



The Digital Manufacturing Institute

MxD PROJECT RECORD

TERMINATION REPORT

DMDII-14-03-01:

Digital Manufacturing Commons

Revision 1.0 Date: July 30, 2020

Contact: Daniel Reed
Senior Project Engineer
MxD
projects@mxdusa.org

MxD
1415 North Cherry Ave
Chicago, IL 60642

SPONSORSHIP DISCLAIMER STATEMENT: This project was completed under the Cooperative Agreement W31P4Q-14-2-0001, between U.S. Army - Army Contracting Command - Redstone and UI LABS on behalf of the Digital Manufacturing and Design Innovation Institute. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Department of the Army.

DISTRIBUTION STATEMENT A. Approved for public release; distribution unlimited.

TABLE OF CONTENTS

I.	Record of Change.....	3
II.	Executive Summary.....	3
III.	Introduction and Background	3
IV.	Project Outcome Summary	4
V.	Technical Summary of Intended Scope	5
	Technical Requirements.....	5
VI.	Project Final Outcome	11
	Lessons Learned	11
	Milestones Achieved.....	13
	Deliverables Received.....	14

I. RECORD OF CHANGE

Revision	Date	Sections	Description
1.0	30 July, 2020	N/A	Original

II. EXECUTIVE SUMMARY

The Digital Manufacturing Commons (DMC) was envisioned to be an open-source platform to foster real-time collaboration among various stakeholders across the engineering lifecycle. The platform would democratize the development and use of design-build tools by hosting a cloud-based marketplace for digital thread applications. The DMC would leverage foundational CAD and analysis tools but also encourage an ecosystem of user-based applications through open application programming interfaces (APIs) and services. These key innovations would enable both professionals and community contributors to design components, together or independently, and then utilize the myriad of DMC-based tools to analyze, test and harden those designs before release.

This platform would be overlaid with identity controls to allow users to secure or share their projects, models and data openly or in a secure manner. This would allow a broad range of use cases from open-source, community-driven projects to efforts driven entirely within internal organizations. The DMC would enable the US industrial and innovation ecosystem by connecting the right people with the right data and the right tools for advanced design and analysis.

Technical development commenced for two years, but the program was impacted by both technical and programmatic obstacles. These obstacles were managed effectively until the project was no longer feasible, cost-effective, or advancing along set milestones. At that point, the program was cancelled because it no longer aligned with the needs of the membership base. The team recouped project work and the investment was ported into what became and currently serves as the institute's Membership Portal, housing member-only project and technical information.

III. INTRODUCTION AND BACKGROUND

MxD (then DMDII) is the nation's flagship research institute for applying cutting-edge digital technologies to reduce the time and cost of manufacturing and strengthen the capabilities of the U.S. supply chain, and reduce acquisition costs for the DoD. DMDII worked to develop and demonstrate digital manufacturing technologies and then deploy and commercialize these technologies across key manufacturing industries.

The goal of this project, "Digital Manufacturing Commons," was to establish and implement the core elements of the Digital Manufacturing Commons (DMC) as an open-source platform for secure and trusted real-time collaboration during the design-make process and to develop an initial set of foundational applications that utilized the DMC platform which were seen critical to the function of the Institute.

The DMC was architected as an open-source platform with the goal to revolutionize the way products are designed, made, and distributed by facilitating collaboration, data analysis, and integration across all parts of the product life cycle. It was envisioned that the DMC would bring together approximately 1 million users—thousands of SMEs, manufacturing companies, and universities—to collaborate on manufacturing and to accelerate technologies that integrate the digital thread.

