Department of Energy: Jobs and Innovation Accelerator Challenge (JIAC) Program

Final Report

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Innovation Realization: Building and Supporting
an Advanced Contract Manufacturing Cluster in Southeast Michigan

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Acronyms and Abbreviations

AM&S	Advanced Modeling and Simulation
AoA	Analysis of Alternatives
CAR	Center for Automotive Research
CFC	Carbon Fiber Composites
CP	Connection Point
DM SIG	Digital Manufacturing Strategic Interest Group
DOE	Department of Energy
EDA	Economic Development Administration
EHS	Environment, Health & Safety
ExP	Experimental Portal
FMEA	Failure Mode and Effects Analysis
IMCP	Investing in Manufacturing Communities Program
JIAC	Jobs Innovation Accelerator Challenge
MEDC	Michigan Economic Development Corporation
MEP	Manufacturing Extension Partnership
MIIA	Make It in America
MMTC	Michigan Manufacturing Technology Center
MRL	Manufacturing Readiness Level
MRP	Manufacturing Readiness Plan
MSA	Modeling, Simulation and Analysis
NCMS	National Center for Manufacturing Sciences
NIST	National Institute of Standards and Technology
NHTSA	National Highway Traffic and Safety Administration
OEM	Original Equipment Manufacturer
SMMs	Small and Medium-Sized Manufacturers
TRL	Technology Readiness Level
UD-CCM	University of Delaware Center for Composite Materials
VoC	Voice of the Customer
WIN	Workforce Intelligence Network

1. Executive Summary

1.1 NCMS Digital Manufacturing Initiative

The people and businesses of Southeast Michigan have long been known for their prowess in the automotive industry, a sector built on the innovation of the assembly line and the rise of mass production as a manufacturing model. Just as the assembly line was the key to a strong manufacturing base a century ago, a digital manufacturing infrastructure is critical to the future of industry. Economic uncertainty has slowed innovation, but access to cutting-edge tools such as high performance modeling, simulation and analysis (MSA) provides a bold path forward, ensuring global competitiveness and transforming our manufacturing processes. Digital manufacturing is, essentially, the virtualization of processes that had been physical. Many larger manufacturers have embraced it, but the majority of small and medium-sized manufacturers (SMMs) have not. The Digital Manufacturing Initiative is a bold, national effort by the National Center for Manufacturing Sciences (NCMS) to put manufacturing innovation on fast forward, and bring the future of industry into the present. SMMs need a broader array of access options, training, support, and guidance. Providing access will supercharge any organization with tomorrow's tools, as positively disruptive and potential-laden as the assembly line once was.

Sustainable success in the State of Michigan requires the development of foundational infrastructure, the exploration of initial inroads with various manufacturers of all sizes, and the initiation of a prototype engagement mechanism applicable for other future regional efforts. To accomplish this NCMS leveraged complimentary State and Federal funding opportunities (shown in Figure 1) along with a coupled voice of industry market research study. A brief summary of each opportunity is found in Appendix A. At the heart of the Michigan effort was the development of an access portal (www.doitindigital.com) and the development of partnerships with local large manufacturers (OEMs) who could provide pull to encourage SMMs (current and future suppliers) to participate. Central to this entire effort was the opportunity that this Final Report documents corresponding to the specific tasks associated with the U.S. Department of Energy (DOE) funded component of the InnoState Jobs Innovation Accelerator Challenge (JIAC) Program.

1.2 Project Background

The DOE-funded JIAC Program is part of the overarching Workforce Intelligence Network (WIN) Innovation Realization: Building and Supporting an Advanced Contract Manufacturing Cluster in Southeast Michigan initiative launched in 2012. The WIN initiative (made up of seven workforce boards and eight community colleges in partnership with business, economic development, universities, and not-for-profits) is intended to align Federal, State, philanthropic, local and private resources to support the transformation of the Southeast Michigan region by leveraging the region's manufacturing (and automotive manufacturing)

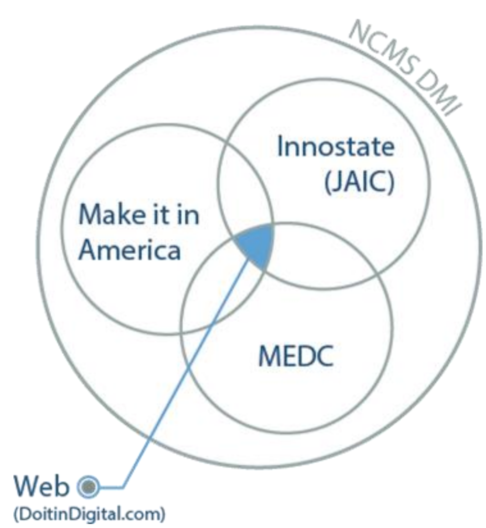

Figure 1. Leveraged Funding Opportunities

base. By growing the size, visibility, and economic role of a manufacturing and related-services cluster, the intent is for Southeast Michigan to become a global destination for firms looking to develop actual products and processes that could buffer the region in economic downturns as well as adding diversity to the region's manufacturing base.

This report documents the final results of the DOE-funded effort that was part of a larger interagency effort called the JIAC which is part of the Obama Administration's Regional Innovation Cluster Initiative. The overall effort was named InnoState. It was one of 20 high-growth, regional industry clusters jointly funded by various Federal agencies (including DOE, U.S. Department of Commerce's Economic Development Administration, and the National Institute of Standards and Technology Manufacturing Extension Partnership). The overarching goal of the national JIAC effort is to spur job creation and economic growth, help catalyze and leverage private capital, build an entrepreneurial ecosystem, and promote advanced manufacturing and cluster-based development in regions across the United States.

As mentioned above, the Southeast Michigan cluster, InnoState (www.innostatemi.com), seeks to supplement the Southeast Michigan region's traditional parts-making economy with a fast-growing community of firms pursuing a different business model (Figure 2). In addition to NCMS, InnoState is comprised of three other regional organizations well-positioned to support the cluster's development and growth. They are the Detroit Regional Chamber Connection Point (CP), the Workforce Intelligence Network (WIN), and the Michigan Manufacturing Technology Center (MMTC). As a member of the InnoState team, NCMS' primary role was to provide cluster members access to digital manufacturing tools and a deeper understanding of the value advanced composites could bring to some of their applications. The roles in the broader InnoState

Figure 2. Seeking New Regional Businesses

effort via JIAC will be separately documented in final reports to both EDA and NIST. For a high level summary of the overall project, funding agencies, team members, and roles please reference Appendix B. In addition, you can find some examples of the broader InnoState success stories in Appendix C.

1.3 Objective/Purpose

In support of the broad InnoState objective, the purpose of the DOE-funded NCMS activities was to develop and validate cost-effective, high strength materials technologies, including Carbon Fiber composites that will ultimately save energy by reducing the weight of end products without compromising performance, safety or recyclability. From this, two project outcomes were to be realized:

- Identify new energy-efficient manufacturing processes that can be utilized with new composite materials to improve their manufacturability and lower costs.
- Engage SMMs (and Advanced Modeling and Simulation – AM&S) tools in the development and prove-out of the new composite materials.

The first outcome leveraged ongoing NCMS collaborations in both the aerospace and automotive sectors promoting broader applications for composites. By engaging SMMs (the second outcome) NCMS ensured the knowledge realized from this study can be utilized to transition into new supply chains in multiple industries (automotive, aerospace, and defense) which is aligned with the NCMS

Digital Manufacturing Initiative. This Final Report encompasses the results, successes, challenges and opportunities moving forward.

