

Forging Industry Technology Roadmap

2022 Revision

November 29, 2022



Sponsored by:



Forging Industry Association (FIA)
**Forging Industry Educational and
Research Foundation (FIERF)**

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TABLE OF CONTENTS

Executive Summary	4
I. Overview.....	7
Introduction	7
Vision	7
Driving forces.....	7
Strategic Imperatives	8
II. Challenges & Activities	9
Challenges	9
Activities	9
Highest Priorities.....	11
III. Strategic Imperatives	13
Four Strategic Imperatives	13
Summary	14
IV. Implementation	15
Introduction	15
Implementing the Current Roadmap	15
Closing Words.....	15
Appendix A: Complete Set of Challenges Facing the Forging Industry	16
Appendix B: Complete Set of Research, Education, and Other Activities Needed to Overcome the Challenges	18
Appendix C: Link to Completed Projects.....	20

EXECUTIVE SUMMARY

The forging industry has achieved an essential place in the North American 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 fatigue life and fracture toughness are critical for human and equipment safety considerations. Despite the fact that these industries have come to depend on it as a key supplier, the North American 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 recast foundation of that workshop formed the basis for the *2008 Forging Industry Technology Roadmap Update*, the *2016 Roadmap Update*, and *this 2022 Roadmap Revision*.

The 2022 Roadmap Revision redefines 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 2022 Roadmap Revision.

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, 2008, and 2016 updates. In 2022, the industry's original vision remains: **a future in which the North American 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:

- **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.
- **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.
- **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, as well as supply chains, that seek to offer an alternative to domestic forged components, including component manufacturers who employ different value-added strategies as well as different methods of metal processing (e.g., casting, high speed machining, additive manufacturing technologies, etc.) and 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 offering new benefits.

STRATEGIC IMPERATIVES

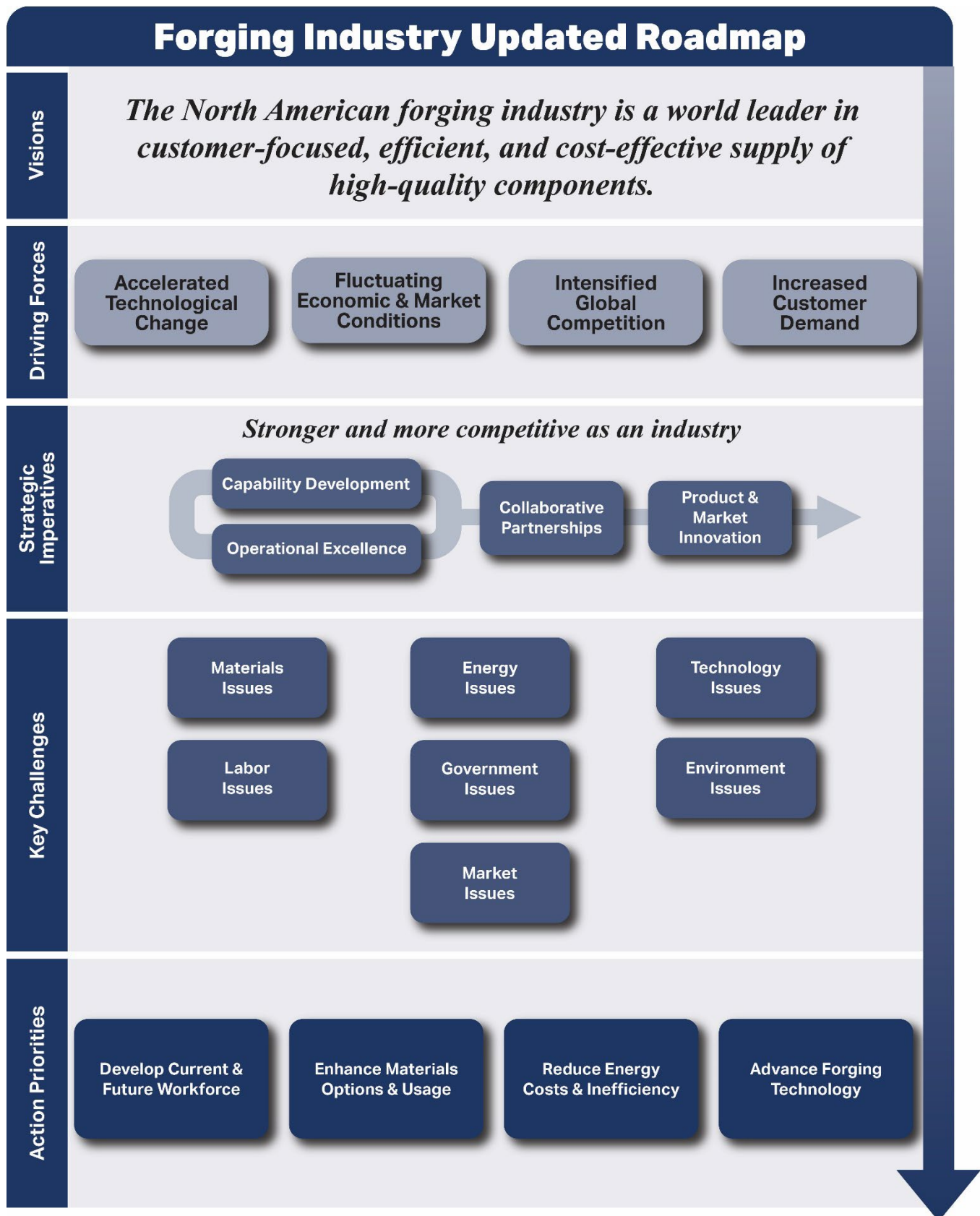
Individual forging companies not only compete among themselves, but also as an industry against alternatives to forged metal components. To reach its vision, the forging industry must become stronger and more competitive *as an industry*. Four strategic imperatives have emerged to meet this competitive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

