SPRING 2025

SYLLABUS

EGRMGMT 577 (7036):[1]
***Challenges and Strategies for the Design Thinker and Innovator* ("CDT")**
Duke University, Master of Engineering Management Program
Wednesdays, 3:05 – 5:50 p.m., Teer 115
Seth A. Watkins, Ph.D., J.D.
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There are no prerequisites for this course, which may be taken either before, or after, EGRMGMT 576 (Design Thinking and Innovation). It is **not** a substitute for 576. In contrast to 576, this course follows a case study approach, exploring both theoretical and applied perspectives, to develop your intuition as a leader on a design thinker and innovator team. We will study the theory and practice behind design and innovation, beginning with Vitruvius, the 1st century BC engineer who illuminated the design trifecta *firmitatis* (strength/durability), *utilitatis* (utility/usefulness), *venustatis* (beauty) that still resonates today. We will strive to:

- understand how ancient wonders were designed and built without the benefit of the technologies that we take for granted today (like microchips, internal combustion engines, heavy lifting equipment, etc.);

- identify lessons learned from engineering failures and how the design process and the designs emanating from it necessarily evolve (of course, the design process is iterative and few designs are "pioneers") and conversely how products may be *designed* to fail;

- identify lessons learned from engineering successes, how the design process benefits from a team of role players including the designers, managers, subject matter experts, and stakeholders, and how "best practices" can support transformation;

- understand how the work of standard-setting bodies (like the International Telecommunications Union (ITU)) and certification entities (like UL Solutions f/k/a Underwriters Laboratories) impacts the design process (e.g., product features like "USB" or "5G"), and gain an appreciation for mandatory conformity marking (e.g., the European Union's Conformité Européenne (CE) Mark); and

- understand how laws, and their counterpart regulations promulgated by myriad government agencies, impact the design process (consider: how is the Americans with Disabilities Act implemented in everyday life, from web browsing to conducting financial transactions at an Automated Teller Machine (ATM)?).

In this course, interactive lectures will be paired with work in small, student breakout groups assigned randomly for each class. All students will have opportunities to prepare and deliver short PowerPoint presentations during classes. There will not be a comprehensive final exam. Participation and an open note, open book assignment will determine a final grade. Our goal is to

[1] This course previously was assigned course number EGRMGMT 590.09 or 590.06. In March 2024, the Engineering Faculty Council ("EFC") approved EGRMGMT 577 as the permanent course number. This change has been implemented beginning with the spring 2025 semester.

explore the design process from diverse perspectives and observe how design thinkers change the world with inventiveness, resourcefulness, and team-oriented approaches.

Design in the Ancient World. Imagine the tasks of design and innovation in the ancient world, without the benefits of semiconductors. No computers. Not even calculators. No email or text messages. No smart phones or "walkie talkies." No global positioning system (GPS). No software for computer-aided design (CAD), computer-aided manufacturing (CAM), design of concrete foundations and piles for buildings, finite element analysis for modeling stresses on an engineering prototype, product or project management systems, or logistics and supply chain management systems. No digital libraries chronicling the state of the art or past experiences, whether successes or failures. No modern, mass transportation. No LinkedIn for attracting job applicants for product development roles! Imagine a time without extensive laws impacting design and innovation, a time without government agencies to implement and enforce those laws through regulations. No formal safety standards. No building codes. No prohibitions against discrimination based on disability. No recourse for product-related illness or injury.

The "ancients" built structures of astonishing scale and complexity. The Great Pyramid of Giza, constructed over less than 30 years during the 26th century BC, is formed from over two million stone blocks including some weighing almost 60 tonnes apiece. The Great Wall of China, spanning 13,171 miles (21,196 km) largely along the Himalayan mountain range, was constructed from the 3rd century BC to the 17th century AD with the combined efforts of *millions* of workers. In Florence, Italy, the Campanile bell tower, standing about 278 feet tall (85 meters), was built in phases during the 14th century, with interruptions caused by design flaws and "the plague of Florence" (a/k/a the Black Plague) which wiped out 60% of the city's population during the latter part of construction. In Agra, India, the combined efforts of 20,000 people built the Taj Mahal over two decades during the 17th century, using building materials including white marble sourced from a distance of about 250 miles (400 km) and gems unearthed throughout India and elsewhere in Asia. The ingenuity that designed and built these wonders is most evident in the fact that they still stand today, many centuries after their construction. The innovators of past millennia must have done something right during the design process.

