Teaching Project Survival Skills: Lessons from 'The Martian'

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Jeff first joined UW-Madison's faculty in 1989 as an assistant professor in the Department of Civil and Environmental Engineering, where he co-founded the Construction Engineering and Management Program and developed the construction curriculum. In addition, he has authored and co-authored papers on the subject of educating civil engineers. His body of work demonstrates his commitment to using emerging technology in the classroom to prepare the next generation of engineers and other students for the challenges of the future.

Jeff was honored in 2014 with an Outstanding Projects and Leaders Lifetime Achievement Award by the American Society of Civil Engineers. He holds a bachelor's degree in civil engineering from University of Cincinnati, master's and doctoral degrees from Purdue University, and is a registered professional engineer in Wisconsin.

Jeff grew up in a construction family where his father ran the field operations for a small regional contractor in northeast Ohio. He spent his youth working in construction, learning the value of hard work, integrity, organization, and leadership. He has always respected the important role of labor in achieving project success.

Strongly influenced by his sister, who has Down syndrome, Jeff values the importance of family, the joys of life, and the appreciation of differences and diversity.

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Adapting Graduate Project Management Education for Practicing Professionals to the High-Stakes, Turbulent World where Projects Live or Die

Introduction

The popularity of the movie [1] and book [2], "The Martian," provide an interesting and helpful launching point for reconsidering what it takes to be an effective project manager in today's world where projects must often adapt with agility to changing conditions or fail.

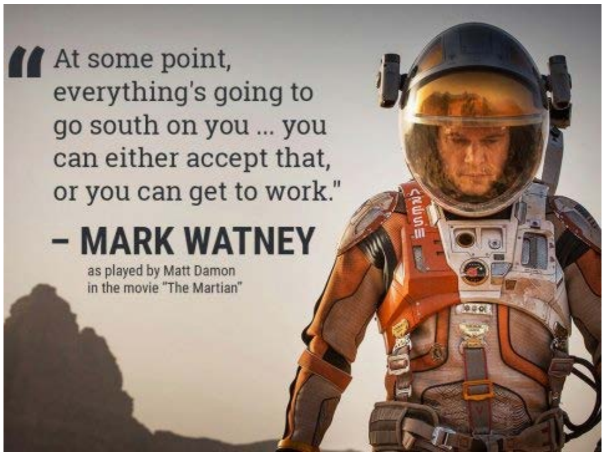

Figure 1: Photo, credit 20th Century Fox, Business Insider [3]

In "The Martian," astronaut, mechanical engineer, and botanist Mark Watney is left behind on Mars when the team needs to rapidly evacuate due to a sudden sand storm. Watney is presumed dead after being hit by flying debris and the team is unable to rescue his body before the ship needs to launch to avoid tragedy. Watney regains consciousness, only to discover has team has left and he needs to figure out some way to stay alive long enough, with very limited food, oxygen, and supplies, to possibly rendezvous with a return mission to Mars in four years. Realizing his predicament, Watney, speaking to his camera diary, says, "I'm gonna have to science the shit out of this." Watney's reaction is a life-or-death version of the reaction that real-world project managers feel at some visceral level when their projects take some major, unexpectedly bad turn. Virtually all projects, even those best planned, funded, and credit staffed, face these externally imposed dilemmas when world events, markets, or the forces of nature throw a major curve ball at a seemingly well-planned project.

Watney survives because he has education and experience that give him the needed science knowledge, but also because he has a deep reserve of courage, resilience, emotional intelligence, and effective adaptability to the challenge before him. Near the conclusion of the movie, Watney is speaking to a class of astronauts in training. Watney uses his experience to speak to the challenges that lie ahead for this new group of space explorers: "At some point, everything's going to go South on you. You're going to say, 'This is it. This is how I end.' Now, you can either accept that, or you can get to work. You have to solve one problem, and then solve the next problem, and then solve the next problem, and if you solve enough problems, you get to go home."

Perhaps you, like the authors, have heard experiences from engineers leading major, complex projects who have had their own moments of "This is it. This is how I (or my project/career) end." What can we as engineering educators do to best equip our students to prepare for those moments and challenges, and have the knowledge, resolve, and adaptability to solve enough problems to get their projects home?

This paper explores that challenge and some related lessons that we, the authors, have learned and which we seek to continue to explore with like-minded educators and practitioners. Our goal is to find how best to prepare project managers that have both the deep knowledge and honed adaptability to navigate their projects and teams through tough, challenging crises that they are certain to experience. We don't pretend to have all of the answers, and invite dialogue and shared learning with fellow engineering management educators.

Background

This paper draws upon the experience of the authors' research and practice, which informs how they teach a project management course for experienced, practicing engineers as part of the Master of Engineering Management MEM) program [4] at the University of Wisconsin-Madison. Key features of the subject program follow:

Students

- All students are practicing engineers, working full-time, as they pursue their graduate studies. All entering students must have at least four years of professional practice. At present, students average about ten years of preceding professional experience, with some having as many as thirty or more years. This broad base of experience among students is actively engaged throughout the program for collaborative, authentic learning grounded in real-world experience.
- Students range in positions from project engineers, to project managers, to chief executive officers of engineering organizations. The unifying goal is that all seek to be more effective managers and leaders.
- All admitted students have at least a B.S. from an ABET–accredited engineering program. Some students have subsequent engineering masters or PhD degrees, and occasionally MBA's; these students are seeking to complement their technical or general business skills with advanced engineering management knowledge and abilities.

Program Design

- The MEM program employs a cohort design in which up to 30 students are admitted each year, and the group progresses through a fixed curriculum as a cohesive, well-supported learning community. Courses are designed to enable students to customize their learning through the selection of individual and team projects in each course.
- All courses employ a problem- and project-based curriculum. Students pursue and apply their learning through required discussions with colleagues at their workplace, critiquing current practices, and applying appropriate new approaches to their real workplace projects and teams.