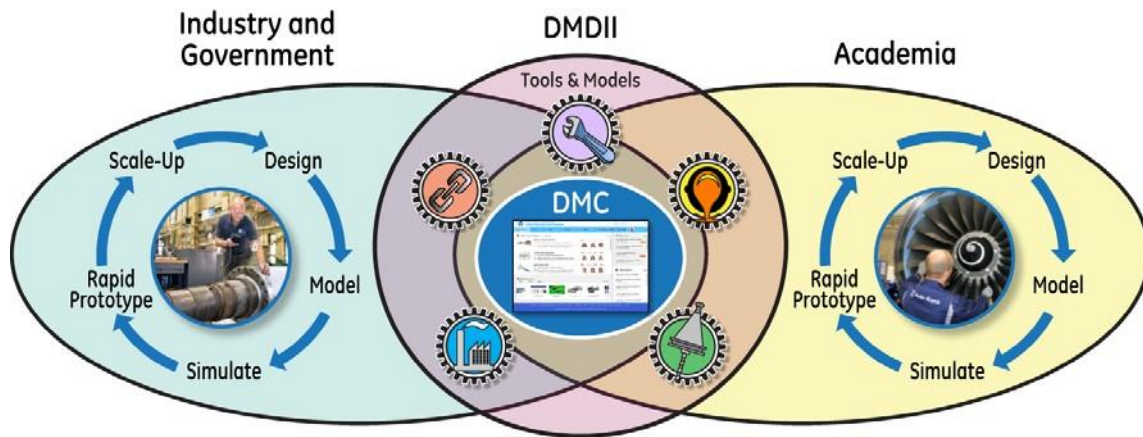


Figure 1. Illustration of what Digital Manufacturing is and what part of the process the DMC covers. Design innovation is the ability to apply these technologies, tools and products to re-imagine the entire manufacturing process from end-to-end.

The DMC would enable a fundamentally new way for digital information to be collected and used across the entire product life cycle, to and from intelligent machines and workers on the shop floor, and through supply chains. The DMC was to be a mechanism for project collaboration among Institute members. The DMC would provide a low barrier-to-entry collaboration platform where the broader digital manufacturing and design innovation community can contribute content. The DMC platform would allow distributed teams to collaborate within a common virtual workspace, allowing designers and makers to work together on projects by sharing data and files. The DMC would allow connections to software and analysis tools, cloud computing and high-performance computing. The structure of the DMC would allow for the addition of functionality in the form of applications from a broad community.

IV. PROJECT OUTCOME SUMMARY

Development on the Digital Manufacturing Commons was halted on April 15, 2017. Until that point, the team had built a platform with identity controls, active workspaces where organizations could run multiple physics-based apps, a marketplace that hosted available applications, an institute member portal, and an interface point for digital manufacturing workforce development content.

DMDII along with its members and Executive Committee explored many potential applications of the DMC platform and evaluated its corresponding software development business model. That analysis showed that DMC's DOME-based architecture involves significantly higher development and maintenance costs as compared to more modern micro web services and container-based approaches. The consensus feedback across DMDII partners was that the DMC as originally conceived will not drive a significant ROI for their organizations and will be too costly to successfully scale. As a result, DMDII shelved its work on the DOME-based platform and has actively pursued new lightweight, commonly used architectural models that can more cost-effectively support specific cloud-based applications on an as-needed basis.

After it was determined that the DMC did not meet the current needs of the membership, UI Labs leadership decided to focus on the member portal component of the DMC. This decision was made due to mounting technical risk and lack of engagement by the broader consortium, which was an

indicator that there was not clear value to the target customer base. A portion of this disinterest could be related to the fact that the DMC posed a competitive platform to the larger solution providers in the institute's ecosystem, but also to the fact that the simulation marketplace concept was still ahead of its time. The technology is feasible as demonstrated by the DMC, but the market is still immature.

Most of the manufacturing sector still incorporates traditional business processes that are rigid and siloed. Thus, the adoption of such a platform would be reliant on more than traditional marketing, engagement and training, it would also have to be focused on selling the benefits of distributed manufacturing and a new way to do business. Due to its marketplace/commons concept, the DMC's value proposition required engagement to create a community of value. While the technology to create a physics-driven simulation marketplace was feasible, the amount of investment in time and technical resources to populate the platform with user-submitted content was not a compelling value proposition to the UI Labs membership at the time. Overall, the key takeaway is that the platform contained technological interest and potential, but did not have sufficient product/market fit and was not something the membership was willing to invest further in. Having made this determination, the team pivoted towards refining the piece of the DMC that had clear value for the consortium moving forward.

The Member Portal was a platform that incorporated many of the community-driven features of the DMC such as identity authorization and access controls but had a much more directed focus. The Member Portal was built as MxD's engagement platform, to allow all members of the consortium to interact and get access to the latest information on events, workshops, and most importantly, enterprise projects. At its core, the portal would host all the technology outcomes for the institute's research portfolio and members would be able to access these outcomes in accordance to their tier level as defined by the institute's Membership Agreement. The Member Portal is the main access point to MxD's R&D deliverables and is still in use today.

V. TECHNICAL SUMMARY OF INTENDED SCOPE

TECHNICAL REQUIREMENTS

Task 1 – Software Development

Rationale

The team will use an Agile approach to build the DMC operating environment to include the core infrastructure, test environments, user interface (UI) and user experience (UX), feature planning and development, as well as feature extensions and releases over the period of performance. The DMC will integrate with an existing identity provider to provide various levels of access and different types of user authentication. The system will also undergo third-party security assessment and functionality testing. The system will include demonstration models based on a broad community application and one with a military focus and will allow for custom executable models.

