FIBERS
Facilitating Industry by Engineering, Roadmapping and Science
Composites Industry Consortium

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Mapping the Course to Advance Composites Manufacturing in the U.S. through the FIBERS Roadmap

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University / Non-Profit / Government Participation

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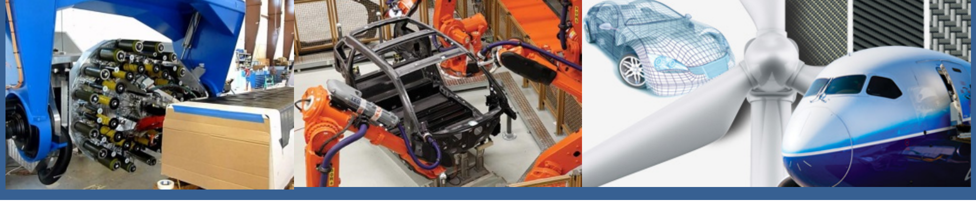
ACMA
American | Composites | Manufacturers | Association

Iowa State University
of Science and Technology

University of Delaware

Rensselaer

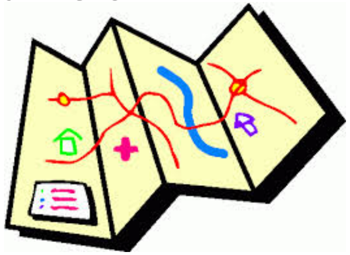
Oak Ridge National Laboratory



Consortium Activities

NIST awarded a 2-year grant (June 2014 to May 2016) to the FIBERS Team to strengthen U.S. Composites manufacturing and innovation.

- National and Regional Meetings
  - Roadmap Identifies
    - → Industry/Sector Drivers and the associated Challenges/Barriers
    - → Opportunities for growth
  - Aggressively and cooperatively address identified Challenges/Barriers – Actionable Items
    - → Pre-competitive research and demonstration projects



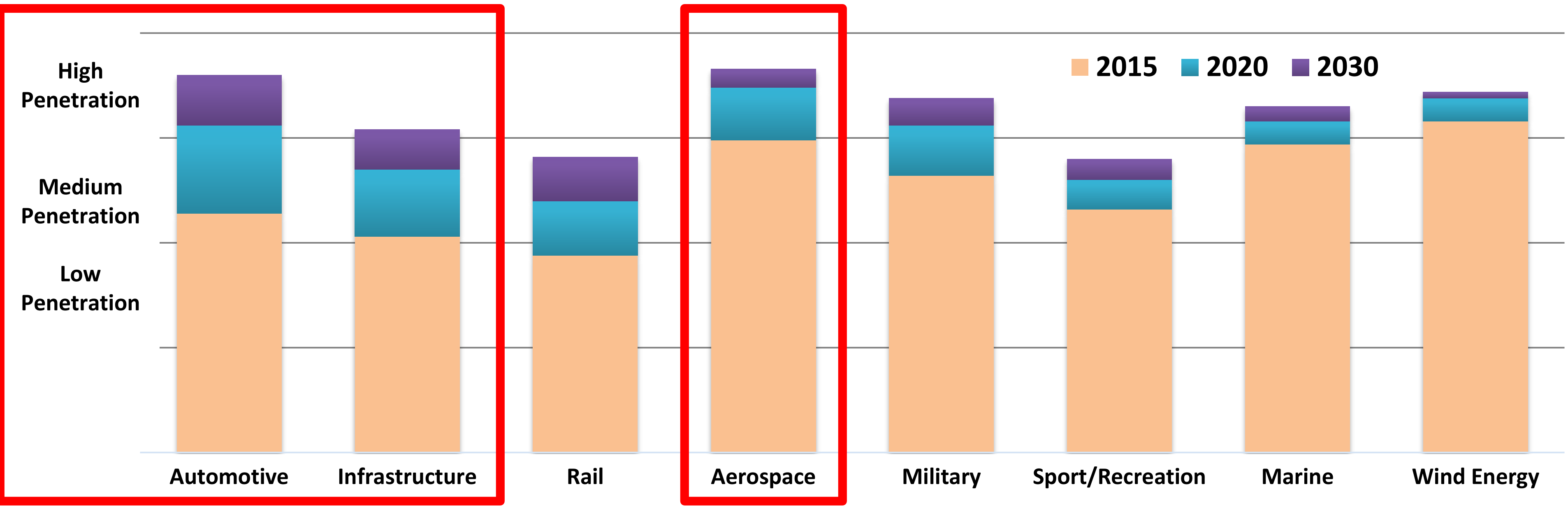
- Targeted Roadmapping Workshops for Industry Sectors
- Surveys
- Site visits with companies

Growth Opportunities for Composites

Industry Survey Results

- Conducted in 2014 and 2015
- 354 demographically balanced participants

Three sectors identified as having the greatest opportunities for growth



Growth Opportunities for Composites

Survey results

- Greatest Growth: Automotive & Infrastructure
- Highest Penetration: Aerospace

Automotive

- Require widespread use of automation
- Increased use of predictive modeling
- Low-cost carbon fiber
- Composites can facilitate a 40% wt reduction
- 2-min. cycle time