- Instructors intentionally, actively engage the experience and expertise of students, all of whom are experienced engineers leading real projects, as part of each course's learning. Student-student interactions occur as part of team assignments, asynchronous discussion forums, and student-led presentations during course web conferences.
- All courses have live, weekly web conferences, which enable high, meaningful interactions between faculty and students. Web conference are designed as interactive presentations and discussion, typically including student-led sharings regarding best practices, tools and strategies.
- The program's curriculum is listed in Table 1.

Table 1: Master of Engineering Management Curriculum

- Foundations of Engineering Leadership
- **Technical Project Management** (course addressed by this paper)
- Management Accounting
- Effective Professional Communications
- Engineering Problem Solving with Computers
- International Engineering Strategies and Operations
- Engineering Applications of Statistics
- Quality Engineering and Quality Management
- Applied Leadership and Management of Engineering Organizations
- Independent Reading and Research in Applied Engineering
- Summer Residencies (two; each 1 week)
- Strategies, Tools, and Practices for Effective Learning and Professional Practice
- Electives
  - Creating Breakthrough Innovations
  - Key Legal Concepts for Professionals
  - Effective Negotiation Strategies and Principles

Program Track Record

- The Master of Engineering Management program has graduated over 400 engineering leaders since its inception in 1999. The program's effective combination of structure and flexibility have enabled students to achieve 95% on-time degree completion over the program's first 15 graduating Classes.
- The quality of education offered by the MEM program has been recognized by major awards from the Sloan Consortium [5], the University Continuing Education Association [6,7], and the U.S. Distance Learning Association [8]. In selecting the program for its Distance Learning Community of Practice Program of Excellence Award, UCEA judges said:

  "The program is as good as it gets as a model of the development, implementation, and maintenance of a distance education degree program. This degree does everything by the best practice book, such as extensive literature

review and surveys to initiate the courses, careful selection of technology for each pedagogical task, development of intense group cohesiveness within the cohort and piloting each course for a semester before it is offered in the degree program.” [6]

The Course: Technical Project Management

The course examined in this paper is Technical Project Management, a 3-credit graduate course available only to practicing engineers enrolled in the Master of Engineering Management program. Course weekly topics, and the elements of a semester-long team project are shown in Figure 2.

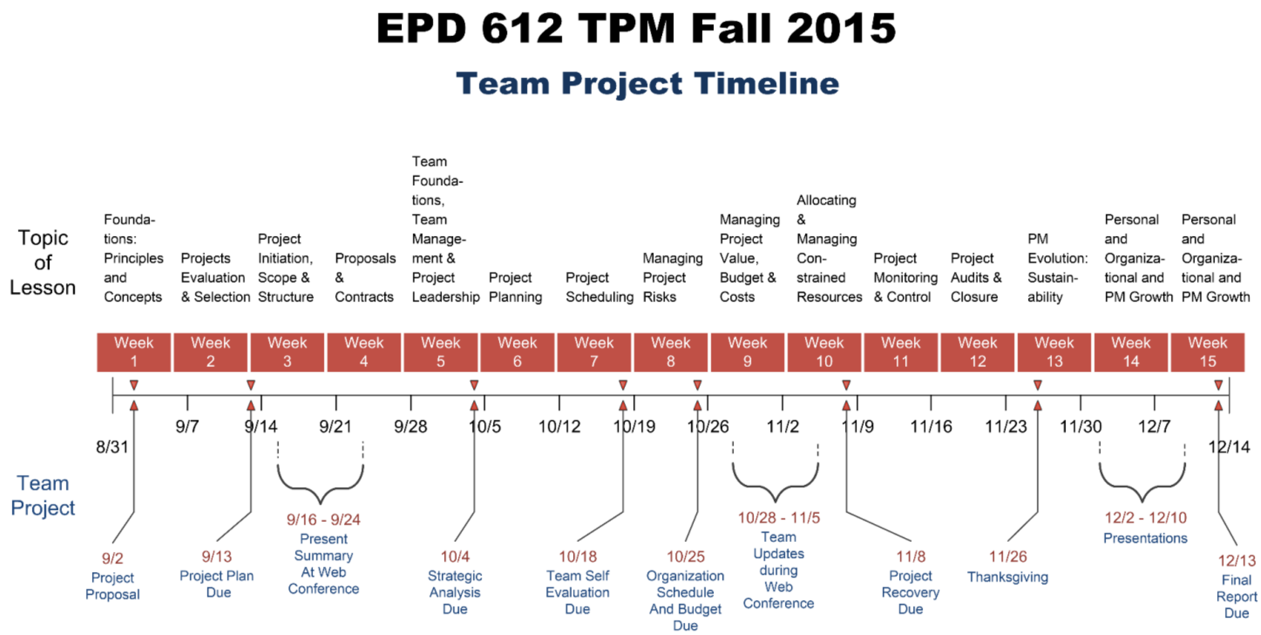

Figure 2: Course Elements of Technical Project Management

A key part of the course is the semester-long team project. At the preceding Summer Residency session on campus, students are divided into teams of three or four students. Teams are formed to include members of different organizations, cut across different geographic and cultural boundaries, and group students with similar interests (e.g., capital projects, software/information technology (IT) projects, and product development/manufacturing projects). Students choose a major, actual project at one of their workplaces to form a case study for the team’s applied learning. Over the course of the semester each team will prepare: (1) a proposal, which details the project charter; (2) a plan detailing the team’s organization and approach to the case study; (3) a strategic analysis addressing how to best ensure project success; (4) a plan detailing the project’s proposed organization, schedule, and budget; (5) a recovery plan that addresses a major unexpected crisis in the project; and (6) a team presentation and (7) final report prepared for an executive review committee. Teams are required to self-assess their functioning on two occasions during the semester and to share what they are learning about improving their teamwork with the rest of the class. Consistently, these graduate students, all of whom have considerable professional experience, say the course's team project, while very challenging and time-consuming, is a high quality learning experience that sharpens their project management skills and their abilities to effectively collaborate virtually as members of a geographically distributed team.