Approach

An Agile development process is envisioned for the DMC. Agile development processes emphasize early feedback and accommodating evolving requirements. An Agile approach will proactively accommodate these changes quickly.

Task 1.1—Establish Core Infrastructure (Q1, 2015)

Task 1.2—Establish Performance Testing Environment (Q1, 2015)

Task 1.3—Develop UI/UX (Q2, 2015)

Task 1.4—Plan Features (Q3, 2015)

Task 1.5—Develop Capability, Feature Extensions and Releases (Q1, 2015 – Q3, 2016)

Task 1.6—Integrate Large Scale Identity Provider (Q2, 2015)

Task 1.7—Asses System Security, Enhancement and Patching (Q3, 2015)

Task 1.8—Customize Site (Q1, 2015 – Q3, 2016)

Task 1.9—Integrate Information Technology Infrastructure (Q1, 2015 – Q3, 2016)

Task 1.10—Complete Software Quality Assurance (Q1, 2015 – Q3, 2016)

Milestones

- Prioritized software development backlog – Q1, 2015
- Initial release of DMC branded website – Q2, 2015
- DMC platform release with recommended security risks mitigated and validated – Q3, 2015
- Software quality environment established and populated with initial testing procedures – Q1, 2015
- Software release incorporating newly developed user experience and functionality – all quarters

Task 2 – Administrative Services

Rationale

Administrative services will be developed to manage the underlying processes to keep the DMC secure and functioning as expected. These include processes for enrollment of individuals and groups, security, and risk mitigation, Governance procedures and user and website support.

Approach

An Agile development process is envisioned for the DMC. Agile development processes emphasize early feedback and accommodating evolving requirements. An Agile approach will proactively accommodate these evolving changes quickly.

- *Task 2.1—Develop, manage and maintain process to enroll individuals into the identity service (Q1, 2015 – Q3, 2016)*
- *Task 2.2—Develop, manage and maintain process to enroll groups into the identity service (Q1, 2015 – Q3, 2016)*
- *Task 2.3—Establish, manage and implement security and risk mitigation procedures (Q1, 2015 – Q3, 2016)*
- *Task 2.4—Establish and manage governance procedures (Q1, 2015 – Q3, 2016)*
- *Task 2.5—Establish and manage UI and website (Q1, 2015 – Q3, 2016)*

Milestones

- Initial DMC user Identity established – Q2, 2015

- User support documentation released – Q4, 2015

Task 3—Community Onboarding

Rationale

The team will develop a methodology to train individuals to use the DMC to ensure the longevity of the DMC.

Approach

An Agile development process is envisioned for the DMC. Agile development processes emphasize early feedback and accommodating evolving requirements. An Agile approach will proactively accommodate these evolving changes quickly.

Task 3.1—Develop and test digital lab onboarding framework (Q1, 2015 – Q3 2015)

Task 3.2—Develop training, documentation and DMC system engineering workshop (Q1, 2015 – Q3 2015)

Milestones

- Initial DMDII funded project on-boarded to DMC – Q3 2015
- Hosted semi-annual DMC workshop – Q3, 2015 and Q1, 2016
- Initial DMC use cases deployed and publicized – Q2, 2015

Task 4 –Community Management

Rationale

The team will develop strategies for sale and marketing the DMC. This includes developing a knowledge center to inform users of things such as, “how to... and FAQs”.

Approach

An Agile development process is envisioned for the DMC. Agile development processes emphasize early feedback and accommodating evolving requirements. An Agile approach will proactively accommodate these evolving changes quickly.

Task 4.1—Develop and implement a marketing and sales strategy (Q1,2015– Q3, 2016)

Task 4.2—Develop and Implement a User’s Knowledge Center (Q1, 2015 – Q3, 2016)

Task 4.3—Develop a process to Manage DMC content (Q1, 2015 – Q3, 2016)

Milestones

- Knowledge center released as part of DMC platform – Q1, 2016

Task 5—Program Management

Rationale

The Principal Investigator will monitor the development process to ensure all deliverables are being met on-time and on-budget. The Principal Investigator will also be responsible for recruiting talent to fill key positions required at the DMC

Approach

An Agile development process is envisioned for the DMC. Agile development processes emphasize early feedback and accommodating evolving requirements. An Agile approach will proactively accommodate these evolving changes quickly.