1.4 Scope

Through the use of novel processes, materials and AM&S tools, work was performed to validate alternatives to replace the manual, hand-applied Carbon Fiber layup process. Competing designs were evaluated based on cycle time, quality and cost (materials and processing) that could have applications across manufacturing sectors (i.e. aerospace and automotive). Drivers included material properties, design for manufacturing, geometrical limitations, and performance. A 75% cost savings over current hand layup process was the target. The team, made up of GE, Munro and Associates, BMW, University of Delaware, National Highway Traffic and Safety Administration (NHTSA) and NCMS used a business tollgate process that leverages the industry standard Manufacturing Readiness Level (MRL)/Technology Readiness Level (TRL) metrics to evaluate study progress.

Work was previously completed by at least one OEM in the Southeast Michigan region to develop a feasible, cost effective composite manufacturing process to replace the traditional layup process. The result was a workable process from concept to MRL/TRL 3-4. NCMS' plan was to learn from this previous work as well as to investigate a wide variety of materials and processes that had been through at least a proof of concept with the end goal of defining a workable composite substitution process that was capable of reaching a MRL/TRL 8 stage. AM&S was to be used to validate proposed alternatives performance characteristics without physical testing where possible.

Finally, to bridge the gap between manufacturers and digital resources and technologies, NCMS developed a Portal (www.doitindigital.com) educating SMMs on means to gain access to tools, technologies, training, community, and activities in one place.

2. Advanced Manufacturing Processes Using Composites

2.1 Objective/Purpose

The first objective of the DOE-funded JIAC was to identify new energy-efficient manufacturing processes that could be utilized with new composite materials to improve their manufacturability and lower costs.

To achieve the objectives of JIAC, NCMS was awarded to a multi-year project scope with specific tasks and deliverables defined. Budget Period 1 and 2 Tasks have been completed and were reported earlier (see Appendix D and E). This report encompasses the results of Budget Period 3 as well as provides some general conclusions, benefits achieved and recommendations resulting from all three Budget reports.

2.2 Approach/Tasks

Budget Period 1 (also see Appendix D)

The primary task in Budget Period 1 developed a technical roadmap to define content and functionality requirements to effectively evaluate alternative processes and materials against standardized MRL/TRL metrics. Using defined MRL/TRL criteria, a Manufacturing Readiness Assessment was performed by the team (led by Munro & Associates) on three levels of composite technologies applied to a lightweight metallic substrate. Note that testing was done on test coupons that do not fully represent production relevant components. Risk levels were assigned for each scenario – hand layup, compression mold, and an automated process. The end result was to assess the available technologies through MRL/TRL 4 considering these key Sub-Threads:

Maturity: Materials have been produced in a prototype environment.

Supply Chain Management: Supply Chain Sources have been identified and planning has been done to minimize risks.

Modeling & Simulation: Initial simulation models have been developed at the component level.

Manufacturing Process Maturity: Process capability requirements have been identified.

Environment, Health & Safety (EHS): EHS approval and sign-off prior to scale up process development.

The study focused on assessing the process of applying Carbon Fiber to a lightweight metal substrate. A Test Matrix was developed in support of the three process scenarios investigated – hand layup, compression mold and automated carbon placement. The Test Matrix consisting of Aluminum/Carbon Fiber Composite (CFC) and Lightweight Steel/CFC Systems for evaluation is shown in Table 1.

The test coupons were prepared by GE for testing by Ford. Carbon Fiber adhesion technology is well known and is currently applied in industry. However, the surface treatment of the substrate prior to the application of the Carbon Fiber and the resultant adhesion characteristics was unknown. Therefore, the study centered around testing the adhesion characteristics of the various surface treatments for each of the three processes evaluated.

Budget Period 2 (also see Appendix E)

The tasks during Budget Period 2 expanded the Tollgate Review to evaluate other composite applications (more real world) using the same MRL/TRL criteria and Sub-Threads from Budget Year 1. The overall objective was to evaluate the alternative materials and processes through MRL/TRL 5-6.

To achieve closer to a real-world assessment, the team leveraged composite automotive

Table 1. Aluminum/CFC and Steel/CFC Systems Test Matrix

Test Matrix: Al/CFC and Steel/CFC Systems

(Application studies at GE)

Aluminum surface treatment	CFC prepreg (0.25mm thick)	Comments
A) 6111 Alum. 2.0mm (951 only)	4 – 12" X 12" Plaques w/ 1.5 -2.0mm thick CF	Orientation 0 degrees & 90 degrees , 6-8 layers
B) 6111 Alum. 2.0mm (951/DC2-90 Lube)	4 – 12" X 12" Plaques w/ 1.5 -2.0mm thick CF	Orientation 0 degrees & 90 degrees , 6-8 layers
C) 6014-T4-E32 2.0mm w/ 951 only (EDT) Electro-Discharge Texturing	4 – 12" X 12" Plaques w/ 1.5 -2.0mm thick CF	Orientation 0 degrees & 90 degrees

Steel surface treatment	CFC (regular)	Comments
A) DP800 Steel - 2.0mm (uncoated)	4 – 12" X 12" Plaques w/ 1.5 -2.0mm thick CF	Orientation 0 degrees & 90 degrees
B) DP800 Steel - 1.9mm (Electro galvanized)	4 – 12" X 12" Plaques w/ 1.5 -2.0mm thick CF	Orientation 0 degrees & 90 degrees

B-Pillar efforts being developed for the NHTSA to determine the level of its MRL/TRL maturity. The material was a thermoplastic composite, required due its complexity and application. Survey information was used to obtain feedback for participants to assess MRL/TRL maturity for the process. Where possible, participants provided input beyond the B-Pillar project to assess technology maturity beyond the B-Pillar. Several materials were assessed for this phase including Tencate (Nylon Pre-preg), Aonix (Thermoplastic), and Concordia Fibers (Co-mingled Fabrics).

As a follow-on to the previous study (Budget Period 1), the same set of relevant MRL categories were selected (Materials, Process Capability and Control, Quality Management, and Facilities).

The task of Budget Period 3 was to optimize the technical roadmap approach developed over three years to move forward as a tool to assess business, technology, financial and other factors that could impact and/or hinder development of a production-ready composite material. Additionally, the intent of Budget Period 3 work was to use the MRL/TRL Manufacturing Readiness Assessment approach to evaluate the steps and timeline necessary to bring the thermoplastic composite B-Pillar to an MRL/TRL for a real-world application.

Survey information was used to obtain feedback from participants at the University of Delaware to assess MRL/TRL maturity for the process. Due to the focus on the performance, safety, and recyclability of the thermoplastics themselves, the *Supply Chain Management*, *Inspection Systems and Gages*, and *EHS* Sub-Threads were not included in the questionnaire sent to the University of Delaware. This helped create a more focused roadmap for bringing the thermoplastics to a MRL for a real-world application.

2.3 Key Deliverables

Key deliverables were to perform successful MRL/TRL Tollgate Reviews resulting in the following achievements:

Budget Period 1: MRL 4/5 Status for selected composite materials and processes.

Budget Period 2: MRL 5/6 Status for selected composite materials and processes.

Budget Period 3: MRL Status for selected composite materials.