Infrastructure

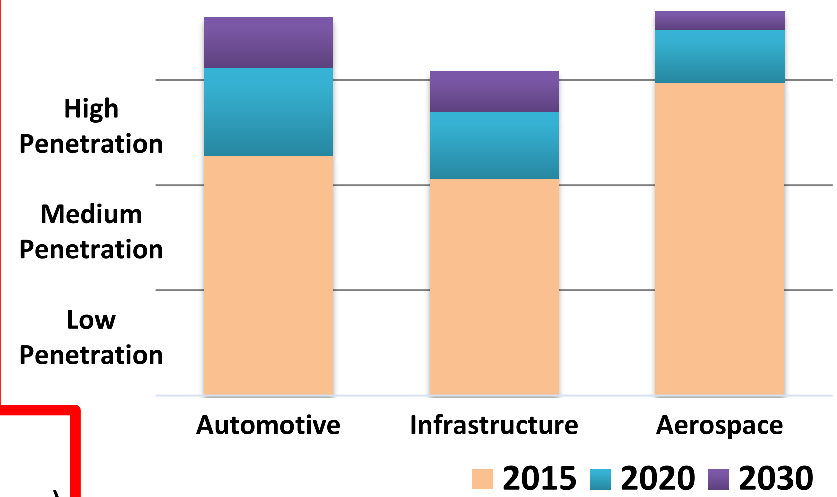
- Require the materials to be low specific cost ($$/mass)
- Long service life
- Large parts → long cure time to fully wet the part

Aerospace

- Has been the leader in the use, processing and advancement of composites – can justify cost
- Critical to pushing the envelope on composite performance and processing

Wind, Marine and Sports & Recreation -- Continued but slower market penetration

Anticipated Composites Penetration by Market Segment and Year



Growth Opportunities for Composites

All sectors will benefit from the advancements in

- **Materials**
- **Processing**
- **Automation**
- **Modeling**
- **Workforce development**

Growth Opportunities for Composites

- Automation and cycle-time reduction

  → Research and development
  - New quick-curing resins
  - Forming processes

- New resins and processes

  → Increased use of modeling to explore in a virtual environment how these innovations will impact the design and tuning of composite manufacturing processes

Grand Challenges

Four grand challenges to the growth of the U.S. Composites manufacturing industry were identified through the roadmapping activities.

1. Advancing Processing Methods → Reduce Cycle Time
2. Expansion of the knowledge and access to the tools that enable manufacturers and designers to use new processing methods and materials
3. Advancement of the material performance
4. Development of a well-trained and sufficiently-sized workforce