Task 5.1—Kick-off (Q1 '15)

Task 5.2—weekly items of interest (Q1, 2015 – Q4, 2016)

Task 5.3—monthly meetings and updates (Q1, 2015 – Q4, 2016)

Task 5.4—Quarterly reports (Q1, 2015 – Q4, 2016)

Task 5.5—Recruitment and hiring (Q1, 2015 – Q4, 2016)

Task 5.6—Transition DMC to long term operations team (Q1, 2015 – Q4, 2016)

Milestones

- DMC operations transferred to UI Labs – Q3, 2016

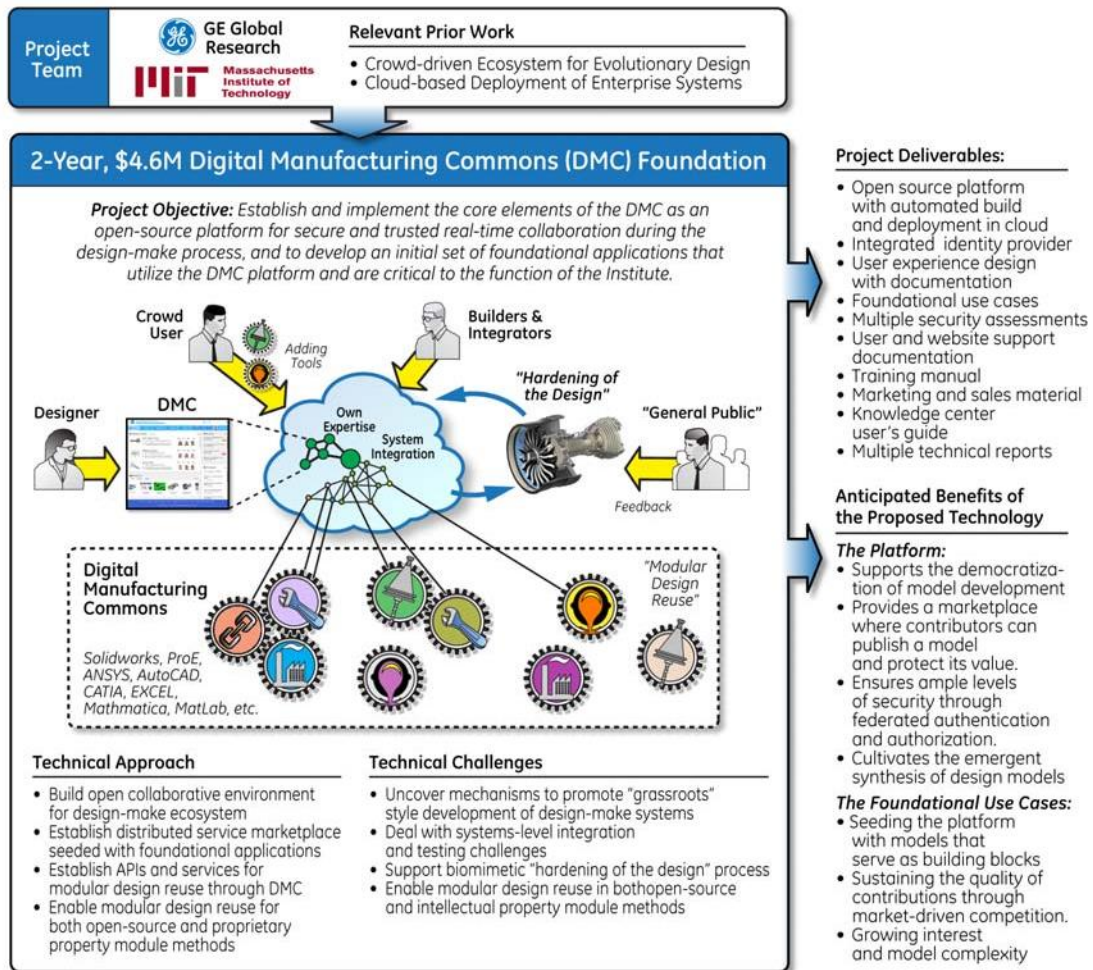
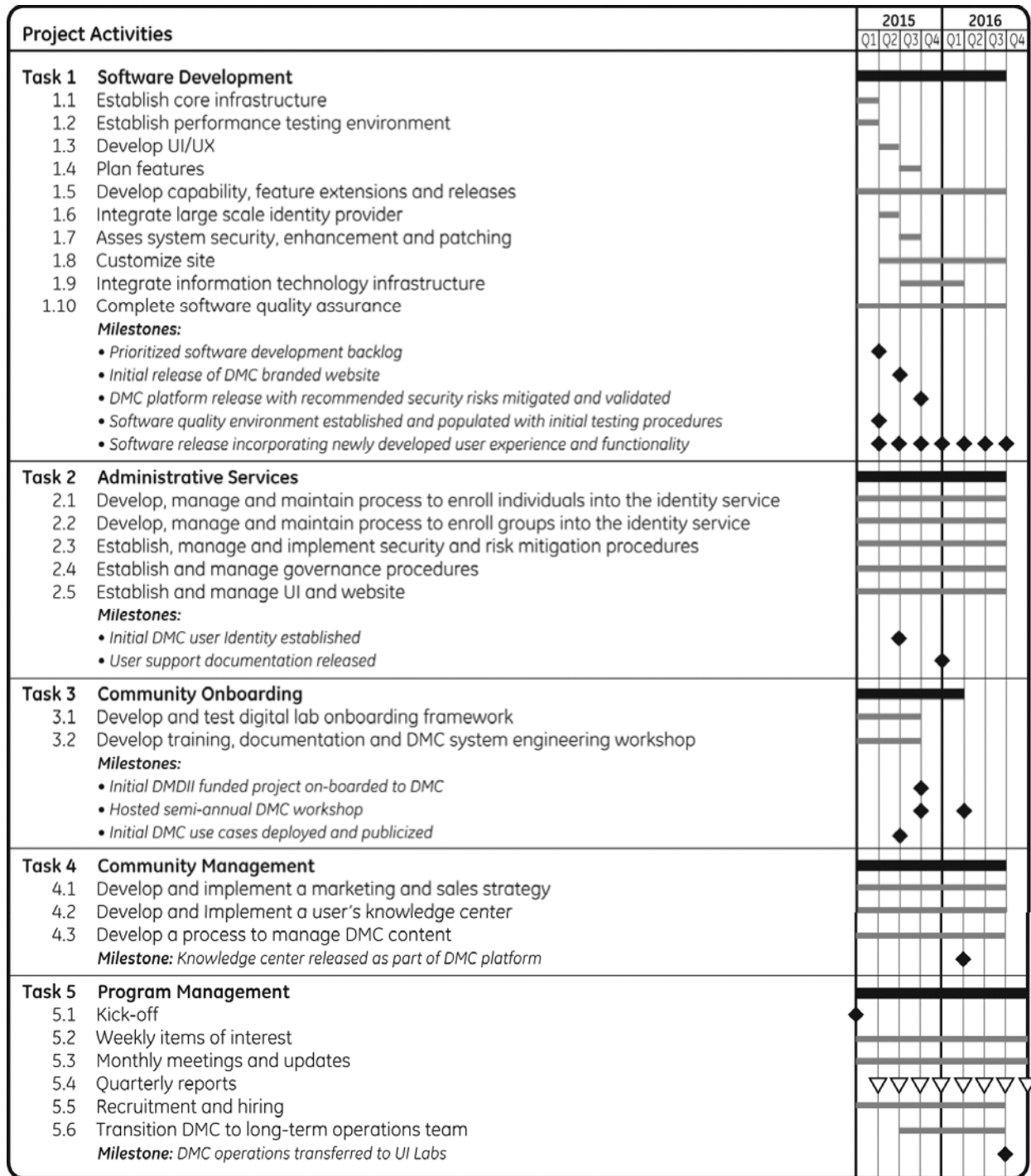
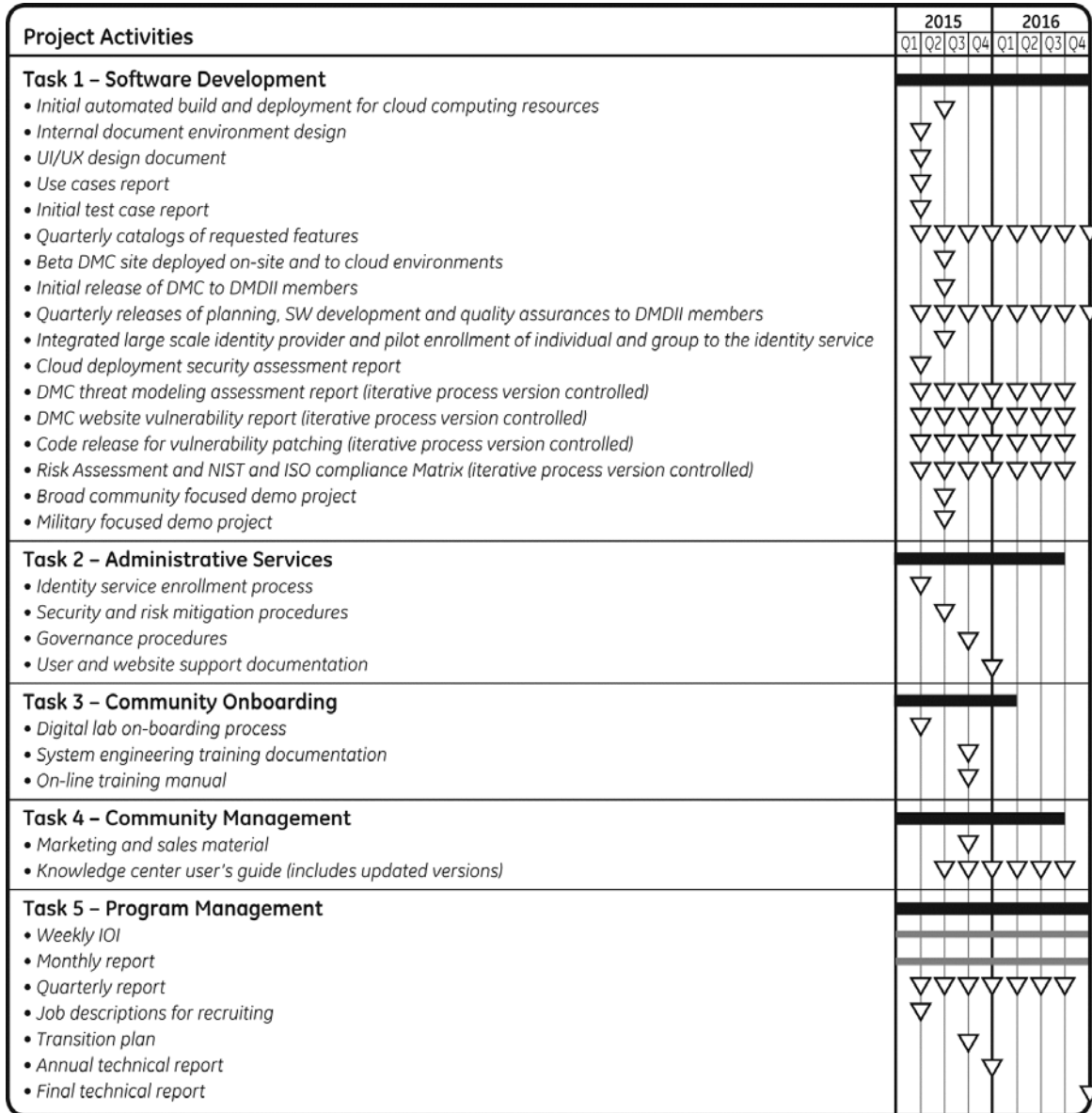