Design Failures. Not all designs work well and withstand the test of time. **In 1940**, the Tacoma Narrows bridge—spanning the Puget sound in the state of Washington—collapsed during strong winds that caused the bridge, which lacked proper damping and pressure balancing measures, to wildly oscillate and twist. **In 1954**, two de Havilland "Comet" passenger aircraft literally broke apart mid-flight due to design defects, cracks having propagated around the corners of the windows – a major problem during high altitude flight when the cabin was pressurized. **On a cold day in 1986**, the Challenger space shuttle launched and then was lost after 73 seconds—to the horror of a huge national television audience—with all seven astronauts including the first "teacher in space" perishing. A Presidential Commission famously concluded: "*[T]he cause of the Challenger accident was the failure of the pressure seal in the aft field joint of the right Solid Rocket Motor.* The failure was due to a faulty design unacceptably sensitive to a number of factors. These factors were the effects of temperature, physical dimensions, the character of materials, the effects of reusability, processing, and the reaction of the joint to dynamic loading." **In 2010**, DePuy Orthopaedics (part of Johnson & Johnson) issued a "voluntary" recall of its "ASR" (Articular Surface Replacement) hip implants. Similarly, **in 2012**, Stryker Corp. initiated a "voluntary" recall of its "Rejuvinate" hip replacement implants. A fundamental design problem was to blame: metal-

on-metal joints (a metal ball against a metal cup), which, over time, experienced fretting, corrosion, and migration of particulate. In **December 2015 to January 2016**, a buggy software update to the Nest "smart" thermostat (Google!) caused the units to fail during these cold winter months and while families were on holiday vacations. The thermostats stopped functioning—because the Nests lost power and went offline—such that any pre-set heating temperature was not maintained.

In 2021 in the nation's capital, Washington, DC, *three-quarters* of the fleet of Metrorail train cars were removed from service—with major, long-term implications for commuters—after a design defect allowed the wheels to shift apart by two inches beyond specification (well beyond the allowable tolerance of 1/16 inch) causing a derailment with 187 passengers onboard. **On October 30, 2022**, a historic, four-foot-wide, 755-foot-long pedestrian bridge spanning the Machchhu River in Gujarat, India tragically collapsed with nearly 150 people losing their lives including many elderly people and children. The suspension-type bridge was newly reopened but without a "fitness certificate" or permission from relevant authorities. The bridge was tremendously overloaded with people at the time of the collapse (an overload failure) *and* bridge maintenance had been undertaken by a company whose qualifications have been sharply questioned after the fact. **In late December 2022**, a huge winter storm resulted in the cancellation of about 16,000 Southwest Airlines flights and consequently the stranding of countless passengers during the holiday season. Southwest has long operated according to a "point-to-point" rather than "hub-and-spoke" design, and that model of managing airplanes, crews, and passengers, coupled with an antiquated scheduling system (software), caused considerable chaos. On **June 18, 2023**, a catastrophic failure killed a pilot and four crew (tourists) on the "Titan" submersible during a dive to explore the RMS Titanic wreckage at a depth of about 12,500 ft. (3,800 m) on the North Atlantic Ocean seabed about 380 nautical miles south of Newfoundland, Canada. Descent to that depth took about two hours. Before the accident, Titan's operator OceanGate, Inc. had boasted: "*Through the innovative use of modern materials*, Titan is lighter in weight and more cost efficient to mobilize than any other deep diving submersible. . . [G]round-breaking engineering and off-the-shelf technology gives Titan a unique advantage over other deep diving subs . . ." The pressure vessel, with overall dimensions 22 ft. x 9.2 ft. x 8.3 ft. high (670 cm x 280 cm x 250 cm), was made of carbon fiber and titanium, weighed 23,000 lbs. (10,432 kg), was allegedly "designed to go to the depths of 4000 meters (13,123 feet)," and used four streamlined brushless DC, oil filled and pressure balanced motors (thrusters) for propulsion (two vertical and two horizontal). Titan also had a "large viewport" – apparently formed of 7-inch-thick acrylic (plexiglass), 15 inches (380 mm) wide. Speculation about the failure notably focuses on the poor strength of carbon-fiber composites in compression (i.e., under increasingly high pressure from surrounding water as depth increases) as well as the potentially poor performance of the acrylic window material at the high pressure experienced at depth. As much can be learned from design failures as from design successes.