Advancing Processing Methods

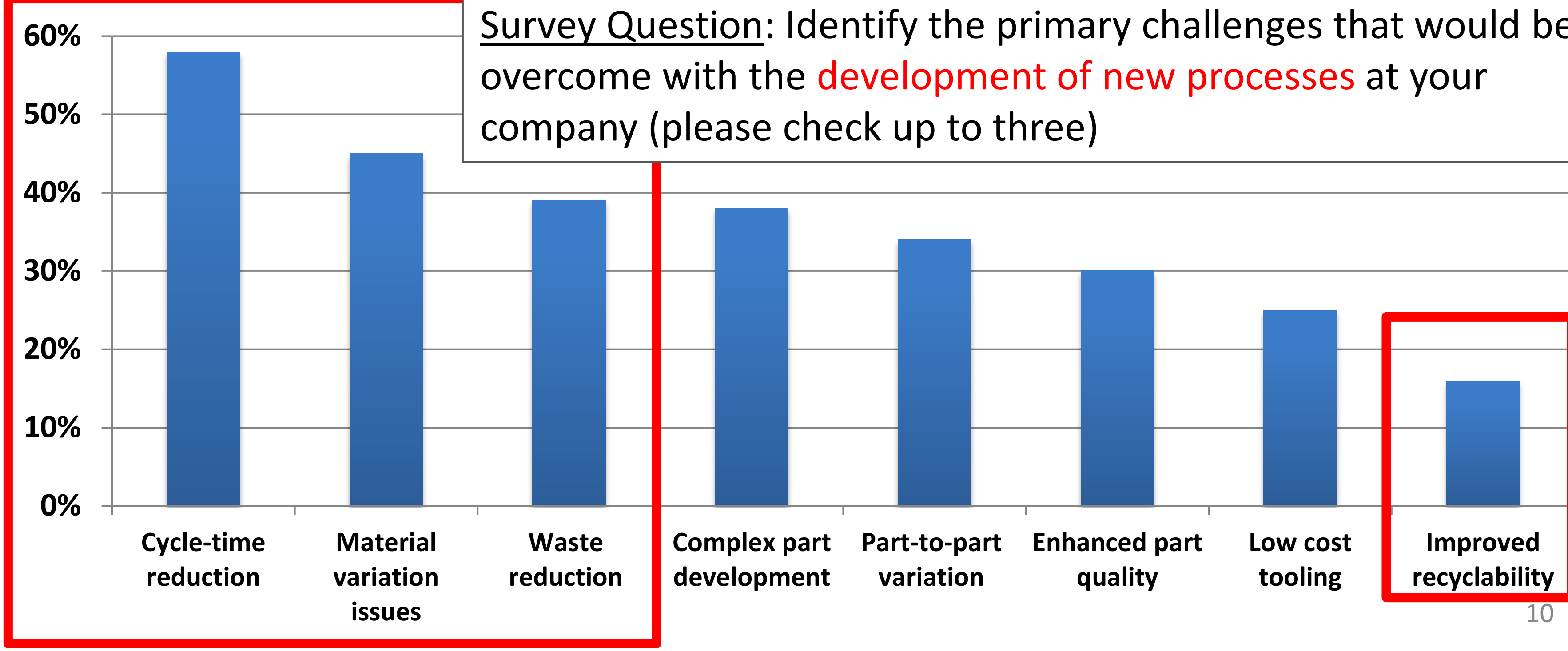
Drivers

- Reducing variability
- New process development
- High cost of composite structures due to the labor-intensive, time-consuming processing methods
- Reduce cycle time

Barriers

- Lack of a deep understanding of the physics
- Lack of automation

Survey Question: Identify the primary challenges that would be overcome with the development of new processes at your company (please check up to three)



Advancing Processing Methods

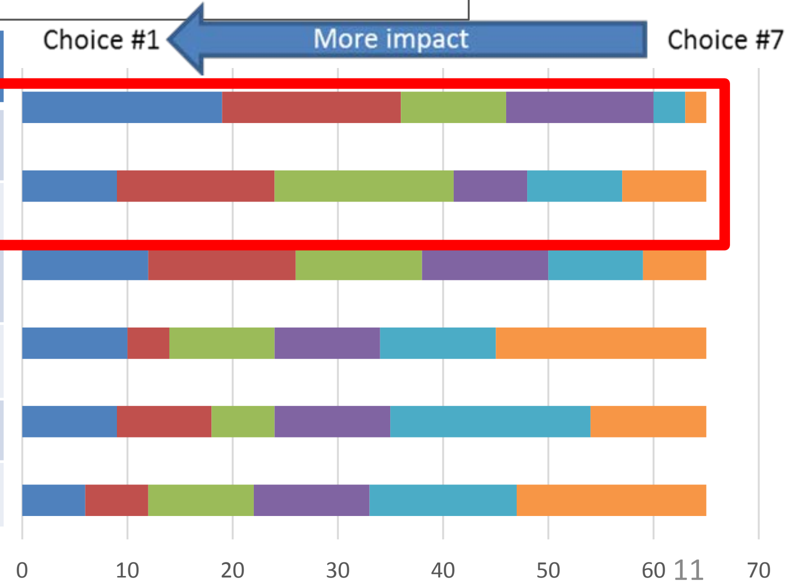
Opportunities/Challenges

- Develop new and innovative manufacturing processes
- Understanding the physics associated with a processing method
- New resins to reduce processing time and lower per part cost
- Automation
  - Driven by need for shorter processing times and lower labor costs
  - Next 15 years will see increase in aerospace and automotive

<u>Survey Question</u>: Rank the impact of the following actions on the development of new processes

Actions

- Develop robust predictive modeling tools to reduce risk before committing to equipment or process changes
- Develop automation with process sensing, monitoring and control
- Develop reliable and repeatable NDE (non-destructive evaluation) techniques to detect and characterize defects
- Establish regional centers and industry consortia to provide the technological resources and document best practices
- Investigate thermoplastic processing methods
- Develop additive manufacturing processes for composite materials



Innovations in Predictive Modeling Tools

Drivers

- Decrease product development costs while improving performance compared to existing composite and metal products
- Need for a virtual environment
  - for investigating
    - new composite designs and
    - processing methods
  - to redesign
    - existing processes or
    - add new processes that can facilitate improvements in the manufacturing process
- Ability to link manufacturing process conditions to the models of in-service performance
- Help to explore the benefits and consequences of such changes as
  - material choices,
  - processing conditions and
  - capital equipment options

  before going down the long and expensive path of product and process development.

Innovations in Predictive Modeling Tools

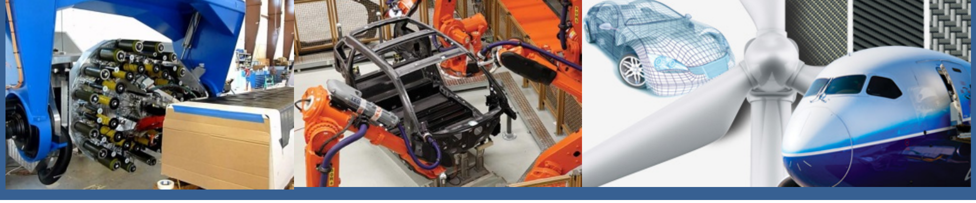
Barriers

- Lack of a comprehensive Material Property Database
- Limited recognition of the advantages that can be gained from modeling
  - Continued attraction to rely on past experiences
- Cost and access to training in the proper use of the tools