- **Operational excellence** –Improving 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 more competitive.
- **Capability development** –Looking 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 more competitive because it speaks to the industry’s ability to adapt and pursue new markets.
- **Collaborative partnerships** –Represents a shift from an inward to a more outward focus moving toward a vision which will require the coordinated participation of multiple stakeholders. It asks, “What could we know and do together?”
- **Product and market innovation** –Focusing 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.

MAJOR CHALLENGES

Pursuing the strategic imperatives will require the industry to confront several major challenges. The challenges 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 several research and technical challenges involving materials, energy, and forging technology. The industry also faces broader business issues involving labor, government, the environment, 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.

Figure 1: Roadmap Structure & Content



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 updated the roadmap in 2008 and 2016. This 2022 update to the Roadmap encompasses the changing environment due to global trade and technological advancement.

VISION

The 1997 roadmap was based on a vision of the future in which *the North American forging industry is a world leader in customer-focused, efficient, and cost-effective supply of high-quality components*. This vision was reiterated in the 2003/08/16 update of the *Forging Industry Technology Roadmap*.

DRIVING FORCES

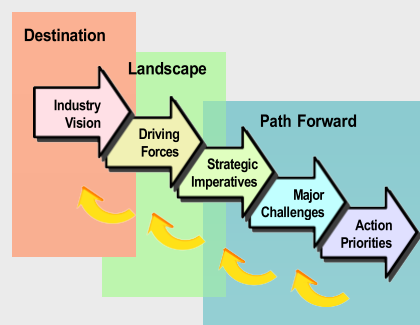
To achieve its vision, the forging industry must navigate a dynamic market and business landscape that has been, and will continue to be, shaped by a number of external driving forces. These driving forces create both obstacles and opportunities for the forging industry as it pursues its vision. They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

- **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.
- **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.

Purpose of an Industry Roadmap

An industry roadmap is an organizing framework for strategic action at an industry level. Roadmaps are based on a logic that allows an industry's vision of the future to be linked to concrete action in the present.

Within the overall structure of a roadmap, the vision provides the destination. The driving forces describe the terrain, strategic imperatives, major challenges, and key activities mapping out the best path to the destination.



A roadmap is based on the input of experts and leaders, both inside and outside of the industry. A completed roadmap represents the industry's collective wisdom about how it should position itself for the future. An industry roadmap enables the future by inspiring participation, attracting external resources, and stimulating and focusing action.

- **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).
- **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-public partnerships, and product and market innovation.**

II. CHALLENGES & ACTIVITIES

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

CHALLENGES

Our membership has identified many challenges the forging industry faces today. A content analysis of these items revealed 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 FIA Technical Committee reviewed and updated the extensive list of 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, these areas were indicated as having the highest priority.

- **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:
 - Expand/personalize our 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 projects, 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.
- **Enhance Material Options and Usage** – Materials represent the most 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 optimize 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 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 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 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 key technology agendas for the forging industry:
 - Research/Analyze emerging technologies that impact forging process and product. (i.e., Additive Manufacturing/3D Model/Print)
 - Pursue innovations in all aspects of the forging process, as well as the processes and logistics of the entire supply chain.

HIGHEST PRIORITIES

As stated above, each action agenda represents an important priority for action. The FIA Board of Directors and FIERF Board of Trustees came up with key drivers of change for the industry based off the environmental scan developed during Strategic Planning in early 2022 (See Appendix A). Key drivers of change are powerful forces that necessitate FIA to develop strategies to address. They are conditions and dynamics in the relevant environment that will make tomorrow very different than today.