Re-Examining Projects and Project Management

Despite significant advances in project management theory, education, and standard practices, far too many projects still fail to deliver expected results. The Project Management Institute's latest survey of projects [9], summarized in Figure 3, shows that only 62% of surveyed projects met original goals or business intent, with only 53% completed within the original budget and 49% completed on time.

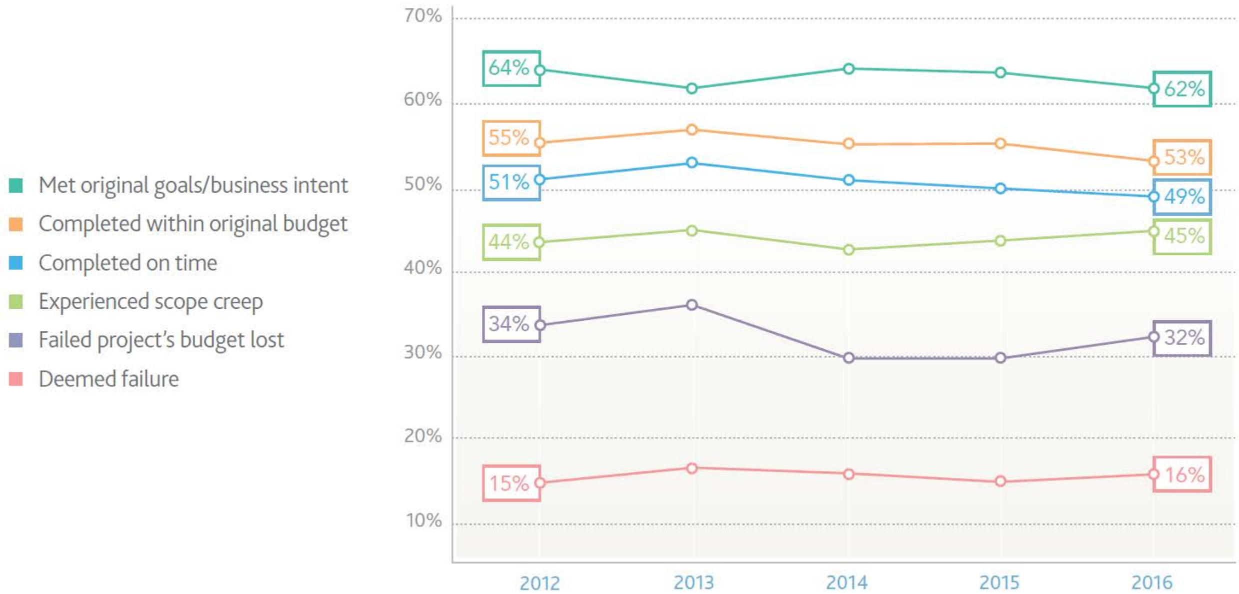

Figure 3: Consistent Project Success Remains Elusive
Source: PMI, 2016 [9]

Matta and Ashkenas, in an insightful article on project failure in the Harvard Business Review, [10] note that:

> *Big projects fail at an astonishing rate … The problem is, the traditional approach to project management shifts the project teams' focus away from the end result toward developing recommendations, new technologies, and partial solutions. The intent, of course, is to piece these together into a blueprint that will achieve the ultimate goal, but when a project involves many people working over an extended period of time, it's very hard for managers planning it to predict all the activities and work streams that will be needed.*

Managers use project plans, timelines, and budgets to reduce what we call "execution risk"— the risk that designated activities won't be carried out properly—but they inevitably neglect these two other critical risks—the "white space risk" that some required activities won't be identified in advance, leaving gaps in the project plan, and the "integration risk" that the disparate activities won't come together at the end. So project teams can execute their tasks flawlessly, on time and under budget, and yet the overall project may still fail to deliver the intended results.

Matta and Ashkena's observations about project failure suggest:

- Traditional project management practices often lose focus on value-based outcomes, diverting that focus to push-driven activities that may, in the end, deliver little customer value.
- In complex problems, it is very difficult, at the start of a project, to identify and plan for all needed work, risks, and possible adjustments.
- Even when the "project plan" is executed flawlessly, the project may not deliver the desired outcomes. Needs of stakeholders, market conditions, and other externalities may have required a mid-course correction that was not taken.

The bottom line here is that we often fool ourselves by thinking that project success is best ensured by developing the perfect project plan, then ensuring that all project partners know and follow the prescribed plan. The reality is that we rarely know the future as well as we think we do, project circumstances change, and unless our project strategy and plans adapt, we are liable to miss the moving target of project success. Project management educators know and experience that in their lives and projects daily. However, too often our teaching of project management fails to fully embrace this reality and prepare our students to succeed in a world of projects that shift frequently and often unpredictably in project requirements, resources, and time demands.

The importance of intentionally building team capacity for adaptability and agility was reinforced by a recent Project Management Institute study. As summarized in Figure 4, PMI concluded[11] that an intentional focus on building and supporting organizational agility significantly increased projects' likelihood of: meeting project goals (from 56% to 78%); being completed within budget (from 45% to 66%); being completed on time (from 42% to 64%); and meeting project return on investment (from 38% to 63%).