Figure 2. Summary of the proposed project.



Legend: ◆ Milestone ▽ Deliverable

Figure 3. Schedule, tasks, and milestones of the proposed program.



Legend: ▽ Deliverable

Figure 4. Program deliverables.



VI. PROJECT FINAL OUTCOME

LESSONS LEARNED

The DMC was built off a code base that was advanced at GE after being received by MIT. This core technology—the Distributed Object-based Modeling Environment (DOME)—possessed some of the functionality required by the DMC as a baseline, however it also represented a large volume of legacy code. This presented significant challenges as a greater-than-expected amount of work was needed to design interfaces around DOME to support new features. Due to extensive costs and the unforeseen risks that would not materialize until later in the project's future, the program did not decide to modernize the core intellectual property with new technology. In hindsight, this would have been the more efficient path as a considerable amount of work was put into developing compatible interfaces over building new value.

In addition to the challenges posed by the legacy code base, there were additional challenges that arose that put additional technical pressure on the team. On July 1, 2015, the Digital Manufacturing and Design Innovation Institute (now MxD) released the “15-16: Open-Source Software Applications for Digital Manufacturing” project call that was focused on funding proposals for populating the DMC with open data and applications to demonstrate how open applications can solve real world problems for manufacturers. This project call was the next step in the platform's product roadmap but added additional challenges for the team. The internal team was now in the core of platform development but also balancing the unique project integrations as well. Each of these integrations required hands-on time with the project participants to understand unique project-specific requirements, design and develop the appropriate interfaces and employ effective technology management across the project.

Programmatic Lessons Learned

As with all endeavors, the technical soundness of a venture does not always correlate to its success. In the case of the DMC, there were many programmatic issues that presented obstacles to the UI Labs technical team in completing their objectives for the platform and ultimately led to the cancellation of the project. The programmatic hurdles are described in detail below.