FIA-FIERF Key Drivers:

1. Labor shortages due to less young entrants in the industry
2. Automation: increase shop safety, quality improvement; major robotics and AI focus
3. Technology development
4. Changes at all levels of government that impact trade, energy and environmental policies, skilled labor
5. Generational shifts in education and work experience
6. EVs, extinction of the internal combustion engine, government mandate
7. Dramatic restriction of trade; unfair trade practices
8. Global destabilization; fear of world change/unrest; cybersecurity; conflict/competition with China
9. Increased quality requirement, traceability, Industry 4.0
10. Competitive technologies advancement: 3D, additive, powder
11. Equipment & technology coming from outside North America
12. Post-COVID: changes temporary or permanent? E.g., remote work
13. Supply chain importance & need to educate
14. Physical vs. mental & other stressors
15. Overall labor: trend of mfg. plants moving to rural areas
16. Pace of tech & materials development
17. Lightweighting everything!
18. Labor expectation: this is how I will work for you
19. Geographic boundaries are a non-issue.
20. Culture and buy-in
21. Environment/sustainability; ESG – Environment, Social, Corporate Governance

Key Driver of Change	Implications for Industry	Implication for FIA
Lack of labor	Automation; focused degrees. competition for labor between members; consolidation increases	Revenue and engagement Loss of members
Working longer/longevity	Jobs less strenuous Job share/flex More contractors	New member benefits from AARP Nursing independents
Birthrate	Fewer young entrants	Fewer members
Automation	Different skilled labor	New training programs Less to train More virtual training
Politics - Trade - Energy - Fiscal - Environmental	More demand Higher pricing Higher costs	Workforce development Need for policy advocacy More fundraising
	Lower demand Lower pricing Lower costs	More trade organization collaboration
Technology	Lower cost	Fewer members Focus on technology development
	Lower demand	Fewer members Focus on technology development
	Higher demand	More financial support Focus on technology development
	Different talent qualifications	Need workforce development Focus on technology development
	Lower prices	Focus on technology development
Policy Makers	Make or break	Make or break Must engage
Population shifts (workforce)	Shift from US Shift towards automation	Extinction Reduced Workforce and/or higher level of training – mid-high-level positions
Electric Vehicles	Profound	Evolve or perish
Trade	Supply disruption Growth	Conflicted position Reg more advocacy Attract members
Workforce	Brain-drain Shortage	Opportunity to rally the membership
Fear – World Activities • Change • Unrest	Forge plant consolidations Paralysis	Impact membership Lack of engagement
Opportunity • Reacting to our fears	Expansion/Investment Tech development to be world players Not separate entities	Advanced Training Stronger World presence Galvanizing membership

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 collaborative 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. Create challenging 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 a clear and practical picture of the industry's vision and path forward. Establish common understanding and alignment of interests that are the basis for effective partnerships.

Communication & promotion of industry value and needs – 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.

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 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, 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

During its strategic planning in early 2022, the FIA Board of Directors and the FIERF Board of Trustees did an environmental scan of the forging industry. Below you will find statements from the group on the conditions, trends, and assumptions for each challenge facing the forging industry.

Demographics:

1. There will continue to be a shortage of skilled and unskilled labor
2. There will continue to be a decreased interest in manufacturing careers
3. Global sourcing will continue to grow
4. Too many in 4-year schools
5. There will be an increase in female employees, in shop floor positions, engineering and elsewhere
6. Urbanization will continue
7. There will be greater cooperation regionally to solve workforce development challenges
8. Protectionist attitudes will continue
9. People will have an increased lifespan and will be working longer, even into their 80's
10. There will be a population downturn
11. As automation reduces physical strain on the workforce, it allows existing workers longer careers
12. There will be continued changes who you hire, such as software engineers
13. Humanoid robots – collaborative AI

Business/Economic Climate:

1. In the short term, demand is growing and there is a need to increase hiring while the business climate is positive
2. Longer term hiring
3. Short term: low-intermediate skill; longer term – 4-year degree etc.
4. Increased fracking activity will continue to drive demand in the energy sector: stable for now, but uncertain in the future
5. There will be increased nationalistic trade policies that will impact global trade, emphasis on regional supply chains
6. Supply chain issues are paramount
7. Increasing cost of capital
8. The U.S. will achieve energy independence
9. Technology advancement leap
10. Metallurgy departments at schools disappearing, i.e., merged with materials engineering
11. Pandemic exposed supply chain problems (overseas equipment, materials) – how to mitigate interruptions
12. EVs and what does forging look like in 20 years? Longer term issue
13. Mass retirements

Legislation/Regulation:

1. At the local level, environmental policy is becoming more restrictive, while at the federal level, it is becoming less restrictive
2. Large acceleration toward EVs: infrastructure, battery capacity and disposal
3. At the local and federal level, we are expecting more restrictive environmental policy
4. Global trade policy is not clear
5. Tax policy shifting toward higher rates, 'death tax policy'
6. Environmental regulations – electric vehicles
7. Automation – robots, taxation
8. Immigration policy – tech engineers
9. Unintended consequences from tariffs that cause 'value added' products to come into North America

Politics and Social Values:

1. With the exit of baby boomers there is a transition to next generations and automation
2. OSHA/EPA Regulations
3. Lack of diversity
4. There continues to be a lack of balance between those wishing to go into trades & manufacturing Vs College
5. There could be a dramatic restriction of trade due to trade wars and increased tariffs
6. Global destabilization
7. EV Mandate
8. Realities of EVs
9. Increase policies to support diversities
10. Post-COVID payments
11. Post-COVID government debt
12. Social media, communications, controlling the message
13. Remote work competes with onsite work
14. Stigma of two-year schools lessening

Forging Industry

1. The market will continue to prosper but there will be increased international competition in the forging industry
2. There will continue to be a lack of both skilled and unskilled manpower availability
3. Advancements in technology will increase productivity and deliver process gains
4. Supply Chain – materials, transportation, outside vendors
5. Trade – activity with low-cost countries
6. There will continue to be global unrest and war
7. There will be increased government regulation regarding security and to reduce the carbon footprint
8. Technology and Manpower (EV, AM, AI)

APPENDIX B: COMPLETE SET OF RESEARCH, EDUCATION, AND OTHER ACTIVITIES NEEDED TO OVERCOME THE CHALLENGES

Develop Workforce

- Build real relationships with high schools, technical colleges, Magnet Schools and local communities
- Encourage high schools to teach basic trade skills
- Pursue industry/university joint development projects that put students in the field
- Establish partnerships between businesses and schools to create apprentice and internship programs
- Work with universities and technical schools to improve education quality
- Promote and explain career opportunities in forging industry to young people at a younger age
- Sponsor scholarships and expand project opportunities for student engineers
- Forge the Future Camps
- Forging University
- Take a forging “road show” to the high schools
- Support student competition in manufacturing
- Evaluate present FIA education/training strategy
- Pursue ergonomic safety solutions to improve working conditions and enhance long-term retainment of labor
- 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
- Certified credits for FIA programming
- Promote training opportunities for current workforce to grow within the industry
- Transition existing staff to automation jobs
- Recommended equipment and certificates for community colleges and trade schools
- Hands on forge training

Materials

- Optimize metal losses in die forging process
- Reduce material waste in the supply chain
- Develop additional materials that allow forgers to eliminate heat treatment
- Application and Development of Simulation Tools
- Die Materials, Die Life, Surface Treatment, Die Repair
- Additive Manufacturing
- Alloy Design and Development
- Materials for renewable energy
- Predict final mechanical properties
- Fatigue modeling
- Simulate material models

Energy & Sustainability

- Optimize the heating of the material (process temperature and efficiency)
- 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
- Prepare carbon neutral strategy
- On-site renewable energy
- Methods to reduce energy and waste across the forging lifecycle

Advance Forging Technology

- Pursue technologies, methods, and processes that inherently advantage forgings for the forging supply chain
- Bring new technology to industry and FIA/FIERF to identify the most successful
- Develop improved solutions in process sensors
- Industry 4.0 methods to technology for forging
- Reduce time from design to final forged product (“art to part”)
- Apply nano-coatings for die life improvement
- Improve automation and robotic integration on the application to forging processes
- Improve diagnostics to reduce maintenance
- Reduce dependence for lubricants
- Digital Twin and intelligent process control
- Automated in line hot or cold part and tooling inspection
- Enhance NDT inspection
- Robotic programming for forging

APPENDIX C: LINKS

TECHNICAL LIBRARY

After 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, 2008, 2016 and current 2022 revision, the Forging Industry Educational and Research Foundation (FIERF) and Forging Industry Association (FIA) have funded, fostered and perused best practice industry research to share with FIA Members and partners. **The Foundation's Library of Technical Papers holds project reports and documents** produced by FIERF Magnet School Professors and Students, Government Labs, research partners and industry experts in pursuit of the vision and roadmap outlined by the industry. All can be found at www.forging.org/technical.

EDUCATION INITIATIVES

The Forging Foundation's Technical Education Initiatives include

- Fostering forging curriculum and experiential training in primary and secondary education, trade schools, community colleges, and university engineering departments;
- Providing scholarships to encourage careers in the forging and related industries; and
- Promoting industry awareness and career opportunities to a diverse student community

More information can be found at <https://www.fierf.org/>



**6363 Oak Tree Blvd.
Independence, OH 44131
216.781.6260
www.forging.org | www.fierf.org**