Innovations in Predictive Modeling Tools

Current Practices

- Reliance on past experiences in lieu of a virtual model (Virtual models can expand the range of possibilities)
- Overdesigned parts
- Structural modeling tools for
  - predicting part stiffnesses and completing stress analyses are relatively mature,
  - but their use by SMEs has been limited
- Modeling tools are still emerging
  - for process simulation,
  - predicting in-service fatigue life and
  - life-cycle inventory (LCI)
- Tools are often underutilized for such reasons as
  - limited access to the tools,
  - lack of qualified personnel with experience using them or
  - lack of awareness that the tools even exist. Cost of materials, particularly carbon fiber and epoxy resins, are prohibitively high for widespread use in market segments such as wind power and automotive



Innovations in Predictive Modeling Tools

Opportunities/Challenges

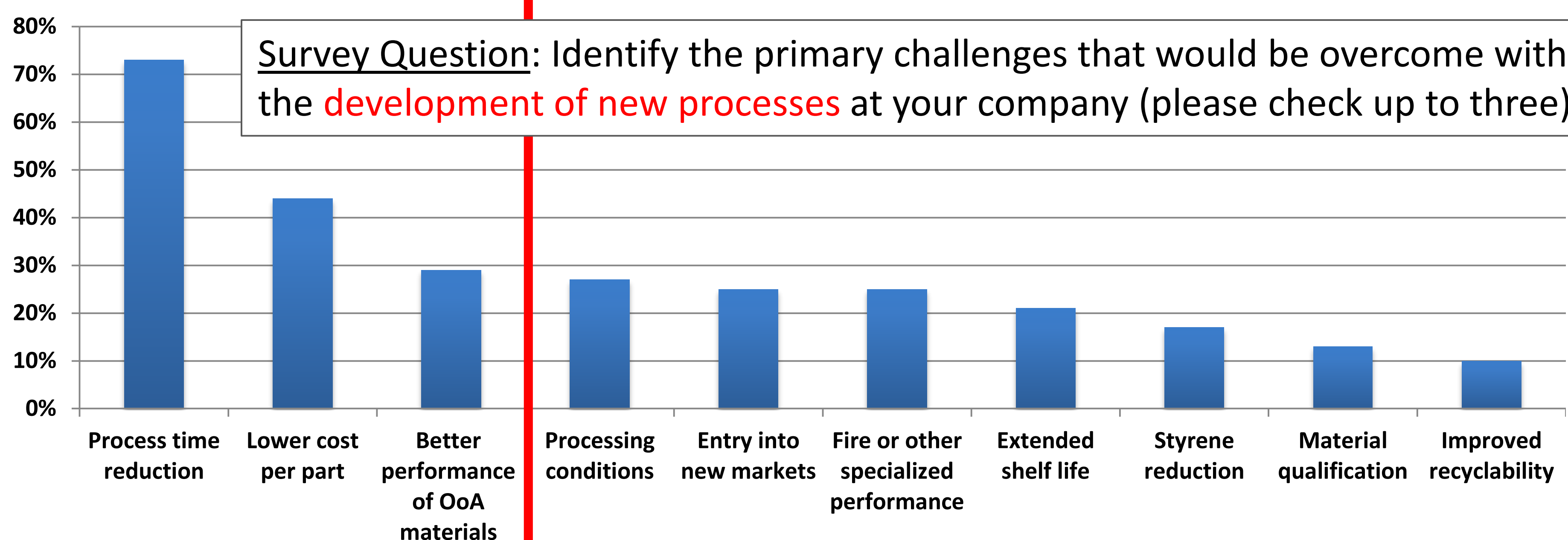
- Pursue demonstration projects and initiatives, which include the use of predictive modeling tools,
  - Can educate industry about the capabilities of these tools and
  - Show their value in expediting the design of manufacturing processes
- Expand materials databases to include the properties needed by these simulations
  - Ideally, a central clearinghouse for the data should be freely available.
  - Could be a collaboration of one or more federal agencies, e.g.
    - Department of Energy
    - Department of Defense
    - Department of Commerce
    - NASA
    - NTSB
    - IACMI
- Life-cycle predictive tools also need further development
  - Need representative, non-proprietary composite life-cycle inventory data for the largest composite end-use product groups
  - Require data for the majority of chemical constituents and composite assembly techniques
  - Develop life-cycle profiles of composite recycling and benefits in recycled or repurposed composite materials.

Future of Materials

Drivers

- Need to develop new resin materials, with the primary aim (2/3 of survey respondents)
  - To reduce cycle times
  - To decrease part cost
- Reduce raw material costs
- Desire for attractive processing parameters

Survey Question: Identify the primary challenges that would be overcome with the development of new processes at your company (please check up to three)



