dependence on airline industry that is not healthy
- Market instability and unpredictability due to market bubbles/booms (e.g., wind power, ethanol)
- Diminishing connection with customers and diminishing knowledge, understanding, experience regarding forging (e.g., perfect vs. practical quality); less appreciation/recognition of advantages of forging
- Increasing competition from other materials

### LABOR ISSUES
- Recruiting and retaining technical expertise to our Forging Industry Association
- Lack of people wanting to work in manufacturing jobs
- Increasing shortage of experienced and technically skilled staff, especially re Germany/Japan (e.g., experienced engineers, technical and metallurgical talent, tool designers)
- Technology advancing faster than education and training; lack of adequate technical training programs/materials needed to upgrade/maintain technical workforce; educational systems lack apprenticeships for skilled trade
- Attracting metallurgical talent into the industry
- Marketing manufacturing as a worthwhile career
- Limited exposure to our industry in schools, starting in high school (schools/formal education is deficient in both exposure and skill development)
- Lack of support skills and good front-line supervisors with technical backgrounds
- Need for training to reduce work place injuries
- Increasing labor costs leading to higher overall manufacturing costs (both manual and technically experienced labor)
- Rising health care costs
<table>
<thead>
<tr>
<th>TECHNOLOGY ISSUES</th>
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<tbody>
<tr>
<td>- Improving energy efficiency of heating</td>
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<tr>
<td>- Reducing costs through improved material use, heating, and die life</td>
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<tr>
<td>- Reducing labor costs through automation</td>
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<tr>
<td>- Forging die wear</td>
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<tr>
<td>- Availability of thermophysical property data</td>
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<tr>
<td>- Developing intelligent sensors for processes</td>
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<tr>
<td>- Need for improved sensor technology</td>
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<td>- Ensuring forgers have the correct equipment for future requirements</td>
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<tr>
<td>- Designing safety systems into forging systems</td>
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<tr>
<td>- Driving innovation in the midst of global ownership and global competition</td>
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<tr>
<td>- Temperature measurement</td>
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<tr>
<td>- Shortening pre-teat times</td>
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<tr>
<td>- Achieving higher strength at lower weights</td>
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<tr>
<td>- Magnetic processing to alter phase diagram</td>
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<tr>
<th>MATERIALS ISSUES</th>
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<tbody>
<tr>
<td>- Rising material costs (steel &amp; other raw materials)</td>
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<tr>
<td>- Need for a new class of steels with lower alloy content but higher properties than presently obtainable</td>
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<tr>
<td>- Limited availability of some materials</td>
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<tr>
<td>- Dependence on steel and lack of less expensive alternative materials</td>
</tr>
<tr>
<td>- Increasing demand for different alloys (rather than steel)</td>
</tr>
<tr>
<td>- Significant void in materials research that was done by suppliers in the past</td>
</tr>
<tr>
<td>- Process inefficiencies in use of materials; too much waste</td>
</tr>
<tr>
<td>- Logistics infrastructure</td>
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<table>
<thead>
<tr>
<th>ENERGY ISSUES</th>
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<tbody>
<tr>
<td>- Rising energy costs (e.g., cost of gas, heating costs)</td>
</tr>
<tr>
<td>- Process/production inefficiencies in use of energy and lack of knowledge regarding efficient energy use (e.g., optimum forging temperature to reduce heating costs)</td>
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<tr>
<td>- Energy inefficiencies due to boom time</td>
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<tr>
<th>GOVERNMENT ISSUES</th>
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<tbody>
<tr>
<td>- Low U.S. government recognition/understanding of manufacturing needs and the importance and value of manufacturing; lack of U.S. government support and alignment with goals of industry</td>
</tr>
<tr>
<td>- Controlling intellectual property; too much U.S. technology going to Asia</td>
</tr>
<tr>
<td>- Government legislation, policies, regulations, trade agreements, etc. that have an adverse impact on forging industry (domestic investment, cost &amp; efficiency, ability to compete globally)</td>
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<thead>
<tr>
<th>ENVIRONMENTAL ISSUES</th>
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<tbody>
<tr>
<td>- Creating a “Green” working environment and reducing adverse environmental impact inherent in current forging process</td>
</tr>
<tr>
<td>- Decreasing tolerance and increasing scrutiny by government, environmental groups, and general public (e.g., environmental and climate change legislation, limits in use of coal, etc.)</td>
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<tr>
<td>- Cost burden of reducing adverse environmental impact inherent in current forging process</td>
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## APPENDIX B: COMPLETE SET OF RESEARCH, EDUCATION, AND OTHER ACTIVITIES NEEDED TO OVERCOME THE CHALLENGES