2.4 Results

2.4.1 Budget Period 1 (also see Appendix D)

A complete Manufacturing Readiness Assessment (Tollgate Review) was completed by the team (led by Munro & Associates) based on three potential Carbon Fiber composite materials sandwiched on metallic substrates (Aluminum and Steel). Processes evaluated were hand layup, compression mold and automated carbon placement. Key partners during this period were; GE Research, Ford Motor Company and Munro & Associates. The Assessment considered key MRL 4/5 Sub-Threads: Material – Maturity, Availability, Supply Chain Management, and Special Handling; Process – Modeling and Simulation, Manufacturing Maturity, and Yields and Rates; Quality – Management, Product Quality, and Supplier Quality Management; and Facilities – EHS. Note that the assessments were based on coupons produced and not real component parts. The Assessment results are as follows:

Material – Maturity (MRL 4)

Test Matrix was prepared to assess multiple materials and surface treatment options.

Projected materials have been produced in a laboratory environment.

Project is beyond the experimental phase, but have not made production prototypes.

Materials have been produced in a prototype environment.

Material – Availability (MRL 5)

Materials used for production part are all currently available for prototype and can be produced at automotive production rates.

Materials are available for prototype units. Coupons have been created using materials for testing.

Material – Supply Chain Management (MRL 5)

Supplier was selected to support the prototype build.

Material – Special Handling (MRL 5)

Requirements conform to existing composite compliance regulations and conformity.

Process – Modeling & Simulation (MRL 5)

Initial process models developed.

Models were created in Design Profit® for material and technology process.

Process – Manufacturing Maturity (MRL 4)

GE and Ford have demonstrated and assessed the capability of critical manufacturing processes and understand the issues and risks for supporting the Analysis of Alternatives (AoA). This data will be used in selecting the alternatives to proceed to the Technology Development phase.

Process capability is understood by using data from coupons defined in the Test Matrix and similar processes to assess whether target costs are achievable. Data generated from this assessment will be used to make design choices, make/buy decisions, and capacity, process capability, sources, quality, key characteristics, yield/rate, and variability assessments. The program manager will continue to assess current process capability versus what is needed to meet program requirements.

Process Yields & Rates (MRL 4)
To achieve MRL 5 and beyond Ford needs to assess product yields and rates and develop targets for growth of these factors at key milestones in the development cycle (e.g. pilot line, LRP, and FRP).

Quality – Quality Management (MRL 4)
Quality plan has been created for producing test coupons by GE, and Ford is applying a systematic repeatable process for testing the coupons for mechanical bond strength and impact.

Quality – Product Quality (MRL 4)
Test and acceptance plan has been created as part of the technology development strategy and is included in a systems engineering plan as it applies to the coupons.

Quality – Supplier Quality Management (MRL 5)
Supply quality capabilities and risk are known.

Facilities – Tooling (MRL 5)
EHS, tooling and special tooling equipment/special inspection equipment requirements have been provided to complete the requirements of the Test Matrix.

Facilities – Prototype (MRL 5)
Manufacturing facilities have been identified for prototype components. Full rate facilities will need to be identified and re-assessed.

The results of this budget period demonstrated that for the MRLs Sub-Threads evaluated, the technologies could meet MRL 4/5 with risks identified. The only failure noted was an initial adhesion failure for the automatic carbon placement process (but passed under the compression molding). A snapshot of the results is shown in the MRL Assessment Matrix prepared by the team (Table 2).

2.4.2 Budget Period 2 (also see Appendix E)

For this budget period, the team was expanded to include the University of Delaware and BMW. The results of Budget Period 1 were leveraged into a more real-word scenario by including work being completed on a composite B-Pillar effort under the aforementioned NHTSA study. The same Manufacturing Readiness Assessment (Tollgate Review) process was used for this new composite B-Pillar composite construction model. The Assessment was completed based on survey information obtained from team participants and are subjective in nature. The results of the Assessment for the various materials of the study are summarized below.

Materials Subcategory – Maturity
Tencate (Nylon Pre-preg) MRL – 10
The team has been provided detailed data sheets for their products. In addition, several applications with this material have been done, although not as a complex design as this. In addition, Tencate is able to make the quantities in scale required for this project application.

Aonix (Thermoplastic) MRL – 8/9
This product is currently not sold in the United States; however it can be bought. Smaller quantities are readily available but not at the desired quantity for the team which provides some risk and lowers the MRL.

Concordia Fibers (Co-mingled Fabrics) MRL – 5/6
For this application, Concordia Fibers would need to provide a custom run of the fabric as it isn't at a product level with this design. They have similar constructions, but this is a new one for them. The estimate is to be able to produce 300,000 pounds and it can be scaled as it matures.

Table 2. Budget Period 1 MRL Sub-Thread Results

Critical Go/No Go (stage gate reviews decisions points)					
		MRL 4	**MRL 5**	**Status / Comments**	**% Complete**
Thread	Sub-Thread	Capability to produce the technology in a laboratory environment	Capability to produce prototype components in a production relevant environment	Focus on Coupons and not component level development	Ford sample processing complete, pending autoclave samples for testing
Materials	Maturity	Survey completed to determine if materials have been used before in a manufacturing environment. Preliminary plans in place to address producibility risks of new material.	Materials have been manufactured or produced in a prototype environment. Maturity efforts in place to address new material production risks for technology demonstration.	Ford agreed to use GE's current production CF materials (Cytech)	Ford portion 100% (Thanks Matt R)
	Supply Chain Management	Survey completed for potential supply chain sources.	Supply chain sources identified. Sole/single/foreign source vendors have been identified and planning has begun to minimize risks.	Alternative CF suppliers known and can be recommended but not necessary. All parties agree to use current CF products on hand.	100%
Process Capability & Control	Modeling & Simulation	Production modeling and simulation approaches for process or product are identified.	Initial simulation models (product or process) developed at the component level.	Component level modeling (by Ford) for product application completed on crush tubes, B-pillars and side intrusion beams.	100%
	Manufacturing Process Maturity	Complete a survey to determine the current state of proposed processes.	Maturity has been assessed on similar processes in production. Process capability requirements have been identified.	Ford has parallel path, including tape application at GE facility and compression molding trials at Wayne State University. Both are production processes being applied to same Steel & Aluminum coupons	100% complete at GE 50% complete at WSU
Quality Management	Inspection Systems and Gages	Measurements made in prototype lab by researchers and technicians using lab scale instruments.	Inspections are applied to all parts, data collected, all parts inspected the same way. Gage repeatability and reproducibility studies complete.	Post coupon fabrication will be mechanical testing at Ford Research	Pending to commence in February
Facilities	EHS	Administrative EHS controls in place. Researcher responsible for maintaining safe working environment.	EHS approval and sign off prior to scale up process development. EHS requirements built into SOP's.	Ford notes excellent safe working practices at GE facility – No issues.	

Materials Subcategory – Supply Chain Management

MRL – 5

The materials being considered for this project are all associated with the known supply chain sources listed above (Tencate, Aonix and Concordia). Plans are in place to investigate alternative vendors/materials for each to ensure equivalent materials from at least one other potential vendor are in place. However, formalized supply chain agreements with the end user are yet to be established.

Process Capability & Control Subcategory – Modeling & Simulation

Structural Design MRL – 10

Modeling and Simulation is something that has been adapted industry wide for use in the composites industry. It is a mature process for structural design of components.

Impact Crash Simulation MRL– 4/5

Material inputs needed into the model (no standard database). For this project, LS Dyna Modeling is being applied. This is something that has not been validated with previous applications and is at the core of the research for this project and the MRL reflects this.