[Let's now transition…] A mid-cabin "door plug" on a Boeing 737-9 MAX airplane catastrophically failed (blew out) during an Alaska Airlines flight on **January 5, 2024**. The Federal Aviation Administration (FAA) subsequently ordered emergency inspections not only for the newer MAX fleet but also the older 737-900ER aircraft because they share the same door plug design. But the storylines in the news didn't just focus on the miracle that none of the 177 people on the plane died. Instead, garnering lots of attention was the amazing survivability of certain objects that were sucked out of the plane when the "explosive decompression" occurred in the cabin. Despite the altitude of about 16,000 feet (3 miles!) when the mishap occurred, an iPhone

14 survived the fall, found on the ground in Portland, Oregon in perfect working condition with no cracks to its glass screen. Ask yourself: was it the amazing resiliency of the iPhone itself, or the amazing protection apparently provided by a Spigen "Cryo Armor" phone case, or a combination of both that provided a superior design? On **March 26, 2024**, the cargo ship MV Dali left the Port of Baltimore heading to Sri Lanka with about 4,700 containers aboard. The ship quickly lost power, drifted into a support of the Francis Scott Key Bridge–across which about 11.5 million vehicles traveled each year—and caused the bridge to collapse. Six people died. On **June 6, 2024**, two astronauts transported by a Boeing Starliner spacecraft arrived at the International Space Station for about a one week stay. Technical mishaps with that spacecraft, however, forced NASA to abandon its use for the astronaut's return, which instead is expected to occur some eight months later. And on **July 19, 2024**, CrowdStrike released a defective software update for its cybersecurity software to millions of Microsoft Windows-based personal computers and servers, causing a global crisis with computer crashes (e.g., the "blue screen of death") on a "historical scale." Air travel was massively impacted; Delta Airlines, for example, canceled thousands of flights. Emergency "911" service was impacted throughout the United States, and state court systems were downed. Hospitals and healthcare companies were impacted too, not to mention Starbucks's mobile app which could not process mobile orders. In short, a massive worldwide computer vulnerability was put on full display. In **January 2025**, wildfires in southern California burned entire neighborhoods to the ground with tragic loss of human and animal life. Many thousands of structures (e.g., on residential and commercial properties) were consumed, and economic losses could eclipse $100 billion. The confluence of dry (drought) conditions, low humidity, and fierce "Santa Ana" winds apparently wrought the extreme devastation. Yet, other factors in the "designs" of the impacted properties (and neighborhoods) also may have contributed to the destruction, such as the lack of residential fire sprinkler systems in the overwhelming number of structures that were decades-old and thus exempt from requirements for such technology. So too may have been the property and neighborhood landscaping, which was not designed to arrest—and indeed may have exacerbated—the spread of fire.

In sum, much can be learned from design failures.

Design Successes. Some designs are smash successes. Why do automobiles today have streamlined (curved) bodies rather than "boxy" bodies like vehicles before the 1990s? Why do smartphones have curved corners rather than squared corners? What is it about curvature that is so satisfying to us? One simple (really?) answer is: psychology. Separately, why have Apple's iPhone cameras been critical to the success of the company and how did Apple achieve that success? (The iPhone has only been around since 2007.) Apple revealed in 2015 that its camera design team comprised 800 engineers and the camera itself had over 200 separate parts. It was reported that in 2021, Apple produced *233 million* iPhones. That number overshadows digital camera sales by the likes of Canon, Nikon, and Sony, whose sales have fallen off a cliff since 2010 (but note: Sony has long supplied camera sensors to Apple!). And, why is the Amazon Echo Dot smart speaker a top selling product? Let's start with price, size, and sound quality. Let's add Alexa artificial intelligence, with a preposterous number of "skills" and extensive information available from her at a moment's notice. It was reported that *65 million* Echo Dots were sold in 2021 alone. What guiding design thinking and innovation principles portend success?