(Note: highest priority activities are in **bold**)

### IMPROVE MARKET POSITIONING
- Create a government-industry partnership to support investments needed to provide large castings to nuclear power industry
- Access technology roadmaps from other countries and identify opportunities to collaborate (versus compete)
- Educate customers about benefits of forging
- Develop and conduct ongoing customer training (e.g., forging design seminars) to improve forging design and purchase
- Keep in touch with customers
- Develop a method to track and forecast industry business cycles
- Develop alternative supply chains to balance business cycles across segments
- Re-position forgings as a part of the total product cost, not a commodity
- Facilitate cooperation among all segments of forging industry to create domestic capability and capacity to supply massive forgings (600–6,000 ton forgings) for new nuclear construction
- Determine methods to safely use low-cost foreign competition instead of competing with them

### DEVELOP FUTURE WORKFORCE
- **Build real relationships with high schools, technical colleges, and local communities**
- Encourage high school to teach basic trade skills (e.g., “metal shop”)
- Pursue industry/university joint development projects that put students in the field
- Establish partnerships between businesses and schools to create apprentice programs
- Create college and professional internships
- Work with universities and technical schools to improve education quality
- Explain career opportunities in forging industry to young people at younger age
- Conduct organized industrial engineering co-ops and summer programs to develop future workforce
- Sponsor scholarships and expand project opportunities for student engineers
- Create more defined technical engineering functions
- Cooperate with JVS to train/teach “forging”
- Take a forging “road show” to the high schools
- Conduct national recruitment drive (e.g., “Got forgings?”)
- Promote our industry at JVS/high school

### DEVELOP CURRENT WORKFORCE
- Evaluate present FIA education/training strategy
- Pursue ergonomic safety solutions to improve working conditions and enhance long-term retainment of labor
- Recruit foreign engineers to fill technical labor needs
- Develop/enhance training for forging workforce, including virtual training (e.g., 3-D modeling), activity-specific training programs, training on tooling failure to reduce cost
- Collaborate with other technology societies on training (e.g., ASM)
- Pursue vendor/supplier partnering to secure technical training by the supplier
<table>
<thead>
<tr>
<th><strong>ADVOCATE PUBLIC POLICY AGENDAS</strong></th>
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<tbody>
<tr>
<td>- Seek government support for energy-saving investments</td>
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<tr>
<td>- Promote increased emphasis on math and science education as national priority</td>
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<tr>
<td>- Conduct research and develop publications explaining forging advantages</td>
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<tr>
<td>- Pursue public awareness campaign (e.g., “Got Forged?”), promoting forging’s role in enabling all kinds of energy production, the fact that forgings are part of 20% of all products in the economy, etc.</td>
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<tr>
<td>- Identify government officials that support manufacturing business and the forging industry and promote their election or re-election</td>
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<tr>
<td>- Develop &amp; implement focused lobbying initiatives to eliminate unfair trade practices, update GAAP to be manufacturing favorable, reduce amount of “green” regulations and open available energy resources, reduce healthcare costs</td>
</tr>
<tr>
<td>- Educate public on value of domestic mining and domestic offshore oil and gas exploration</td>
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<tr>
<td>- Develop strategies to address future potential for climate change legislation and CO2 minimization (e.g., high-efficiency combustion, nuclear energy, high-efficiency electric heating)</td>
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<tr>
<td>- Educate elected officials</td>
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<tr>
<th><strong>ESTABLISH INDUSTRY GUIDELINES &amp; BEST PRACTICES</strong></th>
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<tbody>
<tr>
<td>- Benchmark the global industry and competing industries for best practices in enterprise and technological innovation</td>
</tr>
<tr>
<td>- Learn from equipment/ automation practices in other countries (e.g., Germany, Japan, etc.)</td>
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<tr>
<td>- Form “strategic alliances” to identify &amp; establish best practices within non-competitive companies from around the globe</td>
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<tr>
<td>- Identify pros and cons of hot, warm, and cold forging by application and share best practices</td>
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<tr>
<td>- Develop means of calculating (predicting) minimum (lowest cost) heating times</td>
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<tr>
<td>- Determine guidelines regarding optimum forging temperatures to ensure optimal energy use</td>
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<tr>
<td>- Consider creating forging standards (e.g., ISO standard, application protocol for product data, etc.)</td>
</tr>
<tr>
<td>- Ensure equipment manufacturers are aware of and meeting forging industry requirements/standards</td>
</tr>
<tr>
<td>- Build on recent safety survey to identify best practices</td>
</tr>
<tr>
<td>- Develop better understanding of overall cost of production and establish cost benchmarks</td>
</tr>
<tr>
<td>- Develop guidelines regarding the lowest-cost material for the application (balance alloys for carbon and cost)</td>
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<tr>
<th><strong>ENHANCE MATERIAL OPTIONS &amp; USAGE</strong></th>
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<tr>
<td>- Reduce metal losses (e.g., flash) in die forging process</td>
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<tr>
<td>- Collaborate with customers to find alternative, lower alloy materials to reduce cost</td>
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<tr>
<td>- Establish a scrap cooperative</td>
</tr>
<tr>
<td>- Work with American Iron and Steel Institute to determine true ultimate strength of materials to optimize use of expensive alloying elements</td>
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<tr>
<td>- Reduce material waste in the supply chain</td>
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<tr>
<td>- Implement synchronized material sourcing</td>
</tr>
<tr>
<td>- Integrate steel mills with forging processes</td>
</tr>
<tr>
<td>- Develop alternatives to higher alloys to reduce surcharge cost for both scrap and alloy</td>
</tr>
<tr>
<td>- Develop higher-strength, lower-weight materials</td>
</tr>
<tr>
<td>- Develop additional materials that allow forgers to eliminate heat treatment</td>
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## Reduce Energy Costs & Inefficiencies