Process Simulation MRL – 6/7

There has been limited documentation on the process simulation with thermoplastics, especially on parts that are this complex in design. Again, this is another area in which the research will be expanded in hopes of maturing the technology.

Process Capability & Control Subcategory – Manufacturing Process Maturity

MRL– 5/6

Specific to this project, it is a very geometric complex design and for a high performance application. The production rate is anticipated to be 50,000 units a year. In addition for the selected MRL, this is still an area of development and research and is not at a level beyond at this time.

Quality Management Subcategory – Inspection Systems and Gages
Systems Related to Incoming Materials
MRL – 5 to 7
While no test specifications have been documented yet for this effort the consensus is that existing instrumentation, inspection techniques, criteria and specifications will be more than adequate for these types of materials. The team continues to work to document this part of this project.

Facilities Subcategory – EHS
MRL – 6/7
While both thermoplastic and traditional composite components are currently in production with all required EHS standards used, this novel notion of thermoplastic composites introduces additional evaluations to ensure existing protocols are sufficient. They do require different equipment for handling, but they have been used in several applications for other applications from a B-Pillar. While the issues are addressed and primary risks have been mitigated, a formal Failure Mode and Effects Analysis (FMEA) was not completed.

MRL Assessment Summary

Table 3 is a roll-up chart NCMS and its industry partners felt exemplified the maturity levels of thermoplastic composites. For those categories with a range of values presented, a conservative value was selected.

A summary of the results are shown in the MRL Assessment Matrix prepared by the team in Table 4.

Table 3. MRL Maturity of Thermoplastic Composites

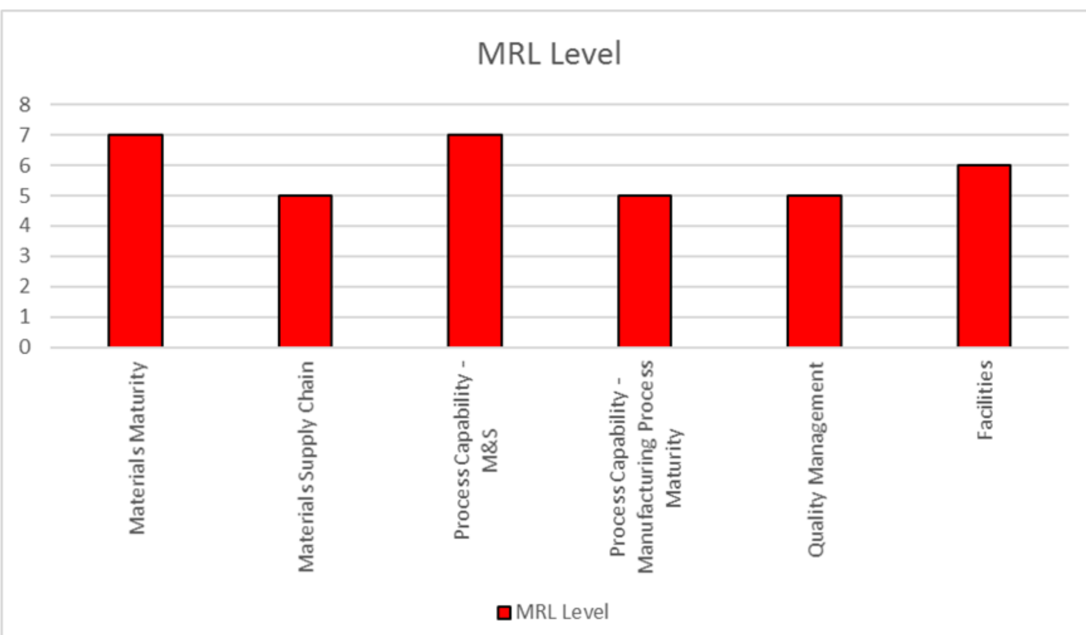

Table 4. MRL Assessment Matrix Results

Critical Go/No Go (stage gate reviews decisions points)

Thread	Sub-Thread	MRL 4	MRL 5	MRL 6	MRL 7
		Capability to produce the technology in a laboratory environment	Capability to produce prototype components in a production relevant environment	Capability to produce a prototype system or subsystem in a production relevant environment	Capability to produce systems, subsytems or components in a production representative environment
Materials	Maturity	Survey completed to determine if materials have been used before in a manufacturing environment. Preliminary plans in place to address producibility risks of new material.	Materials have been manufactured or produced in a prototype environment. Maturity efforts in place to address new material production risks for technology demonstration.	Material maturity verified through technology demonstration articles. Preliminary material specifications in place.	Materials maturity sufficient for pilot line build. Material specifications approved.
	Supply Chain Management	Survey completed for potential supply chain sources.	Supply chain sources identified. Sole/single/foreign source vendors have been identified and planning has begun to minimize risk.	Supply chain plans in place (e.g. teaming agreements, etc.) leading to first, low quantity, contract award.	Effective supply chain management process in place. Completed assessment of supply chain firs tier.
Process Capability & Control	Modeling & Simulation	Production modeling and simulation approaches for process or product are identified.	Initial simulation models (product or process) developed at the component level.	Initial simulation models developed at the technology, sub-system or system level.	Simulation models used to determine system constraints and identify improvement opportunities.
	Manufacturing Process Maturity	Complete a survey to determine the current state of proposed processes.	Maturity has been assessed on similar processes in production. Process capability requirements have been identified.	Manufacturing process demonstrated in production relevant environment.	Manufacturing processes demonstrated in production relevant environment.
Quality Management	Inspection Systems and Gages	Measurements made in prototype lab by researchers and technicians using lab scale instruments.	Inspections are applied to all parts, data collected, all parts inspected the same way. Gage repeatability and reproducibility studies complete.	Gages and inspection systems identified for production environment. Test specifications are documented	Key inspection criteria are down selected. Data records assembled for each part produced, providing the ability to correlate performance with a process data.
Facilities	EHS	Administrative EHS controls in place. Researcher responsible for maintaining safe working environment.	EHS approval and sign off prior to scale up process development. EHS requirements built into SOP's.	Elevated EHS awareness through regular pilot team communications	EHS issues addressed proactively and documented. SFMEA completed. Highest priority risks are mitigated through engineering solutions

2.4.3 Budget Period 3 (also see Appendix F)

For Budget Period 3, the results from Budget Period 1 and 2 were leveraged to fully develop and validate the composite materials and processes. The development work from the companion NHTSA Study on High Performance Computing Study for Composite Intensive Vehicle Design using an all-composite (replacing steel) automotive B-Pillar as a surrogate for demonstration of advanced vehicle design and manufacturing using composites, had progressed to the point where an assessment of MRLs could be made. The details of the NHTSA Study are included in Appendix F. Information was collected from the University of Delaware Center for Composite Materials (UD-CCM), detailing what steps needed to be taken to reach high MRLs for the composites thus developing a Manufacturing Readiness Plan (MRP) for Advanced Manufacturing Processes Using Composites, which was a desired outcome of the study. The focus of the MRL/MRP was what was needed to bridge the gap to achieve production readiness, rather than just reporting on the current state of the technology. The results of the assessment of the progress made on the NHTSA Study are summarized below.

Materials Subcategory – Maturity
Tencate (Nylon Pre-preg)
Budget Year 3 – MRL: 10

The Tencate Nylon Pre-preg remained at an MRL of 10 for Budget Period 3. The team has been provided detailed data sheets for their products and several applications with this material have been done. Tencate is able to make the quantities in scale required for this project application, demonstrating full-rate production.