Most modern projects live in what Peter Vaill has describes as, "permanent whitewater" [12]. Whitewater is churning, constantly changing, often unpredictable, and potentially dangerous. The authors have found the image of whitewater to be particularly helpful when talking with students about facing the challenge of complex, robust projects. When approaching a dangerous or new set of rapids, whitewater canoeists will scout the rapids. They do so by grounding or tying their boats to shore, then walking along shore to the bottom of the rapids. From the end of the run, the canoeists look upstream and try to determine at least one safe passage from the beginning to end of the rapids. Unless at least one safe path and set of maneuvers can be found, the canoeists will need to portage their canoe by land around the rapids. If a reasonably safe

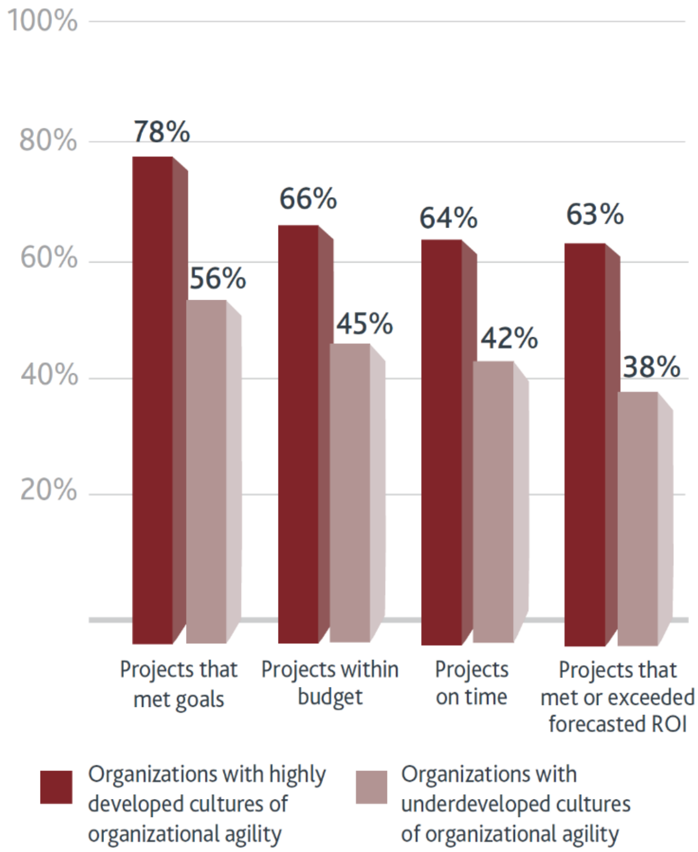

Figure 4: Organizational Agility Improves Success of Projects
Source: PMI, 2015 [11]

route can be identified, the canoeists will walk upstream to their launch point, stopping occasionally to take a better look at key transitions to plot their maneuvers just upstream of those points. The whitewater navigation analogy reminds us that:

- The best view of project requirements is from the end, looking upstream. From there we can “pull” plan our best set of moves.
- As we walk upstream from the end, key transitions (milestones) can be identified and the associated preceding moves planned.
- Ultimately success of the voyage will not be determined whether the exact planned path and associated maneuvers are followed, but whether the canoeists, canoe, and equipment make it safely to the bottom of the rapids.
- Good planning by experienced scouts, who have learned how to read rapids is important to discern whether the rapids are navigable. These skills, plus the practiced abilities to quickly shift course, provide a well of talents that the canoeists will need to draw from as their decent through the rapids unfolds. A similar deep pool of skills and experience gave Mark Watney the ability to adapt to his whitewater experience on arid Mars.

Evolution of What and How We Teach

As described earlier, the authors teach graduate project management to students who are all working professionals, most with considerable to extensive project management experience.

These, like nearly all adult learners, want education that is authentic, relevant, immediately applicable to their work, and substantiated by experiences of their own or credible peers [13,14,15,16]. As the authors have taught this course over the past eight years, a shared, consistent goal and commitment to our students has been to make the course "authentically real," speaking directly to the experiences and learning goals of these project-experienced professionals. Following is a brief description of a few key ways in which our teaching of effective, real project management has evolved.

An Emphasis on Living Order

"Living order" is a concept that the authors have found helpful in exploring the definition of project success and how to best strategize to achieve success. Alex Laufer has written extensively about living order and its application to project planning and management [17]. Laufer draws upon the French philosopher Henri Bergson's 1907 book, Creative Evolution [18], describing Bergson's two orders in this way:

> *Bergson claimed that there is no such thing as disorder, but rather two sorts of order: geometric and living order. While in "geometric order" Bergson related to the traditional concept of order, in "living order" he referred to phenomena such as the creativity of an individual, a work of art, or the mess in my office."*[19]

Applying these two forms of order to projects, Laufer writes:

> *…all projects aim to reach a perfectly functioning product with geometric order. At the start, they may face great uncertainty – living order – that does not completely disappear over the entire course of the project. Gradually, some parts of the project approach geometric order, though in an era of 'permanent white water,' the project as a whole does not assume geometric order until late in its life.* [20]

As applied to projects, the concept of living order recognizes that projects happen in dynamic environments. The occurrence of unexpected events should be understood as a part of most projects' life cycle. Project managers, their teams, their culture and practices should highly value the agility that is needed to anticipate and adapt to change. Strategies and plans must remain flexible and need to intentionally incorporate practices that enable the project team to learn from each step and adjust, just like the whitewater canoeist adjusting his planned course as the route unfolds.

Mark Watney's mission to Mars, meticulously planned by NASA, seemed to be proceeding in predictable, geometric order. An unexpectedly severe dust storm and accident threw the mission into a living order that required expertise, agility, and a commitment to learn as Watney broke the seemingly impossible challenge into problems he could successively tackle.

We will return to the consideration of living order and its application to project managements after addressing lean management practices, a second major evolution in the authors' approach to teaching project management.

Integration of Lean Management Strategies and Practices

Lean management practices are foundational for leading global manufacturers in America [21, 22]. These practices have systematically identified and attacked waste, defined as anything that does not add value. A primary change in manufacturing operations is that processes are driven by pull from customer orders, rather than a push to create available inventory.

Increasingly, project management practices are seeking to integrate lean thinking into project practices. A good example is the adoption of agile project management in software development, placing increased value on intermediate, working code than comprehensive, documented, complete systems. Nevertheless, most legacy project management systems and practices continue to rely on push-oriented activities that fail to capture efficiencies that can be gained from pull-driven, value-focused strategies [23].

Watney was forced to practice ultimate lean project management. His resources, using normal practices, would not enable him to survive until help might arrive. He needed to ration and find ways to reuse every waste in a way that would sustain life.