Design Success Achieved by Designing to Fail. Question: Why are batteries *glued* into Apple AirPods? One answer: some products have "death clocks." The products are intentionally

designed not to work beyond a certain time frame (and cannot be repaired). Why is the concept of "mean time to failure" (MTTF) used in design? How does "life cycle" planning impact design?

Design to Reflect Industry Standards and Certifications. Look on the back of a product —especially an electronic product—or on product labeling, and an extensive set of markings often are present. The markings often designate certifications for Electromagnetic Compatibility (EMC), safety, and Restriction of Hazardous Substances (RoHS) that are country or region specific. The acronyms and symbols seem endless: CE, UKCA, FCC, ICES, RCM, KC, VCCI, BSMI, c-UL-us, CB, BIS, . . . Sometimes, the markings represent compliance with a standard from a standard-setting body. Wireless innovation, for example, not surprisingly relies heavily on standards. To this end, international bodies include the International Telecommunication Union (ITU), the 3rd Generation Partnership Project (3GPP), the International Standards Organization (ISO), and the International Electrotechnical Commission (IEC). Regional or national bodies include the American National Standards Institute (ANSI), the European Telecommunications Standards Institute (ETSI), the Alliance for Telecommunications Industry Solutions (ATIS), the China Communications Standards Association (CCSA), and the Standardization Administration of China (SAC). All influence (or essentially dictate) certain design features.

Design to Conform with Laws and Regulations. Designs must adapt to changes in societal norms and reflect expectations for health and safety set by the government.

Single-use plastics, for example, are increasingly disfavored. A June 2019 Directive from the European Union seeks to "significantly reduce the dispersal into the environment of beverage container caps and lids made of plastic" which, to this end, "may be placed on the market only if the caps and lids *remain attached to the containers* during the products' intended use stage." Even in advance of the implementation deadline (July 2024), Coca-Cola Great Britain introduced plastic bottles with tethered caps. Next on the horizon was to be Canada's Single-Use Plastics Prohibition Regulations (issued June 2022) banning single-use plastic ring carriers (e.g., six-pack soda can carriers), with the prohibition taking effect over the next several years. But Canada's efforts bogged down in litigation. Nevertheless, what designs will find acceptance as adequate replacements to plastic ring carriers?

Consider also "accessibility," which is not a product feature on a "wish list" but instead is dictated by the Americans with Disabilities Act (ADA), enacted about 35 years ago. The most visible implementations may be accessible parking spaces reserved for disabled individuals and our sidewalks, which have been standardized with respect to width, slope, surface texture, curb ramps, and elimination of trip hazards. But these examples really are the tip of the iceberg. Consider the design factors (actually, requirements!) related to the conduct of banking transactions at an Automated Teller Machine (ATM), including expectations not just for basic accessibility (e.g., use while wheelchair-bound or with vision impairment) but also privacy during access. There are design standards by which web sites are deemed to be "accessible" too.

Why do we have air bags in automobiles? The answer: because a famous Duke alumna (!) signed an order requiring them when she was the Secretary of Transportation for President Reagan. What happens when certain designs for safety devices prove to be unsafe? A recall.

What happens when a medical device has design defects? What happens when the device already is implanted in someone's body when a recall occurs?

How do the many government agencies ("regulators") at both the federal and state level in the United States protect health and safety by dictating and enforcing standards for product design? Who are these regulators and what is the process by which they promulgate (adopt) detailed regulations that impact the design process?