Aonix (Thermoplastic) MRL
Budget Year 3 – MRL: 8/9

The Aonix Thermoplastic remained at an MRL of 8/9 for Budget Period 3. Although production of this product has been demonstrated, only small quantities are readily available, not the desired quantity for the team. This provides some risk and lowers the MRL. To raise the MRL of the Aonix Thermoplastic, full-scale production would need to be demonstrated.

Concordia Fibers (Co-mingled Fabrics)

Budget Year 3 – MRL: 5/6

For Budget Period 3, the Co-mingled Fabrics remained at an MRL of 5/6. For this application, Concordia Fibers will still need to provide a custom run of the fabric as it isn't at a product level with this design. They have similar constructions, but this is a new one for them. To raise the Co-Mingled Fabrics to higher MRL, Concordia Fibers would have to raise production levels enough to produce 300,000 pounds and it can be scaled as it matures.

Materials Subcategory – Supply Chain Management
Budget Year 3 – MRL: 5

The materials being considered for this project are associated with the known supply chain sources listed above: Tencate, Aonix and Concordia. However, formalized supply chain agreements with the end user need to be established to give a definitive timeline of bringing Supply Chain Management to a higher MRL.

Process Capability & Control Subcategory – Modeling & Simulation
Structural Design
Budget Year 3 – MRL: 10

Structural Design remains at an MRL of 10, as Modeling and Simulation is something that has been adapted industry-wide for use in the composites industry. It is a mature process for structural design of components.

Impact Crash Simulation
Budget Year 3 – MRL: 4/5

Current industrial practices for structural metallic component design is establishing deterministic material properties, process specific property knockdowns values and fixed crash loading conditions to evaluate the structural and crash performance. This is an acceptable practice for traditional materials where material and process properties are well established. In contrast, the probabilistic properties of the composite material (fiber, polymer) and manufactured microstructure (fiber volume fraction, ply-by-ply fiber orientation, defect size and locations, etc.) as well as loading cases (location, impact velocity, etc.) of CFC is not well identified. This results in a non-optimum weight solution with factor of safety multipliers where a small variation of the CFC properties could significantly impact crash safety.

In addition, current crash simulation packages do not allow changes in geometry, layup or process induced variation in material properties to be iterated easily in one environment. This increases the time for analysis and optimization of the design. A fully integrated software package is needed combining all these features.

To bring Impact Crash Simulation to a significantly higher level of manufacturing readiness, a database with probabilistic material properties of the current commercial thermo-plastic CFC material is needed to consider material variability and allow design with these properties. This includes variability in incoming material, process variability, and joining (composite to metal). In addition, a software package combining all the tools required including the ability to model the probabilistic effects would allow optimization of the design for safety critical applications. Completion of these steps would take two to three years.

Process Simulation
Budget Year 3 – MRL: 6/7

Modeling of the thermoplastic forming is still in its infancy. A comprehensive evaluation of the fundamental mechanisms together with material characterization for forming processing is needed to implement high-fidelity process simulations. To raise the Process Simulation MRL closer to a production-ready level, the team must define and validate fundamental physics of forming, work with exiting process simulation company to integrate into their process solution suite. This process would take up to three years.

Process Capability & Control Subcategory – Manufacturing Process Maturity
Budget Period 3 – MRL: 5/6

This is a field of continuing development efforts by various companies. Fabrication of the thermoplastic blanks is time-consuming and costly, uniform heating (in-plane and through-thickness) is difficult to achieve with conventional infrared heating system. Press requirement during final forming is still not validated. All these technical issues have to be solved to improve process repeatability. Completing these steps to raise the Manufacturing Process Maturity MRL would take three to four years.

Quality Management Subcategory – Inspection Systems and Gages
Systems Related to Incoming Materials
Budget Year 3 – MRL: 5 to 7

The existing instrumentation, inspection techniques, criteria and specifications will be more than adequate for these types of materials.

Facilities Subcategory – EHS
Budget Year 3 – MRL: 6/7

Thermoplastic composites introduce additional evaluations to ensure existing composite protocols are sufficient, but they have been used in several applications for other applications from a B-Pillar. To assess the steps necessary to raise the EHS subcategory to a higher MRL, a finalized production model will need to be produced and the corresponding protocols will subsequently be created.

MRL Assessment Summary

Table 5 details what NCMS and its industry partners felt were the next steps towards manufacturing readiness of the thermoplastic composites.

Table 5. Next Steps for Composite Manufacturing Readiness

<table>
<tr><th>Thread</th><th colspan="2">Sub-Thread</th><th>Next Step Towards Final Development and Validation</th></tr>
<tr><td rowspan="4">Materials</td><td rowspan="3">Maturity</td><td>Nylon Pre-preg</td><td>Full-rate production already demonstrated.</td></tr>
<tr><td>Thermoplastic</td><td>Full-scale production would need to be demonstrated by the supplier.</td></tr>
<tr><td>Co-mingled Fabrics</td><td>Full-scale production would need to be demonstrated by the supplier.</td></tr>
<tr><td>SCM</td><td>SCM</td><td>Formalized supply chain agreements must be established once materials and amounts are finalized.</td></tr>
<tr><td rowspan="4">Process Capability and Control</td><td rowspan="3">Modeling and Simulation</td><td>Structural Design</td><td>Full capabilities already demonstrated.</td></tr>
<tr><td>Impact Crash Simulation</td><td>Create a comprehensive impact crash simulation database. This step would take 2-3 years.</td></tr>
<tr><td>Process Simulation</td><td>Define and validate fundamental physics of forming and work with existing process simulation company to integrate into their process solution suite. This step would take 3 years to complete.</td></tr>
<tr><td colspan="2">Manufacturing Process Maturity</td><td>Press requirement for fabrication of thermoplastic blanks needs to be validated. This step would take 3-4 years to complete.</td></tr>
<tr><td>Quality Management</td><td>Inspection Systems and Gages</td><td>Systems Related to Incoming Materials</td><td>The existing instrumentation, inspection techniques, criteria and specifications will be adequate for the composites.</td></tr>
<tr><td>Facilities</td><td colspan="2">EHS</td><td>A finalized composite production model will need to be produced and the corresponding protocols will be created.</td></tr>
</table>

2.5 Conclusions

The results of Budget Period 3 detailed the next steps necessary to develop and validate the composite materials and processes. It also highlighted several technology gaps in relation to automotive composite structures for crash prediction.

A key finding was the wide range in composite microstructures based on the supplier and material form, and a lack of basic understanding of its effects on properties and performance. It results in different properties and degrees of variability affecting safety for CFC automotive structures.

For automotive applications, cost and performance goals have to be considered together. Various material suppliers are evaluating/fabricating pre-preg material as their primary thermoplastic feedstock for vehicle systems. Traditional thermoplastic pre-pregs (PEEK, PEI, PEKK) are expensive but exhibit high uniformity in terms of void content and fiber distribution with fiber volume fraction in excess of 55%. Lower cost Nylon pre-preg are compatible with most automotive applications but current manufacturing systems lack in terms of fiber volume fraction (40-45%) and exhibit a non-uniform micro-structure. This reduces properties and design allowables which ultimately increases part cost and weight. The process approaches for this class of material needs to be improved, while also keeping low-cost processing viable, to identify new energy-efficient manufacturing processes.