- Develop a low-cost, highly thermally efficient, environmentally friendly heating source
- Optimize the heating of the material (process, temperature, and efficiency)
- Use alternative energy as a means to reduce energy costs
- Partner with energy suppliers to create more efficient heating
- Encourage capital investment in new technology, including technologies to reduce energy consumption
- Develop more efficient heating and furnace systems
- Develop technologies to recover and utilize low-grade and high-grade waste heat
- Direct industry and government funds towards R&D in heating systems that can reduce energy costs
- Conduct energy audits
- Develop open access to natural resources to reduce energy costs

## Advance Forging Technology

- Challenge equipment suppliers to bring new technology to industry and FIA/FIERF to identify the most successful
- Develop improved automation in process sensors
- Pursue automation to reduce labor costs (employee-free forging)
- Reduce time from design to final forged product (“art to part”)
- Apply nano-coatings for die life improvement
- Improve burner design to lower emissions (CO/CO2/NOx)
- Improve robotics technologies and their application to forging processes
- Improve diagnostics to reduce maintenance
- Eliminate need for lubricants
- Develop longer-life die materials (especially for hammers)
- Develop direct quenching and controlled cooling treatment
- Develop affordable retrofit innovations to improve existing technology
- Develop new coating systems to improve die life
- Reduce die costs by using alternative die lubricants
- Pursue methods to reduce carbon footprint
- Improve environmental performance by automation of lubricant application
- Develop near net shape capability to reduce material and energy costs
APPENDIX C: SAMPLE OF COMPLETED PROJECTS

2000-2007 - See FIA Website for reports

An Investigation of the Proper Hot Forging Temperatures for Various Steel Grades, Colorado School of Mines, Finkl Challenge Grant

Application of Advanced Die Materials and Lubrication Systems for Reduction of Die Wear in Warm and Hot Forging, Collaborative Project headed by Ohio State University

Application of Intelligent Component Evaluation to the Design of RSP Tooling, Cleveland State University, Finkl Challenge Grant

| Application of Rapid Infrared Heating for Processing of Aluminum Forgings, Oak Ridge National Laboratory |
| Application of Subtractive Rapid Prototyping for RSP Tooling, Cleveland State University, Finkl Challenge Grant |

Best in Class Practices of Forging Design and Process Simulation Program, Forging Defense Manufacturing Consortium

Characteristics of Materials Used for Forging Dies and Surface Modification Techniques to Extend Die Life, Precision Forging Consortium