The delay in project contracting was a major issue impeding the successful execution of the 14-03-01 project. The project call was released on July 1, 2014, but due to difficulties in pre-award negotiations, the final award was not administered until October 1, 2015. Unfortunately, the delays to the project start did not only shift the expected project kickoff date, it disrupted the availability of the planned resources that were going to participate on the project from GE Global Research. GE had a team of qualified engineers and developers that were proposed to support the effort, but due to the timing of the award and internal issues at GE, the organization could not retain a sufficient workforce to staff the development of the Digital Manufacturing Commons. Per the initial contract, GE was contracted to complete the development and provide the technology to UI Labs to operate and maintain. Due to the difficulties they faced with inadequate staffing and lack of organizational resources, what they provided was reduced to the DOME legacy code base and some design resources, which was a fraction of what they were obligated to provide in the contract. Due to the nature of the consortium and GE's current situation, accountability was shifted away from the GE team and absorbed by UI Labs. The UI Labs team



was then mobilized to recruit a team of technical resources outside of their original staffing plan and complete the development internally.

One of the biggest lessons learned was related to product management. The vision for the DMC was transformative, but the broad multi-functional design of the platform also increased complexity and reduced focus. This was a common theme for the DMC team as the potential for the platform was extraordinary, but the scope was too large to properly demonstrate the business value in the period of performance.

Additionally, this problem was exacerbated because of a consistent change in product leadership and technical staff. There were seven changes in executive leadership, which led to resources being dedicated to knowledge transfer and getting new executives up to speed. With the change in leadership, there was also a change in product vision, which led to inefficiencies in the development as the focus was always in flux. This was further complicated by the constraints of the contract, as each change in focus led to a shift in work, which had to be renegotiated into the contract before the team would execute.

Research and development is central to the competitiveness of the United States, but it is important to remember that it is not a surefire path to success. There is an inherent amount of risk and uncertainty that obscure the potential return on investment of R&D pursuits on the cutting edge. According to the Defense Innovation Unit, only 23% of the organization's completed projects transitioned to the field. This may be a staggering rate of failure for other core activities, but it is the reality for research and innovation. The DMC was a platform that had transformative potential, but the technology, market and staffing related risks proved insurmountable barriers towards its success. Lessons learned and the following recommendations will be incorporated into current and future institute projects.



MILESTONES ACHIEVED

Key Milestones Table

Id.	Title	Plan completion date	Current forecast completion date	Actual completion date
M1.1	Initial release of DMC branded website	30-SEP-15	COMPLETED	23-SEP-15
M1.2	DMC platform release with recommended security risks mitigated and validated	30-DEC-15	COMPLETED	9-DEC-15
M1.3	Software release incorporating newly developed user experience and functionality	ONGOING	ONGOING	ONGOING
M2.1	Initial DMC user identity established	30-DEC-15	COMPLETED	08-DEC-15 [DMC190] 08-DEC-15 [DMC332]
M2.2	User support documentation released	30-MAR-16	COMPLETED	07-JUN-15
M3.1	Initial DMDII project on-boarded to DMC	30-MAR-16	30-SEP-16	See Notes
M3.2	Support DMC workshop	30-JUN-16 30-DEC-16	See Notes	See Notes
M4.1	Knowledge Center released as part of DMC platform	30-JUN-16	30-JUN-16	
M5.1	DMC operations transferred to UI labs	30-MAR-17	30-MAR-17	

Notes

M1.1 Demonstrated at DMDII workshop

M1.2 Corresponds to DMC Alpha release

M1.3 Reference DMC Beta release (19-JAN-16)

M2.1 Completed as part of DMC190 and DMC332

M2.2 Project DMC.org released 7-JUN-15; links to User Support Documentation in Wiki content generated by GE

M3.1 Anticipated onboarding of AVM tool through DMDII-ECBM program rescheduled due to contracting negotiations



M3.2 June-16 workshop delayed due to DMC project call DMDII-15-16 still in contract negotiations. The upcoming DMDII-DMC ‘Hackathon’/User Group meeting 17-JUL is a potential alternate activity for this milestone. It was agreed by the DMC program manager to utilize the summer DMC ‘Hackathon’ as a DMC workshop.