The authors have adapted their teaching to explore with students how lean principles and practices can be integrated into every project. A helpful resource that the instructors use for readings of example strategies and practices is, the joint MIT-PMI-INCOSE Guide to Lean Enablers for Managing Engineering Programs [24]. The following six lean management principles were adapted from Lean Enablers and are used as the basis for discussion with students during each week's web conference:

- Focus on project value as defined by customer stakeholders
- Clearly map the value stream and eliminate waste
- Optimize the flow of work through planned, streamlined, value-adding steps
- Use pull-based project planning and scheduling
- Create and foster a culture of pursuing perfection, while not allowing perfection be the enemy of the very good
- Show respect in relationships with team personnel and partners

A New Course Roadmap

To help students holistically visualize throughout the semester the integration of living order concepts, along with increased emphasis on lean practices, the authors developed a new Course Roadmap, shown in Figure 4. The Roadmap shows:

- The theme for each of the course's 15 weeks.
- A separate "swim lane" for geometric order and living order. The swim lane shows for each week how management by living order and geometric order might offer differing approaches and practices.
- A vertical band showing how lean practices apply to the theme for that week, applicable to both geometric and living order approaches to project management.

The Course Roadmap is re-presented at the beginning of each week's web conference, reminding students each week where we are in the overall progression of the course, and providing a launching point for exploration of geometric and living order applications, bridged by relevant lean management practices.

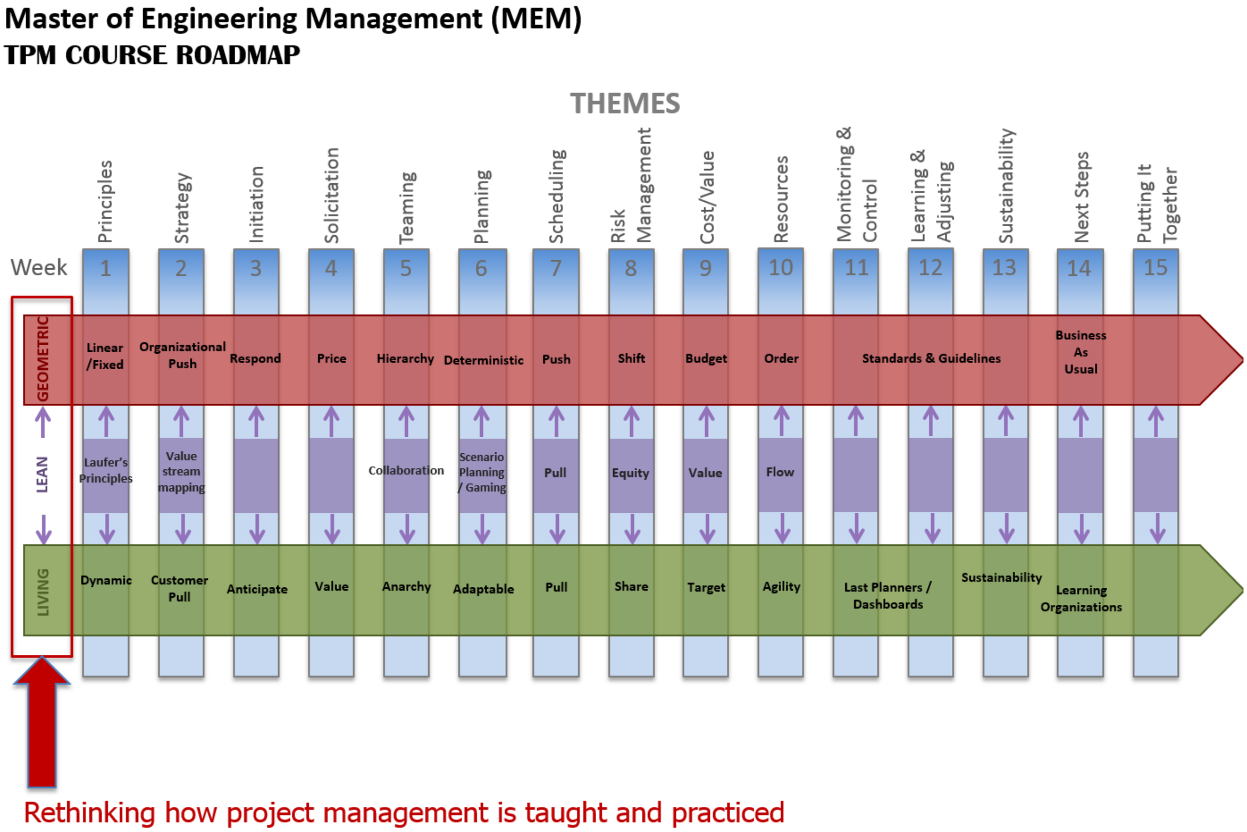

Figure 5: Course Roadmap for Technical Project Management [25]

Examples of How the Course Roadmap is Applied in What and How We Teach

Our teaching and working with practicing engineers continues to inform and evolve what and how we teach as we interact with students and their real-world projects. While we continue to teach fundamental project management concepts and tools, much more of our emphasis is placed on application of these tools and concepts in a project environment that requires a willingness to embrace ambiguity and turbulence, and to confidently, strategically lead their teams through a stream of predictable and unpredictable challenges.

Following are a few examples of how we have adapted our curriculum and its instruction to meet the highly application-focused needs of these experienced engineers we are privileged to serve as teachers.

1. Planning and Scheduling
   Traditionally, much of the Planning and Scheduling lessons in this course focused on

development of a project network and corresponding analyses, including forward and backward passes, calculation of activity slack, activity-on-node and activity-on-arrow exercises, and analyses of critical and near-critical paths. We still cover all of these concepts (except activity-on-arrow networks), though we place these concepts within a larger, application-focused context. It is vitally important that a project manager understand that by identifying a project's critical path he/she can see those tasks that control the project's duration, and can therefor give special focus to the on-time completion of those tasks. Understanding that concept, and enabling one's team to apply it to projects simple or complex, is far more important to the career success of *most* practicing engineers than being able to run sophisticated optimizations of activity networks.