Future of Materials

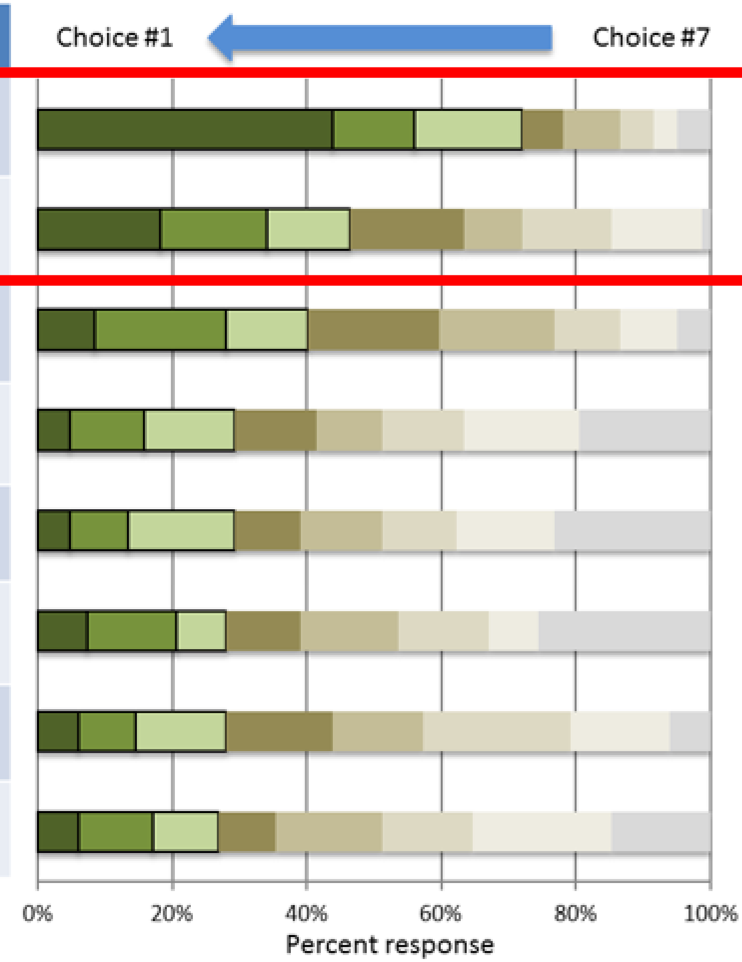
Barriers

- Lack of materials with tight tolerances to produce parts with minimal intervention during manufacturing – especially needed for automation
- Cost of materials, particularly carbon fiber and epoxy resins, are prohibitively high for widespread use in market segments such as wind power and automotive
- Lot variability: forces users to always bias to the most extreme condition – worst-case scenario, which errs on the side of a long cure time
- Costly certifications of both material systems and processes

Future of Materials

Opportunities/Challenges
Rank of the impact of actions in reducing the cost of materials

Action
Investigate low-cost carbon fiber manufacturing processes for non-aerospace applications
Develop material performance standards to transition between alternate materials
Investigate high-strength glass or glass hybrid fibers
Investigate the use of short-fiber composites for high-strength/stiffness applications
Investigate the use of recycled or reclaimed materials
Conduct research and scale-up on high-modulus fibers to replace carbon (e.g., CNT, BNNT)
Increase the supply of fiber reinforcement
Reduce the cost of non-styrenated resins

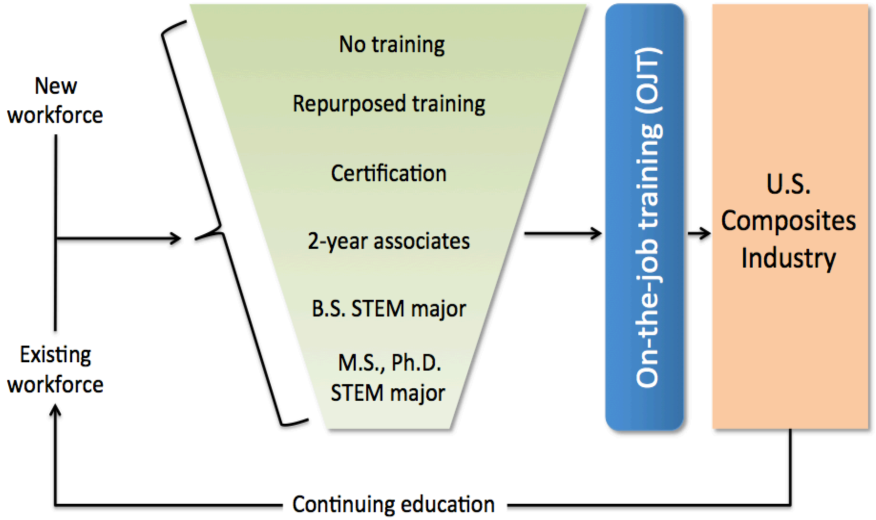


Developing a Skilled Workforce

Background

- Composites workforce resides along a spectrum from no composites-specific training to engineers with doctoral degrees

- Until there is a significant population of engineers with knowledge on how to design composite parts and who understand the processes used to make such parts, growth in the number of composites applications will continue to be slow.



The diverse training landscape for the domestic composites industry workforce.