Characterization of Internal Defects in Open Die Forgings, Colorado School of Mines, Finkl Challenge Grant

Comparison of Mechanical Properties in V and V+Nb Forging Steels, Colorado School of Mines, Graduate Fellowship

| Design of Robust Temperature Specifications for Billet Induction Heating, Pennsylvania State University, Graduate Fellowship |
| Development of Hybrid Rapid Infrared Furnace for Treatment of Aluminum Alloys, Ohio University, Finkl Challenge Grant |

Development of Hybrid Rapid Infrared Superheating Furnace, Oak Ridge National Laboratory

Development of Next Generation Heating System for Scale Free Steel Reheating, Department of Energy

Diagnostics and Control of Natural Gas Fired Forging Heat Treat Furnaces via Flame Image Analysis, University of Missouri
The Effect of Forging on the Tensile Properties and Microstructure of Magnesium Alloys, Case Western Reserve University, Graduate Fellowship

Effect of Nickel Content on Thermal Processing and Grain Growth Characteristics of 4330 Alloys, Illinois Institute of Technology, Graduate Fellowship

Effect of Prior Microstructure and Heating Rate on Austenite Formation Kinetics in Three Steels for Induction Hardened Components, Colorado School of Mines, Graduate Fellowship

Effect of Prior Microstructure on Austenite Decomposition and Associated Distortion, Illinois Institute of Technology, Finkl Challenge Grant

The Effects of Prior Microstructure on Spheroidizing Treatments for Enhanced Cold Forgeability, Colorado School of Mines, Graduate Fellowship

Experimental Investigation on the Use of Welded Preforms to Produce Novel Forgings, Marquette University, Finkl Challenge Grant

Fatigue Performance Comparison and Life Prediction of Forged Steel and Ductile Cast Iron Crankshafts, University of Toledo

Fatigue Performance of Forged vs. Competing Process Technologies: A Comparative Study of Steering Knuckles, University of Toledo

Flow Stress Measurement, Rensselaer Polytechnic Institute, Graduate Fellowship

Forging Process Monitoring and Control through Feature Extraction of Tonnage Signals, University of Michigan, Graduate Fellowship

Heating Response of Different Starting Microstructures and Their Relationships with Important Forging Process Parameters, Colorado School of Mines, Finkl Challenge Grant

HotEye™ Automatic Inline Surface Inspection System for Steel Rod and Bar, OG Technologies

Hybrid Infrared Forging Stock Heating System, Oak Ridge National Laboratory

Improving Fatigue Performance of Aluminum Alloy Forgings using Rapid Infrared Thermal Processing, Ohio University, Finkl Challenge Grant

Infrared Heating of Forging Billets and Dies, Oak Ridge National Laboratory

Innovative Die Material and Lubrication Strategies for Clean and Energy Conserving Forging Technologies, Ohio State University, Finkl Challenge Grant
Innovative Rapid Tooling Technology, Forging Defense Manufacturing Consortium

Investigation of Friction Measurements at CSM for Hot Steel Forging Applications, Colorado School of Mines, Finkl Challenge Grant

Investigation of Workability & Mechanical Properties of Welded Preforms, Marquette University, Graduate Fellowship

Material & Energy Optimization of the Ring Gear Forging Process, Ohio University, Finkl Challenge Grant

MPLUS Program to Determine When Phase Change Occurs on Heating of Large Billets, Oak Ridge National Laboratory

Scholarships The Foundation has awarded 65 Finkl Scholarships since the program began in 2004. These students have gone on to graduate school and to find employment in the forging, steel and customer industries.

Sensor-based Prognostics and Predictive Control for Hot Deformation Processes, Collaborative Project headed by University of Michigan

SmartSmith System to Check Surface Quality and Dimension of Hot Forging in a Closed Loop Control System, OG Technologies

Stress Analysis and Optimization of Crankshafts Subject to Dynamic Loading, University of Toledo

Study of Premium H-13 for Improved Toughness and Temperature Resistance, Rensselaer Polytechnic Institute, Finkl Challenge Grant

Tempering Behavior of Hot Forging Die Steels, Colorado School of Mines, Finkl Challenge Grant

Use of Nano Testers to Evaluate the Surface Mechanical Properties of Hot Forging Die Steels, Colorado School of Mines, Finkl Challenge Grant