To leverage the accomplishments made in Budget Years 1-3 and address the technology gaps identified, three projects have been proposed by UD-CCM, NCMS, and BMW (Appendix J). The first project would include the development of a statistical database for material properties and applying the database to current B-Pillar design, the second project would extend B-Pillar design to include additional load cases, and the third project would extend the study to consider the safety of an all-composite frame structure. Lasting 24 months, these three follow-on projects would capitalize on the current research and help to further develop and validate cost-effective high strength materials technologies, including Carbon Fiber composites.

3. SMM Outreach and Engagement

3.1 Objective/Purpose

The second objective of DOE-funded JIAC was to engage SMMs (small and medium-sized manufacturers) and Advanced Modeling and Simulation (AM&S) tools in the development and prove-out of the new composite materials. Involving the SMMs and AM&S tools will help ensure the knowledge realized from this study could be utilized to transition into new supply chains in multiple industries (automotive, aerospace, and defense).

NCMS was awarded a multi-year project with specific tasks and deliverables defined. Appendix G encompasses the results associated with the overall three year effort and is considered to be the final roadmap document. In addition, NCMS has provided some general conclusions, benefits achieved, and recommendations.

3.2 Approach/Tasks

Accessing the above results and AM&S tools will allow cluster SMMs to design and develop advanced materials that address improved functionality to meet safety and performance requirements, enhance manufacturability using new lightweight materials, and lower the cost development of new material products. However, it is not simply access but also awareness amongst SMMs that is required if an acquisition of information, tools and technology is desired. The following sections outline the overall NCMS dual approach addressing both awareness and access.

3.2.1 Awareness

3.2.1.1 SMM Outreach

What makes a relationship work? There are many correct answers, depending on the people involved. But the common thread is staying connected – building trust, providing support and communicating. To understand the SMMs, and in particular the InnoState manufacturers targeted, it was important to start with an understanding of the Voice of the Customer (VoC) survey[1]. This included interviews and a Roundtable discussion. The goal was to build relationships with the SMMs in Michigan – to listen, learn, and create opportunities, resources, and initiatives that would directly benefit them. NCMS listened, and learned, and continues to engage and entice manufacturers in Michigan.

Ultimately, SMMs want to be involved, and they won't accept solutions unless they truly believe them to be beneficial. Many other digital manufacturing efforts have adopted a "we have the solution to your problem – now what's your problem?" approach that creates immediate doubt and hostility on the part of SMMs. Thanks to the efforts undertaken with Michigan Economic Development Corporation (MEDC) funding as part of this project, NCMS was able to integrate SMMs earlier and build lasting relationships leading toward a bright digital future.

Relationships
NCMS is fortunate to be part of many manufacturing initiatives in Michigan and able to leverage those relationships to connect to SMMs in the area. Through InnoState, NCMS has developed relationships with the Michigan Manufacturing Technology Center (MMTC), our local Michigan Extension Partnership (MEP); the Detroit Regional Chamber; and the Workforce Intelligence Network of Southeast Michigan (WIN).

NCMS partnered with the Center for Automotive Research (CAR) to build capacity

[1] Both the Michigan and subsequent Ohio VoC reports can be found at http://www.doitindigital.com/ *Crain.*

and capability in the bio-materials manufacturing sector in Michigan under the Make It in America (MIIA) Federal grant. Further, NCMS was part of the task force team that submitted the “Advance Michigan” proposal that led to the regional designation to receive major Federal investments aimed at revitalizing manufacturing through the Investing in Manufacturing Communities Program (IMCP). NCMS, along with CAR and MMTC, exclusively wrote the supply chain engagement section of the proposal and NCMS was responsible for the majority of non-automotive industry support the team received.

3.2.1.2 Manufacturer’s Roundtable

Once the VoC survey was completed, NCMS had gathered enormously rich data – a lot of it. Not only did the survey give insight on SMMs in Michigan, but the in-depth interviews helped to create personas of the Michigan manufacturer as well as insights into their thought processes and character. Supporting research showed conclusively that much of the information NCMS had gathered was unique – despite volumes of data on manufacturing, truly intimate portraits of the rational and emotional mindset of the SMM were nowhere to be found outside the NCMS data. This made the data all the more valuable, and revealed much about how SMMs work, think, and feel.

NCMS found the “Top 5 Pain Points of SMMs in Michigan” and needed to take it a step further and validate the findings. NCMS talked to the SMMs that took part in the survey and confirmed that the pain points heard were the ones to be focused upon, and then continued to use the VoC to create solutions for those pain points.

NCMS moved forward with an outlet for several SMMs to connect – an opportunity for them to talk, and an opportunity to continue listening. By partnering with *Crain’s Detroit Business,* a highly influential media partner in Michigan, NCMS leveraged a Roundtable promotional slant that achieved two purposes: promote the VoC study, and offer some free marketing to the SMMs by shining a media spotlight on their participation, which was a valuable incentive for attendees. Nine SMMs from the study were selected and an organized event was arranged with Crain’s and hosted by Lawrence Tech University in Southfield in March 2014.

The event was capped at 2 ½ hours, but could have gone on much longer. SMMs were happy to engage – eager to do so, in fact. They were opinionated, articulate, and willing to share what they thought . . . provided they felt they were being listened to.

The Roundtable started with the Top 5 Pain Points as itemized by the survey: Desktop Computing, Skills Shortages, Process Capability, Shop Management and Advanced MS&A. All five were validated as major concerns among the SMMs, and all the participants shared narratives about concerns in day-to-day operations. Workforce development was a hot topic at the Roundtable; how to train the employees you have and how to recruit new talent. When the discussion turned to new tools such as digital manufacturing, the group focused on the barriers to adoption. As expected, those barriers tended to return to the same sticking points: Risk and Cost. SMMs *can’t* assume the adoption risk, and they don’t want to anyway because many aren’t convinced that digital manufacturing will directly benefit their operations. Meanwhile, even if risk weren’t a factor, the pricing models for MSA software and hardware are designed for big companies and National Labs, not 10-25 employee engineering houses. In general, SMMs were willing to entertain the idea that digital manufacturing had merit; they just hadn’t seen proof yet, and they certainly hadn’t encountered pricing that worked with their tight margins.

The second half of the Roundtable focused on solutions: how to help SMMs stay competitive and grow their business despite the ongoing challenges. Many attendees acknowledged that the Michigan Digital Manufacturing Grid Cell had great potential benefit as a resource, especially when described as – a safe place to collaborate and experiment with new techniques and tools. NCMS' partnership with UberCloud's HPC Experiment was also offered as a solution; a funded, safe way to try MSA in the Cloud.

The Roundtable was designed as an end to the SMM market research project in Michigan – a way to validate findings and give a voice to SMMs. It also served as a starting point to build on the relationships created with the survey. It gave NCMS a foundation of SMMs to work with and rely on for knowledge, engagement and the foundation of a planned SMM advisory group, an important next step in this process.

Modernizing Manufacturing: How to Bend Without Breaking
The Roundtable was a success in every sense of the word. The lively discussion covered the future of SMMs in Michigan and around the country, as well as the tools that those manufacturers want (and don't want) moving forward.

3.2.2 Access

3.2.2.1 Experimental Portal Development

NCMS began with the concept of a Grid Portal™ as the virtual portion of a network, intended to provide a secure collaborative space for manufacturers to engage with digital capabilities. From that perspective the vision for the Portal has not changed significantly since the beginning of the project. What has changed is the team's understanding of the requirements, priorities, approach, and strategy associated with the effort. This change is a direct result of the Experimental Portal (ExP), a prototype and combined technical standards development project undertaken by NCMS and its partners in 2013. NCMS approached the ExP development with a number of goals in mind. The original intent was to develop something that could simultaneously serve as technical standards and a functional wireframe suitable for demonstration of the Portal vision.