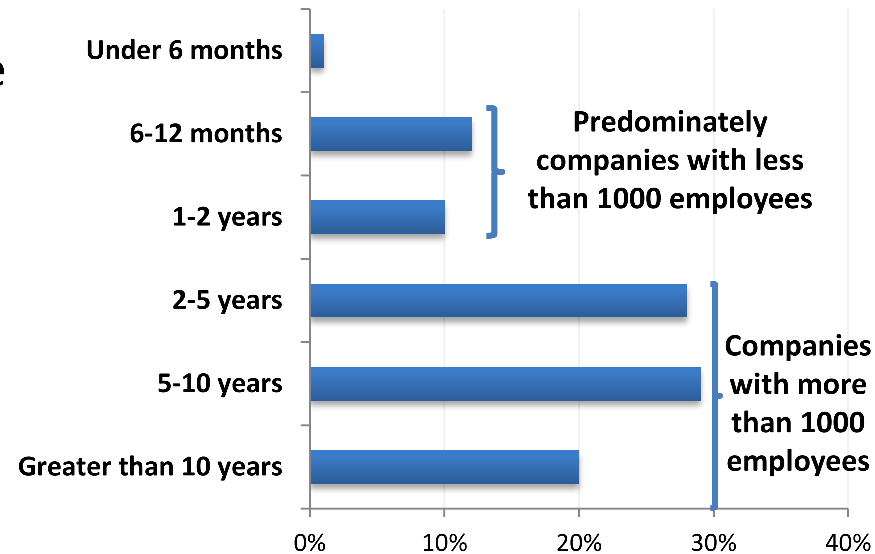
Developing a Skilled Workforce

Driver

- Continual growth of the composites industry requires skilled labor at all levels

Barriers

- Manual, complex and craftsman nature of composites manufacturing impedes the influx of employees from other manufacturing sectors
- Many design engineers are unfamiliar and uncomfortable with the design flexibilities associated with composites restricts the broad adoption of composites.
- Retention of a qualified workforce
  – Company size correlates with length of employment



The average turnover rate for hourly workers in the composites industry.

Developing a Skilled Workforce

Current Practices

- High school graduates enter the workforce or college unaware of composites manufacturing as a career
- Education and training programs may not be tailored to match regional industry requirements
  - Despite a significant fraction of workers remaining geographically local to their respective educational institution.
- No national standards or accreditation body exists for the industry
  - Hinders uniform education standards and transfer of skills between composites companies.

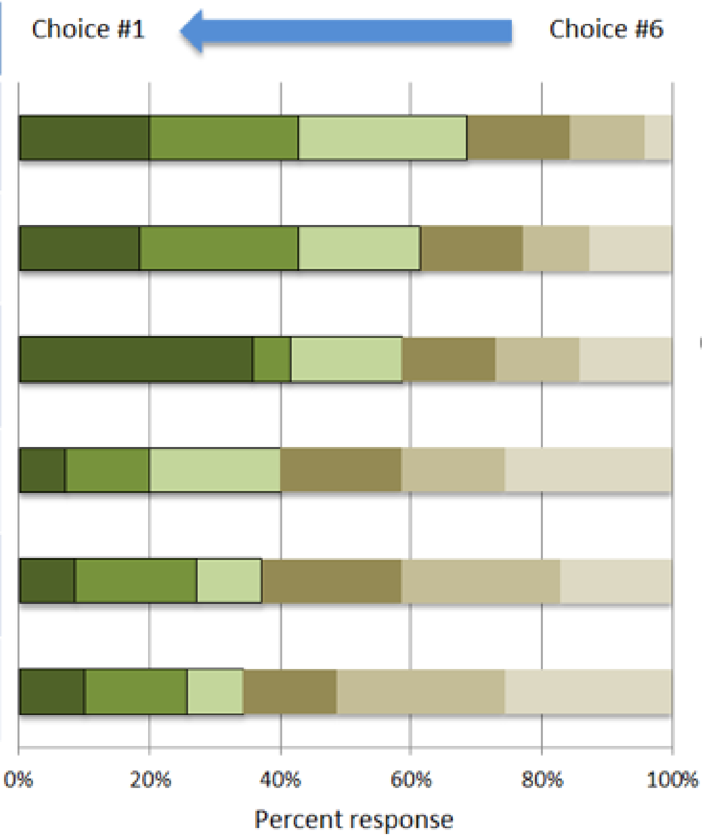
One Word: Composites!

ABET

Developing a Skilled Workforce

Actions as ranked by industry respondents regarding employee retention in the composites manufacturing industry.

Action
Provide training and education in transferable skills
Increase upward mobility potential
Increase pay rate to be competitive with other industries
Provide options for continuing education
Improve work environment cleanliness
Improve work place health and safety



Some General Conclusions

- The **Federal Government** should:
  1. Increase funding to train both engineers and technicians in composites manufacturing
  2. Provide long-term support for R&D activities to assist the U.S. composites manufacturing industry to be on par with foreign competitors – especially in the European Union, where government support for composites is very high
  3. Share Department of Defense knowledge in composites manufacturing automation with U.S. industry
  4. Set up regional technology centers with process and simulation capabilities and technical support services for use by SMEs

Some General Conclusions

- **Opportunity** for the researchers to develop new and innovative manufacturing processes.
- Innovations will require a
  - Fundamental understanding of the physics associated with a processing method
  - Access to modeling tools that can explore how changes in process conditions influence throughput and part quality.
- Companies need to learn to work together for the overall benefit of the composites manufacturing industry
  - Overcome fears about intellectual-property protection are
    - Forcing many parties along the composites manufacturing supply chain to duplicate research and development investments
    - Use outdated processes and approaches.
  - Smaller firms faced with limited to no access to new equipment and analysis capabilities, thereby limiting their ability to explore and justify the cost of new-process adoption.