A helpful perspective on this topic is found in the words of statistician George Box, who said, "Essentially all models are wrong, some are useful." [26] We help students see the value of critical path analysis in focusing theirs and their team's attention, and in identifying slack that can be used for a project's advantage. At the same time we caution about being overly rigorous in adhering to a detailed pre-launch schedule, when adjustments along the way may be to the project's and team's advantage. During live web conferences and in the asynchronous discussion forums, we discuss practical situations in which students are making judgment calls about adhering to a predetermined path versus adjustments made on the basis of midstream-acquired intelligence.

We have also modified our teaching of project planning and scheduling to emphasize lean management principles. A key principle here is teaching students to begin their planning and scheduling from the end of the project rather than the beginning. The goal is to ingrain pull-focused thinking and planning. We ask students to consider what is the final major task to be completed to consider the project successfully completed. What then is the next major upstream milestone, and what has to occur between the two to ensure successful completion? Then keep working upstream, major milestone to major milestone, to the beginning. The result is a high-level plan pulled by project value rather than a plan driven by conventional ordering of activity. The difference is usually expressed in more integrated, cross-team collaborative work rather than serial hand-offs and repeated review-revise cycles.

We then examine how an overall plan and schedule for a project is often best implemented through a series of time-related windows. For example, schedule windows for a construction project could include:

- A phase window (typ. 3 months), which starts from a completed set of work and moves backward to lay out what needs to be done to get there;
- A look-ahead plan (typ. 3 weeks), which addresses planning for materials delivery and pre-work;

- A weekly work plan, conducted with all active project partners at the end of each week and commits to what should be done and can be done. Success is measured each week in terms of how well the week's commitments were met.

We explore alternative models for frequent review and adaptation in other types of projects. For example, we explore stage-gate phased project planning and scheduling for new product development. Correspondingly, we explore how sprints are used within scrum agile project management for productive cycles that produce results and continually refine project focus.

We also discuss with students about how the specificity and use of schedules need to be adapted to the needs of the project and the culture of the members of the team. Team members need to have enough information to know: what they need to do; when they need to do it; and how their efforts fit into the bigger picture. Information that is insufficiently detailed or overly ambiguous information fails to give needed direction to project team members. Conversely, too much unfiltered information may cause team members' eyes to glaze over and fail to focus on priorities for their attention. We discuss how some teams and projects are more like large orchestras, and need highly scripted, detailed schedules to enable coordinated, successful completion. Other teams and projects may thrive more like jazz ensembles, in which highly trained specialists function best with a general plan and schedule, improvising details along the way.

Students apply what they learn about planning and scheduling through individual assignments and through their major team project. As part of their team project students collaboratively develop a work breakdown schedule, an organizational breakdown schedule, a corresponding activity network, and critical path analysis. Students then introduce a realistic major upset to the project that will cause the project schedule to be reduced by at least 20%, and assess options and propose a project recovery plan to a fictitious project executive committee for approval.

2. <u>Project Cost and Value</u>
   Previously this lesson was titled "Project Budgeting." We revised the lesson's title to "Project Cost and Value" to reflect that: 1) in the end, project sponsors care far more about how much the project cost than its original budget; and 2) the most important monetary consideration for project managers is delivering owner/sponsor-defined value.

   In this lesson, we spend considerable effort discussing project value. Effective project managers have thoughtful, probing discussions with project sponsors of project value. Every project has deliverables, whether that be a facility, a product prototype, or functioning software. The goal, however, is to produce project outcomes; e.g., a hospital that provides regional care for children, a refrigerator that is x% more efficient, or an enterprise management system that supports increased asset management. Project managers deliver value to their clients when they help those clients clearly articulate the whole life value (see Figure 6) of the project they are planning to fund. These discussions help to establish a budget in line with the project's value, and help to clarify particularly important aspects of a project's value. For example, the value of the pediatric hospital is not defined in x thousand square feet of floorspace, but in terms of, for example, the facility's ability to enable care for certain numbers of various levels of patients and its supporting a target number of various types of operations over a defined lifetime. Ancillary elements of the facility will have less contribution to core project value and may be more subject to cuts if cost reduction measures are later required.