The team's roadmap for ExP included:

- Develop visual and text standards for layout and navigation.
- Identify technology providers and software framework.
- Begin creative work on interface and user experience.
- Prototype conceptual Portal functionality.
- Create a demonstration-friendly version for show.
- Sort priorities into "desire" and "required".
- Conduct usability testing with a blind focus group.
- Gather and analyze feedback for future Portal efforts.

Building a robust electronic community and marketplace capable of delivering the functionality NCMS had originally envisioned is no easy task. This fact was made even clearer by the ExP project. It became clear early on that the development process was raising a host of new questions no one had considered; questions that – in some cases – NCMS was not qualified to answer on its own. The team treated it as an opportunity to improve its strategy. The lessons learned from the ExP investment put the team on the right track, and probably saved significant time and money in the long term

NCMS had a clear vision for the Grid Portal™ and a long list of ideal features, but it is not an enterprise software developer. For that the NCMS turned to its membership, and in particular, members of the NCMS Digital Manufacturing Strategic Interest Group (DM SIG). Leveraging its collaborative model and members NCMS partnered with Perficient, Inc., a global leader in business technology solutions with a major hub office in the State of Michigan. Since Perficient specializes in developing functional visual standards, or "wireframes," of web-based software, its presence on the team provided technical expertise and a demonstration-ready product as part of the standards.

3.2.2.2 Technical Standards & Requirements

NCMS developed a written technical standards document that provided an overview of the vision for site functionality, layout, interface, security, and accessibility (Appendix H). In enterprise software development, written standards documents can quickly grow to hundreds of pages. Written standards are also "living," in the sense that it is nearly impossible to write the standards and set them in stone. A constant stream of findings, features, changes, and new issues materialize throughout the development process, necessitating ongoing changes to the written standards.

In addition to the written standards, NCMS and Perficient elected to develop a "visual standards" document using an enterprise tool called iRise™. Visual standards complement the written ones by providing a navigable wireframe of the software's structure, layout, and interface. For all intents and purposes, wireframes developed in iRise™ *look* like fully functional websites – the difference is there is no underlying code powering the software. For analogy, imagine a concept car at an auto show: it is designed to look street-ready, with its glossy paint and fully appointed interior… but raise the hood and there's no engine, because the engine hasn't been invented yet.

3.2.2.3 Visual Standards

If you look at an iRise™ wireframe, you'll see what appears to be a fully functional website (Figure 3). It runs in a browser, the graphics and copy are in place, all the buttons work. In fact, even an expert can't tell at a glance that an iRise™ wireframe is not the real thing.

This intermediary step between writing out the vision and actually making a working program seems rather pointless to some. Why go to the trouble of building something that looks functional when you can build something

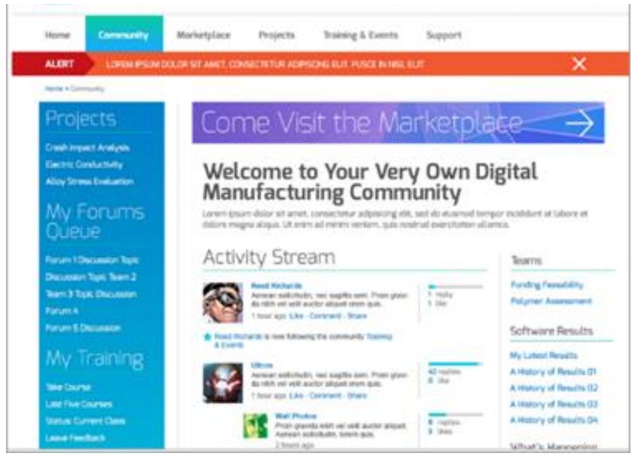

Figure 3. Wireframe Screenshot

functional? Because wireframes like those built in iRise™ bridge the huge gulf between the creator's vision and the working application. More bluntly: nothing works as well in reality as it does in the imagination, and there's no way to test-drive written standards. With a functional wireframe, developers have a foundation to iterate and improve long before they have committed the time and resources necessary to build something fully functional. Programmers use visual standards to experiment with the software's interface and navigation, while artists and user-experience creators populate the wireframe with content that is easy to transfer to the working environment and already matches the standards in the visual definition.

3.2.2.4 Preliminary Business and Implementation Standards

Part of the ExP development called for a set of high-level parameters defining the business requirements and technical foundation of the tools to be developed. Like all standards development, these parameters are iterated upon constantly and represent a logical framework, not hard rules. A summary of these requirements are shown in Table 6.

3.2.2.5 User Roles and Personas

Access and usability are important questions in software development. Who will use the tools, what they will use them for, and what they

Table 6. Business and Implementation Requirements

I. Business Requirements for the Grid Portal™

Objective: hasten the adoption of Digital Manufacturing techniques by…

- Creating a powerful, secure, web-based environment to draw industry adopters into a Digital Manufacturing community
- Providing tools to share knowledge, expertise, and experience
- Developing and/or deploying available training on Digital Manufacturing concepts
- Democratizing price and access to high-level MS&A tools

Terminology

- "Categories" are pre-defined, high-level associations tied to site elements and used for searching, navigation, and organization purposes. Only site administrators can create, assign, or modify Categories.
  - Example Categories: "Software," "Training," "Help"
- "Tags" are granular, user-generated associations created by site participants above a certain level of access. Tags allow more customized searching and navigation, plus a more personalized site experience.
  - Example Tags: "CFD," "Proposals," "Heat Exchanger"

Legal

- Terms and conditions must be presented and agreed to by all users upon first login

II. Technical Parameters

Software

- The Grid Portal™ will be powered by Microsoft's SharePoint™ content management system
- Additional external software may be closely coupled with the Grid Portal and should function seamlessly. This software may include other online MS&A marketplaces, product catalogs, community tools, learning management systems, etc.
  - The site engine is responsible for invisible handshakes and cross-authentication with other services and tools, online and off

III. Security

- The system must be cross-browser compatible and built to World Wide Web Consortium standards for HTML 4, CSS 3, JavaScript, ActiveX, Silverlight, Django/Python, Ruby 3, Rails 2, and .NET
- All content is to be delivered via HTTPS
- Users exist as "Authenticated" and "Unauthenticated"
- All user information, including information not considered personally identifiable, will be hashed and salted for storage at all times
- Account Security
  - Authentication will require a unique username and password
  - The site may inherit password rules from another Microsoft system
  - User must have the ability to reset their password
  - Passwords must be at least six characters and must include at least one uppercase character, one lowercase character, and one numeral
  - Passwords must be changed every six months. Reusing former passwords is not allowed.
  - Accounts cannot be shared
- Unauthenticated Users will not be able to view or access Autheticated pages
- Each Authenticated User will have their own customizable My Stuff page. By default, this page will display their selected Events, Training, Tools, Purchases, and Profile.
  - Upon login, users will land at their My Stuff page
  - No user may access another user's My Stuff page except site Administrators

should and should not be allowed to do and see are all critical. NCMS and Perficient devoted about 20% of the ExP resource allocation to developing the following user logistics and definitions:

Entity: an individual or group of individuals with attributes outside the system user roles. The primary function of an entity is to allow flexibility for purchasing control and ownership or licensing of digital products, so legal issues of ownership are tied to the entity rather than the user.