Some General Conclusions

- Companies need to come together and work with academia to be proactive in lobbying the federal government to make significant investments to support fundamental research collaborations in composite manufacturing.

- IACMI is playing a major role in taking fundamental research results into composite manufacturing demonstration projects, but there needs to be a process for sustaining a pipeline to develop and deliver
  - new material systems
  - innovations in processing techniques
  - advances in modeling.

→ Provide fuel future advances in composites manufacturing

EXAMPLE

CAFE Standards

Drivers, Challenges, Barriers and Actions

DRIVER

Required fuel economy targets

CHALLENGE

Reduce weight with use of composites

BARRIERS

(1) High cost of materials
(2) Crashworthiness

CHALLENGE 1

Reduce cost of materials

BARRIERS

Cost of carbon fiber, need for automation, high cycle time

CHALLENGE 2

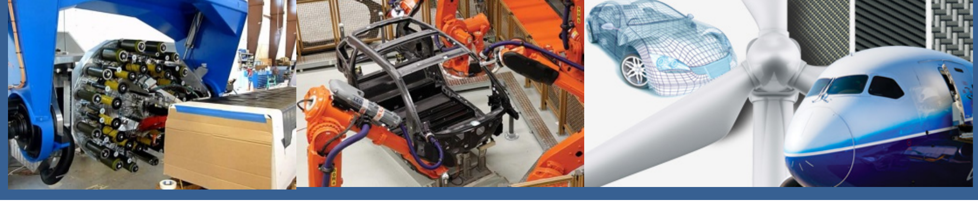
Develop an understanding of how to design for crashworthiness with composites

BARRIERS

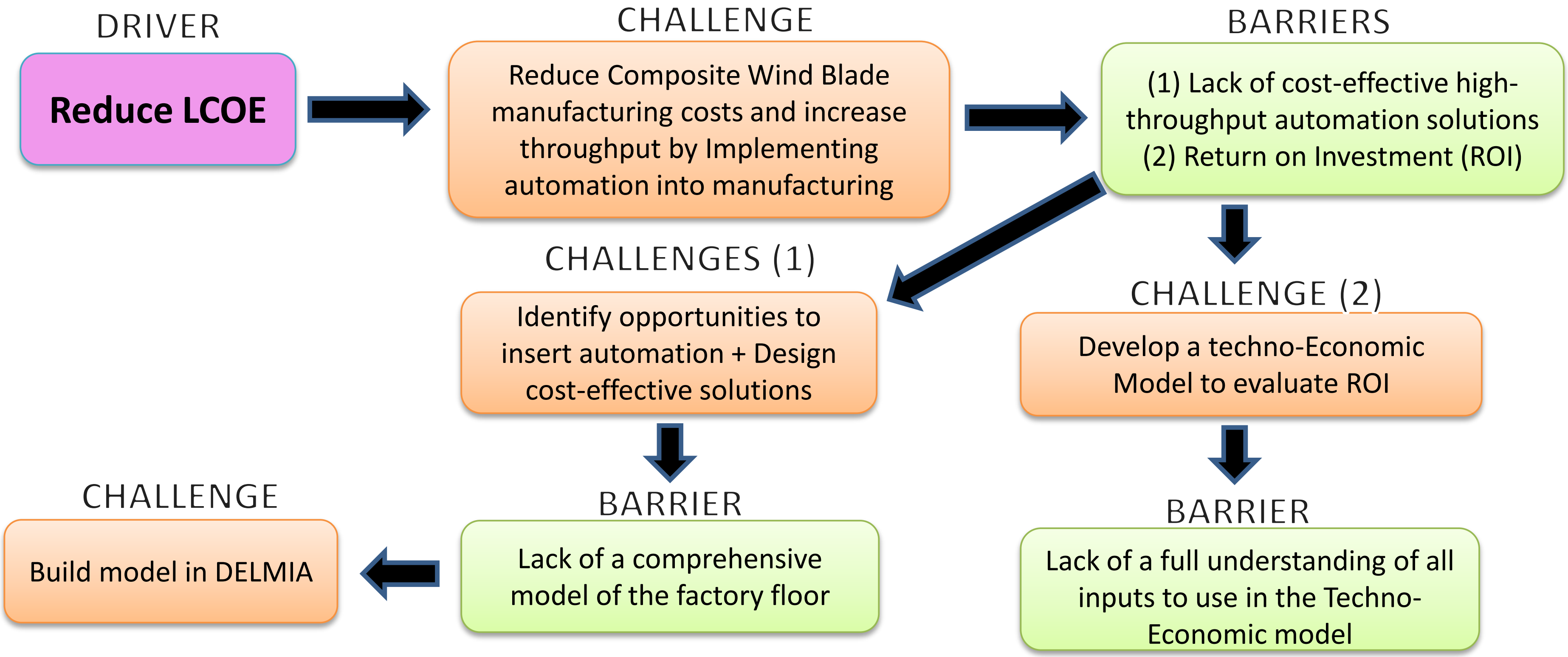
Lack of predictive modeling tools, lack of material standards, process variability