M4.1 DMC752

M5.1 ---

DELIVERABLES RECEIVED

Id.	Title	Plan completion date	Current forecast completion date	Actual completion date
D1.1	Quarterly catalogs of requested features	Quarterly (Q4'15-Q1'17)	Quarterly (Q4'15-Q1'17)	See Notes
D1.2	Beta DMC site deployed to on-site environments	30-MAR-16	COMPLETED	30-MAR-16
D1.3	Quarterly releases of planning, SW development and quality assurances to DMDII members	Quarterly (Q4'15-Q1'17)	Quarterly (Q4'15-Q1'17)	See Notes
D1.4	Integrated large scale identity provider and pilot enrollment of individual and group to the identity service	30-DEC-15	COMPLETED	30-DEC-15
D1.5	DMC threat modelling assessment report	Quarterly (Q4'15-Q1'15)	Quarterly (Q4'15-Q1'15)	See Notes
D1.6	DMC website vulnerability report	Quarterly (Q4'15-Q1'15)	Quarterly (Q4'15-Q1'15)	See Notes
D1.7	Code release for vulnerability patching	Quarterly (Q4'15-Q1'15)	Quarterly (Q4'15-Q1'15)	See Notes
D1.8	Risk assessment and NIST and ISO compliance matrix	Quarterly (Q4'15-Q1'15)	Quarterly (Q4'15-Q1'15)	See Notes
D1.9	Military focused demo project	30-MAR-16	COMPLETED	31-MAR-16
D2.1	Identity Service enrollment process	30-DEC-15	COMPLETED	29-MAY-16
D2.2	Governance procedures	30-DEC-15	COMPLETED	31-MAR-16
D2.3	User and website support documentation	30-MAR-16	COMPLETED	
D3.1	Digital lab onboarding process	30-DEC-15	COMPLETED	31-MAR-16
D3.2	System engineering training documentation	30-DEC-15	30-DEC-15	3-JUN-16
D4.1	Marketing and sales material	30-DEC-15	30-DEC-15	31-MAR-16



D4.2	Knowledge Center user's guide	Quarterly (Q4'15-Q4'16)	Quarterly (Q4'15-Q4'16)	See Notes
D5.1	Weekly IOI	Weekly (Q4'15-Q1'17)	Weekly (Q4'15-Q1'17)	See Notes
D5.2	Monthly report	Monthly (Q4'15-Q1'17)	Monthly (Q4'15-Q1'17)	See Notes
D5.3	Quarterly report	Quarterly (Q4'15-Q1'17)	Quarterly (Q4'15-Q1'17)	See Notes
D5.4	Transition plan	30-JUN-16	COMPLETED	30-JUN-16
D5.5	Annual technical report	30-MAR-16	COMPLETED	1-JUN-16
D5.6	Final technical report	30-JUN-17	30-JUN-17	

Key Deliverables Table

Notes

D1.1 #1:27-MAR-16, #2:31-MAR-16

D1.2 Deployed to playground.research.ge.com 7-APR-16. Demonstrated at DMC user testing at GRC at same

D1.3 #1:29-MAY-16, #2:29-MAY-16 (under revision)

D1.4 Demonstrated via DMC190 and DMC332 (8-DEC-15) with additional documentation provided on 29-MAY-16

D1.5 Replanned due to resource availability estimated 30-JUN-16

D1.6 Same as D1.5 Note

D1.7 Alpha release 9-DEC-15, Beta release 8-Jan-16

D1.8 Security awareness training policy delivered on 7-Jan-16, Physical and environmental protection policy delivered on 7-Jan-16, Physical access control policy delivered on 4-Jan-16, Risk assessment and NIST and ISO compliance matrix delivered on 29-Jan-16, AC - Access Control AU - Audit and Accountability CA - Security Assessment and Authorization CM - Configuration Management CP - Contingency Planning IA - Identification and Authentication IR - Incident Response MA - Maintenance MP - Media Protection PL - Planning PS - Personnel Security PE - Physical and Environmental Protection RA - Risk Assessment SC - System and Communications Protection SI - System and Information Integrity all delivered on 11-MAY-2016, SA - System and Services Acquisition PENDING

D1.9 Document "Military Use Case" delivered on 31-MAR-16

D2.1 ---

D2.2 ---



- D2.3 Delivered via ProjectDMC.org via Wiki edits by GE
- D3.1 Delivered via document “Digital Manufacturing Onboarding Process” on 31-MAR-16
- D3.2 Delivered via document “System Engineering Training Documentation” on 3-JUN-16
- D4.1 Delivered via document “Marketing and Sales Material” on 31-MAR-16
- D4.2 #1:31-MAR-16, #2: Pending
- D5.1 Weekly IOI delivered via TCON daily sprint standup meetings
- D5.2 #1[OCT]:27-MAR-16, #2[NOV]: 27-MAR-16, #3[DEC]: 27-MAR-16, #4[JAN]: 27-MAR-16, #5[FEB]: 27-MAR-16, #6[MAR]: 17-MAY-16, #7[APR]: 25-MAY-16, #8[MAY]: Pending
- D5.3 #1[Q4’15]: 27-MAR-16, #2[Q1’16]: 17-MAY-16, #3[Q2’16]: Pending
- D5.4 Transition Plan pending publication
- D5.5 Annual report published
- D5.6 ---