Individual Entity: a single registered user.

Organizational Entity: a group of registered users that are part of a legal organization (for example, ten users all working for the same company are part of one Organizational Entity. When one licenses software from the Grid Portal™, the license is held by their Organizational Entity, not the individual user who clicked the "Buy" button).

Collaborative Entity: a group of registered users and/or Organizational Entities operating under a binding agreement such as a Memorandum of Understanding.

User Roles: "users" are defined by their state of authentication and level of access.

Guest: anyone who has not registered for the site, and any registered users who are not logged in, are automatically Guests. Users flagged as Guests have "Look Only" privileges, meaning they can browse training and tool catalogs and visit other public areas of the site, but cannot purchase, license, or participate.

User: referred to as a Contributor in SharePoint. A User is registered on the site with an active account. Users have "Look and Touch" access but no special privileges. They have all the access of Guests, plus their own My Stuff page and the ability to purchase and/or license software and training and participate in the community (unless restricted by a superior permission level or Organizational Entity).

Provider: referred to as an Elevated Contributor in SharePoint. Providers are registered Users that own content in the Tools/Training areas. They have "Look, Touch, and Control Possessions" access, but can only control things they own. Providers have all the capabilities of Users, plus the ability to add, create, edit, and delete their products on the marketplaces; view, modify, and delete transactions related to their products; and use their own products without charge.

Manager: referred to as an Owner in SharePoint. Managers are "Look, Touch, and Manage" Users with the (limited) ability to administer Entities belonging to the Organizational or Collaborative Entity over which the Manager has control. For example, the Manager of Organizational Entity A would be able to create, add, and remove Individual Entities from A, offer and revoke certain access permissions, send messages to fellow Entities in their Organization, and administer Organization and/or Collaboration hub pages. Managers may also be Providers. Manager might be a temporary role, as a User or Provider is temporarily placed in charge of an Organizational or Collaborative Entity.

Administrator: as the name implies, this role is a high level administrative access and must be assigned with caution. Administrators have "Look, Touch, Control, Manage, and Destroy" access to ALL SITE LOCATIONS AND USERS with the exception of Root and Root Exclusive Components. They have all the rights of all lower level users (i.e. an Administrator has Manager access to ALL Entities, while a Manager has access to only those assigned).

Root: User Zero is referred to as Root, a single user account with "God" level access, including access to the System Core, databases, and runtime, including soft site code and forbidden fail-safe actions. Root is the only user able to define new User Roles and Entities, and the only user who can assign or revoke Administrator privileges. Otherwise Root has total control over all elements of the site except hard-coded limitations (for example, even Root cannot view hashed and salted data, and no one can revoke or reassign Root's own credentials).

Personas

Personas are imaginary characters created by application developers to represent the different individuals who might access a site or use a piece of software. Personas can (should) be enormously detailed – they're given names, families, interests, backgrounds, problems, even pets. The idea is to "roleplay" actual use cases, forcing oneself to think in the character of a clearly defined persona rather than his or her own perspective. Properly applied, they can help identify and correct many issues well in advance of release.

NCMS provided several User Personas based on market research performed to date. Subsequent market research has suggested potential changes to these personas, but the team elected to address that later since the ExP development was at an end.

3.2.2.6 Development and Focus Testing

Throughout the Summer of 2013, NCMS and Perficient teams worked closely on the ExP development, and met the goal of completing standards and visualization in time to demonstrate the wireframe at the Digital Manufacturing Revolution event on October 2.

In addition to the live demo, the team conducted nine hour-long focus testing sessions with individuals chosen to represent a broad spectrum of likely site users. Participants included software vendors, educators at local colleges and universities, manufacturers, and members of manufacturing non-profits. In one-on-one sessions, the participants discussed and explored the ways that they might potentially use the features and functions of the prototype. Using a "think-aloud" protocol, participants articulated on key areas of the prototype: the homepage, projects, community, training & events, and marketplace.

The purpose of focus testing was to understand the perspective of a potential user:

- Their expectations for key information.
- What they considered most important.
- Terminology or navigation issues that interfered with successful use.
- Portions of the ExP that worked well.
- Missing functionality, content, or services that users expected or would like.

Overall, the focus participants liked the ExP site concept and believed something like it would be of value to them. Almost all judged the page layout and overall look and feel to be professional and appealing. Generally, focus testers' complaints fell broadly into a few categories:

- Lack of clarity on how some site features would work.
  - Insufficient explanatory content in key areas.
  - Confusion over who could participate in site activities.
  - General misinterpretation of terms like "Project" and "Featured".
- Community Page concept and layout.
  - Too many generationally unfamiliar terms ("Activity Stream," for example).
  - Navigation shift seemed jarring.
  - Banner space misinterpreted as advertising.
  - Issue of competitive risk associated with an active community.
- Marketplace Page.
  - Confusing dashboard.
  - Unclear delineations of products.
  - Pricing model was deemed overly simplistic.

The purpose of a focus test is not just to *hear* the negative stuff, but also *listen* to it, remembering that focus testers are also potential customers, so their viewpoint is highly relevant. What matters is what one *learns* from them.

3.3 Results

The ExP project proved that the team needed to conduct more market research and carry out more engagement efforts with the community of SMMs in Michigan. What SMMs wanted was somewhat different from what was originally thought. This led to a strategic rethinking about the importance of market research and SMM engagement, something that is now one of the driving factors in the strategy.

In retrospect it may have been preferable to spend more time on concept and planning rather than building anything, despite the risks of not having a demo version to show. While the lessons learned were harsh in some cases, the ExP was immensely valuable to the overall effort: it made the team much more keenly aware of where attentions should be focused for the rest of the project (Appendix I).

3.4 Conclusions

Among the many lessons of the ExP was an incontrovertible fact: the team had, to some degree, overestimated their understanding of the market. Small and medium enterprises, those Backbone Manufacturers who stood to gain so much from Digital Manufacturing Grid Cell access, were far less receptive than believed.

The truth of this was not in question; ExP focus testing was just one finding that validated a growing concern about awareness and interest from the key SMM demographic. The question was how to handle it.

What was deemed necessary was a new and open-minded attempt to engage and learn about the target market, free from any wishes or assumptions that had been held to date. With that in mind, NCMS set out on what would become the most important new element of the Grid strategy: a clean-slate outreach to the SMMs in Michigan. A full report summarizing this effort and its findings is at www.doitindigital.com

4. Recommendations

It has been a pleasure and a challenge working the InnoState program. As a multi-agency funded effort interwoven with a variety of other collaborations both in the State of Michigan, it was important to ensure NCMS addressed the DOE requirements and deliverables while appropriately leveraging the various other ongoing activities. In the end, this effort not only accelerated the adoption of composites for lightweighting applications, it successfully created an awareness of the technology and tools for SMMs in the State of Michigan and beyond. However, there remains much to do.

This project worked with both aerospace and automotive manufacturers addressing the manufacturing readiness of composites. While much of the development work was funded by the industry partners, this effort helped to document a MRP. There remains much to do to see these materials as viable, broadly utilized options. NCMS is proposing for DOE's consideration a White Paper (Appendix J) authored by the University of Delaware and BMW as an opportunity to continue this effort. Taking the work already done at a component level and exploring the implications at a full vehicle level would both validate the MRP and begin to further elevate the MRL/TRL of these materials.