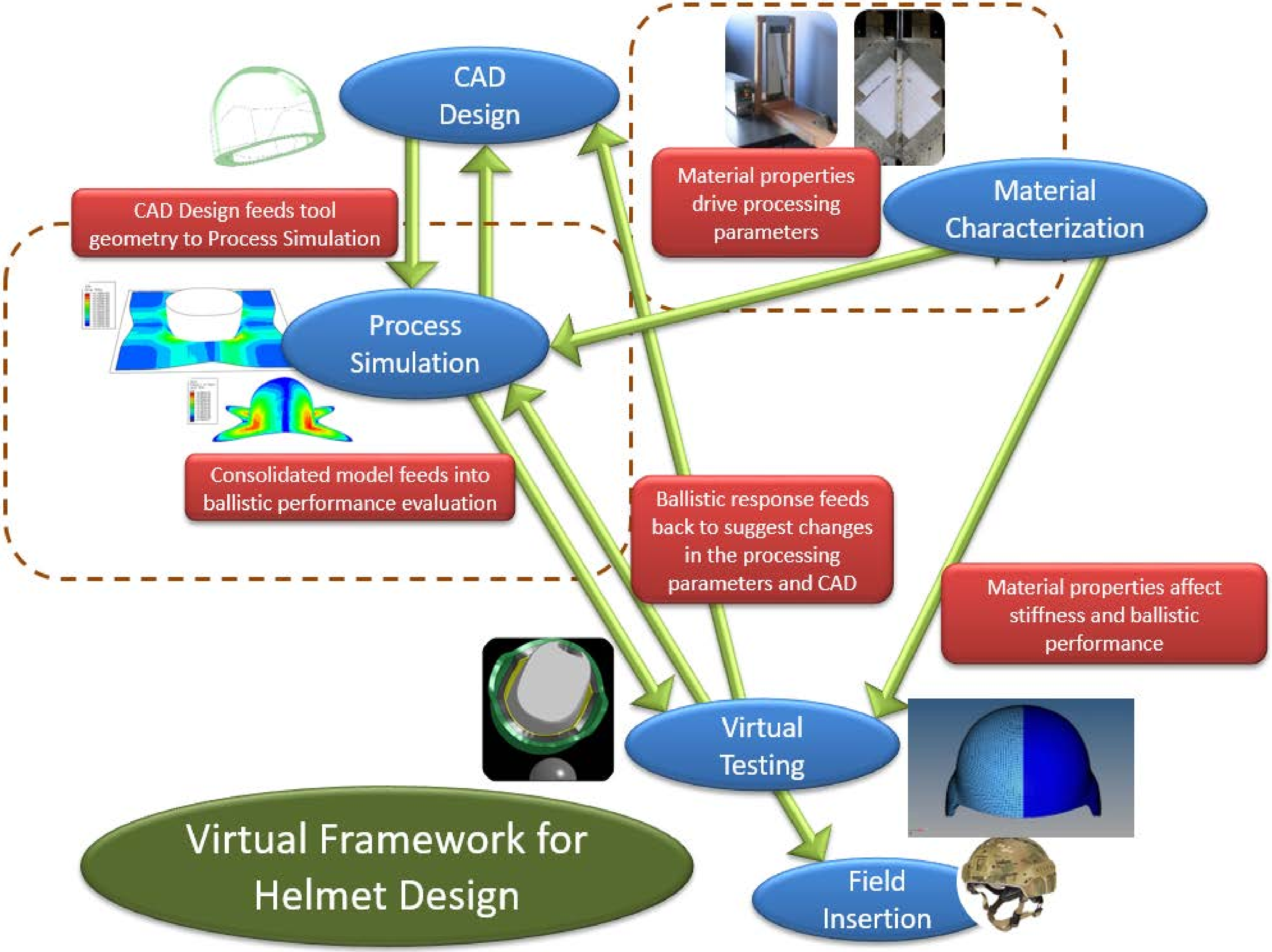
ACTIONS

Hood demonstration project
Material standard initiative
And more….



IACMI Project Title: **Techno-Economic Modeling and Manufacturing Simulation for the Insertion of Automation to Advance the State of Composite Wind Blade Manufacturing**




CAD
Design
Material properties
drive processing
parameters
Material
Characterization
CAD Design feeds tool
geometry to Process Simulation
Process
Simulation
Consolidated model feeds into
ballistic performance evaluation
Ballistic response feeds
back to suggest changes
in the processing
parameters and CAD
Material properties affect
stiffness and ballistic
performance
Virtual
Testing
Field
Insertion
Virtual Framework for
Helmet Design

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Plotting the Road Ahead

The FIBERS Consortium outlines a plan for growing composites manufacturing in the U.S.

By Dr. James Sherwood and FIBERS Team

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Thank you for listening…

Questions?

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