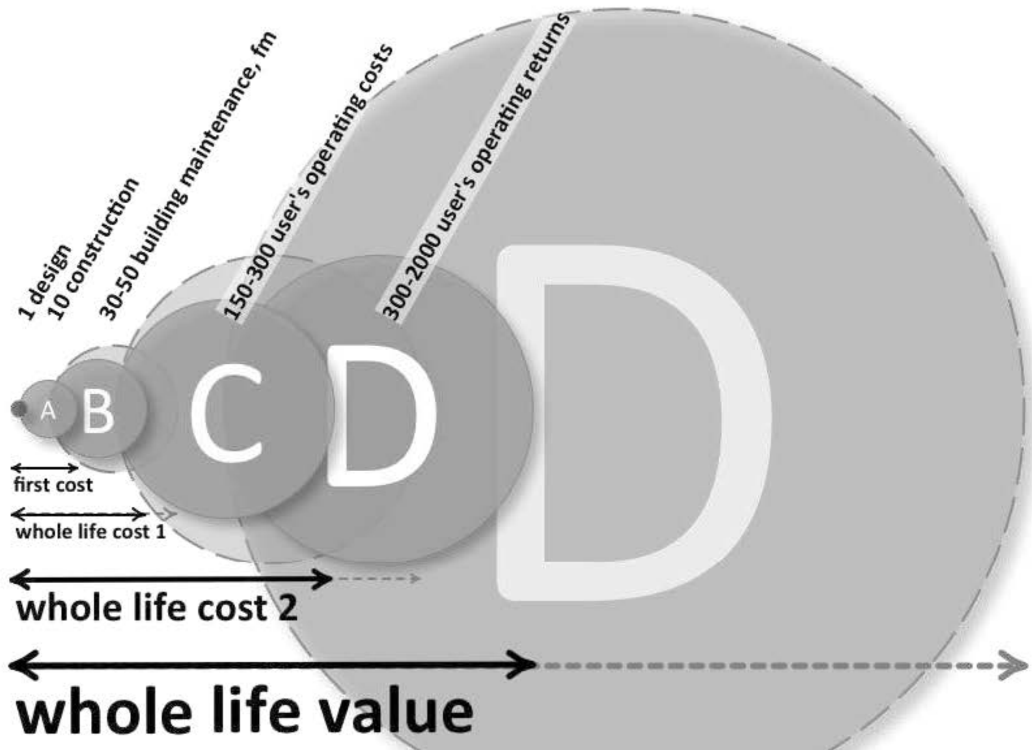

Figure 6: Project Whole Life Value Extends Far Beyond First Cost
Credit: Mossman, Ballard, & Pasquire, [24]

As part of this lesson, the course teaches bottom-up and top-down cost estimation, with an emphasis on an integrated, iterative process. In addition to improving accuracy of results, this approach builds buy-in from all involved project partners. This message reinforces that conveyed during the planning and scheduling lessons: get all partners meaningfully involved as early as possible in project development. Enable the project to benefit from their expertise and develop a shared understanding and commitment to overall project success, not just to their portion of the project.

A concept that we present and explore in this lesson is target-value budgeting and design. The focus in this approach is to establish a budget based on a clear understanding of project value, then allow that value-based target drive design and implementation decisions. In the words of the Lean Construction Institute [28]:

- *Target-Value Design (TVD) turns the current design practice upside-down.*

- *Rather than estimate based on a detailed design, design based on a detailed estimate.*
- *Rather than evaluate the constructability of a design, design for what is constructible.*
- *Rather than design alone and then come together for group reviews and decisions, work together to define the issues and produce decisions then design to those decisions.*
- *Rather than narrow choices to proceed with design, carry solution sets far into the design process.*
- *Rather than work alone in separate rooms, work in pairs or a larger group face-to-face.*
- *TVD offers designers an opportunity to engage in the design conversation concurrently with those people who will procure services and execute the design.*

As part of the discussion of target-value design, we discuss an example of its application in an actual construction project, depicted in Figure 7.

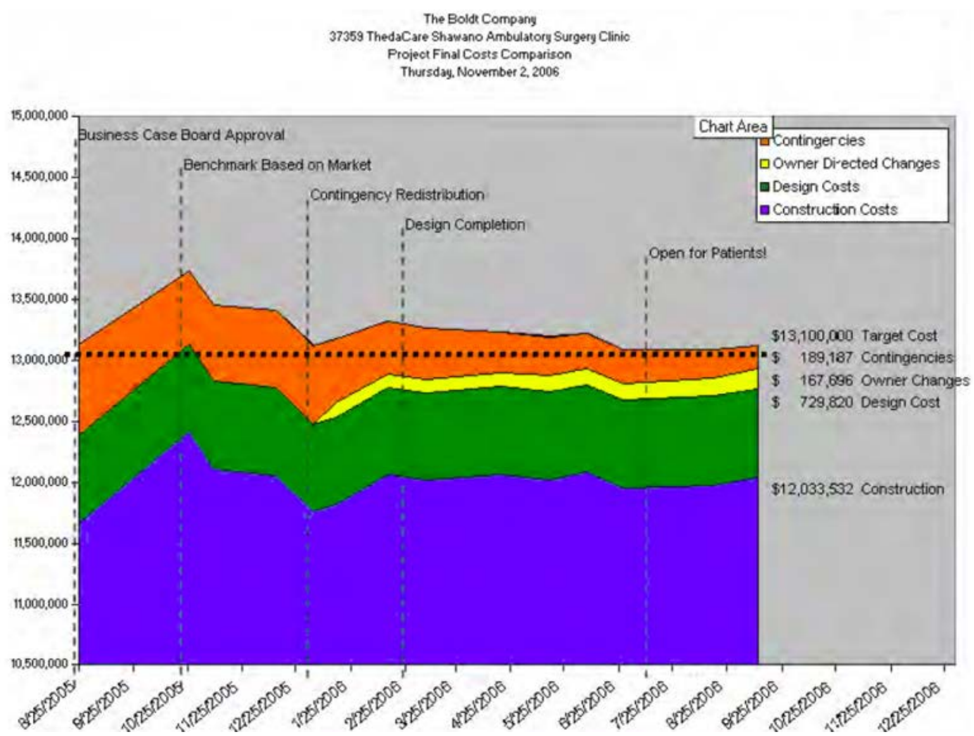

Figure 7: Application of Target-Value Design
Credit: The Boldt Company [29]

This example illustrates how:

- An initial target cost ($13,100,000) was set by the project sponsor
- The initial estimated costs, exclusive of contingencies, were slightly above the target cost

- The design was modified to enable estimated costs, including contingencies, to approach the target cost
- The final design included owner-initiated changes that were covered by contingency allowances. As the project advanced, contingency funds wee used as needed and were reduced as actual costs were managed to align with estimates and keep total cists within the target budget
- Unused contingency funds were available at the end to share among project participants per project partners' original agreement.

Throughout the lesson on costs and budgets, we emphasize: a focus on owner/sponsor-defined project value; early and meaningful engagement of all partners in project budgeting; and developing shared ownership of overall project success.

Student Feedback

The exploration of contrasts and complements between geometric and living order approaches has afforded a rich ground for discussion and learning for students, as well as faculty. Students have engaged with the contrast and comparison as they have initiated and contributed to asynchronous discussions, live discussions during web conferences, and in writings they have prepared for individual and team assignments. Students have also shown great interest in lean project management practices and have written and presented about ways they can move practices within their organizations to more fully embrace lean project management approaches.

As part of the end-of-course evaluation students are asked:

- To self-rate their achievement of specific learning goals for the course;
- To rate the quality of various elements of the course (e.g., readings, web conferences, individual assignments, discussion forums, quality of interactions with faculty, responses to requests for help);
- To identify the most valuable and least valuable lessons;
- To suggest at least one improvement for the course;
- To rate and comment on their team project experience; and
- To rate the usefulness of what they learned in the course to (a) their current responsibilities or job, and (b) their future responsibilities/positions.

Within the Master of Engineering Management program, faculty place great weight on student feedback on the usefulness of what they learn in each course. Recall that these students are all practicing professionals, with an average of ten years' professional practice. Accordingly, the judgment of these students is grounded in substantial workplace experience. They have returned to graduate studies to fill gaps that their preceding undergraduate and graduate education has not provided as they advance in management responsibilities. Feedback summarized in Table 2 shows that students most recently placed a 4.82/5.00 value on the usefulness of their learning related to their intended future responsibilities. Most of the course's emphases that have been described in this paper have evolved over the past three years (2013-2015); feedback from students show that they have found these concepts and teaching relevant to their practice of engineering.

Table 2		
Usefulness of Technical Project Management Course as Rated by Students (on scale of 1-5)		
Year	**Useful in current responsibilities or job**	**Useful in future responsibilities or job**
2006	4.09	4.55
2007	4.20	4.60
2008	4.00	4.60
2009	4.33	4.85
2010	4.35	4.69
2011	4.40	4.70
2012	4.13	4.50
2013	4.70	4.81
2014	4.44	4.81
2015	4.67	4.82

Conclusions

Astronaut Watney made it home because he had an exceptional bank of resources from which to make needed withdrawals. His resources included a broad and deep education, extensive training by NASA, and at least as importantly, a resolve and adaptability developed through his professional and life experiences. Presumably his training would have included high-stress experiential tests that would have required quick thinking and acting.

As project management instructors, we need to ask ourselves are we preparing our students academically and experientially to face the technical, managerial, and strategic issues they will face as their projects encounter unexpected challenges.

Recall Watney's words to his students:

> *At some point, everything's going to go South on you. You're going to say, 'This is it. This is how I end.' Now, you can either accept that, or you can get to work. You have to solve one problem, and then solve the next problem, and then solve the next problem, and if you solve enough problems, you get to go home.* [30]

Let's continue to evolve in building courses and program curricula that go beyond teaching conventional, geometric order and teach students to adapt and thrive in the living order of their fast-paced, complex, constantly evolving projects.

Bibliography

1. The Martian, directed by Scott Ridley, 20th Century Fox, 2015.
2. Weir, Andy, The Martian, Crown Publishing, 2014.
3. Image from Orwig, J., *3 beautiful natural phenomena you can see in 'The Martian' movie that aren't in the book*, Business Insider, October 2, 2015.
4. University of Wisconsin-Madison Master of Engineering Management website; http://management.engr.wisc.edu
5. Sloan Consortium, Award for Most Outstanding Online Teaching & Learning Program, 2004.
6. University Continuing Education Association, Outstanding Program Award – Credit Category, 2002.
7. University Continuing Education Association, Distance Learning Community of Practice Program of Excellence Award, 2002.
8. U.S. Distance Learning Association, Excellence in Distance Learning Programming Award–Higher Education Category, 2003.
9. Project Management Institute, The High Cost of Low Performance, p.5, 2016.
10. Matta, Nadim F., and Ashkenas, Ronald N., *Why Good Projects Fail Anyway*, Harvard Business Review, September 2003.
11. Project Management Institute, Capturing the Value of Project Management through Organizational Agility, p.6, 2015.
12. Peter B. Vaill, Managing as a Performing Art: New Ideas for a World of Chaotic Change, Jossey-Bass, 1989.
13. Barkley, E. F., Student engagement techniques: A handbook for college faculty. John Wiley & Sons, 2009.
14. Barkley, E. F., Major, C.F., & Cross, K. P., Collaborative Learning Techniques: A Handbook for College Faculty. 2nd ed. San Francisco: Jossey-Bass, 2014.
15. Bransford, J. D., Brown, A. L., & Cocking, R. R., How people learn: Brain, mind, experience, and school. National Academy Press, 1999.
16. Fink, D. L., Creating significant learning experiences. An Integrated Approach to Designing College Courses. Nueva York: Jossey-Bass, 2003.
17. Laufer, Alexander , Mastering the Leadership Role in Project Management: Practices that Deliver Remarkable Results, Upper Saddle River: FT Press2012.
18. Bergson, H. English translation 1911, Henry Holt and Company, 1907.
19. Laufer, op. cit., p. 214
20. Ibid.
21. Krafcik, John F., *"Triumph of the lean production system"*. Sloan Management Review 30 (1): 41–52, 1988.
22. Ruffa, Stephen A., Going Lean: How the Best Companies Apply Lean Manufacturing Principles to Shatter Uncertainty, Drive Innovation, and Maximize Profits. *AMACOM*. ISBN 0-8144-1057-X, 2008.
23. Alan Mossman, Glenn Ballard, and Cristine Pasquire, *Lean Project Delivery – innovation in integrated design & delivery*, Architectural Engineering and Design Management, 2010.
24. The Guide to Lean Enablers for Managing Engineering Programs, ed. Josef Oehmen, Joint MIT-PMI-INCOSE Community of Practice on Lean in Project Management, May 2012.
25. Russell, J, Pferdehirt, W. and Nelson, J, Technical Project Management Course Overview, Fall 2015, University of Wisconsin-Madison.
26. Box, G. E. P., and Draper, N. R., Empirical Model Building and Response Surfaces, John Wiley & Sons, New York, NY, 1987, p. 424.
27. Mossman et. al., op. cit., 2010
28. Macomber, Hal, and John Barberio. 2007. *Target-Value Design: Nine Foundational Practices for Delivering Surprising Client Value*. http://www.leanconstruction.org/media/docs/3-Target-Value-Design-LPC.pd
29. The Boldt Company, Appleton, WI, 2008.
30. The Martian movie, op. cit.