Participation, Assignments, and Grading

Participation constitutes 50% of the final grade in this course including one (1) short, individual presentation occurring during the Graduate Reading Period on ***April 23, 2025*** (in lieu of a final exam). One individual, written assignment will constitute 50% of the final grade in this course. Exceptional work will be rewarded with an exceptional grade. An increase of half a letter grade in the final grade may be realized, at the professor's sole discretion, for exceptional participation and/or efforts to make this course a "success." The MEM Program's policy on class attendance (attached) applies to this course regardless of whether a student is pursuing an MEM or other degree. **Attendance will be taken each class; "proxy" attendance indicated by one student on behalf of another student who is not attending a class is strictly forbidden and shall be considered a violation of Duke's honesty and integrity policy for both students**. Please take class participation seriously; it is a substantial portion of the final grade.

It is Duke policy that once final grades have been released, grade changes can only be made "because of an error in calculation or an error in transcription. Changes in grades may not be based on the late submission of required work, the resubmission of work previously judged unsatisfactory, or on additional work."

All assignments will be open note, open book (including your personal notes or the notes you compile in your own study group, any materials distributed during the course including but not limited to PowerPoints, all assigned readings, and dictionaries). There are no specific restrictions unless clearly stated. Ultimately, however, your work product must be your own. Use of generative artificial intelligence (AI) (*e.g*. LLM-based tools such as ChatGPT, Gemini (formerly known as Bard), etc.) is only permitted if explicitly and clearly noted for each and every instance in which it has been used (e.g., quoted, paraphrased, or otherwise relied upon). Any other use will be considered a violation of the honesty and integrity policy. Do not submit work product written by AI or paraphrased from AI.

Teaching Assistant

The teaching assistant for spring 2025 is Chrystel Melhem (chrystel.melhem@duke.edu).

Honesty & Integrity

The Duke Community Standard embodies the governing principles for this course. Please know and embrace this standard: (1) I will not lie, cheat, or steal in my academic endeavors; (2) I will conduct myself honorably in all my endeavors; and (3) I will act if the Standard is compromised.

All students are subject to the University's policies on Academic Dishonesty. THE BULLETIN OF DUKE UNIVERSITY, THE PRATT SCHOOL OF ENGINEERING PROFESSIONAL MASTER'S PROGRAMS includes discussions concerning the Duke Community Standard as well as "Academic Integrity" and the "Academic Standard Resolution Process." The Bulletin is available at https://prattprofessional.bulletins.duke.edu/ (see the link to the complete Bulletin at the bottom of the web page).

Students are encouraged to work together in study groups and prepare joint notes or study guides (jointly authoring and editing a shared document on software like Google Docs is permitted). To be clear, the creation of such jointly authored documents during assignments is permitted, so long as the ultimate work product that you submit has been solely created by you.

Subject to the foregoing, for all individual assignments, each student will be asked to confirm the Honor Pledge which states clearly that "**I will neither give nor receive aid on this assessment**." This means quite plainly that there can be no unapproved discussion, collaboration, or assistance with any other person or use of an unapproved resource in connection with the assignment.

Availability and Submission of Assignments; Extensions of Due Dates

All assignments should be submitted via Sakai by the end of the announced due date (11:59 p.m. EST). For approval of a late submission, please send an email in advance of the due date. Any reasonable request will be accommodated, understanding that you have many burdens on your time. The faculty member teaching this course does not believe in "artificial deadlines," but does believe that extensions should not be used to delay an inevitable "last minute rush" to complete work product by an extended deadline. In other words, avoid taking extensions which simply "kick the can" and will result in the same substandard work product that would have been submitted without the extension. And not to belabor the point, but it needs scarcely to be emphasized that substandard work product always stands out during grading, so make the time and effort to create work product that you are confident will be well-received and you will be rewarded.

Wellness of All Participants

Let's ensure that we work together this semester to prioritize **wellness**—taking care of ourselves and making special efforts to enhance connections. Please feel free to make suggestions about how to make our learning environment work best for you. Your efforts to engage with the materials, the professor, and with each other are important and valued. As a student, you may experience personal or academic stress at any point throughout the semester. Please communicate and seek support.

Student mental health and wellness are of primary importance at Duke, and the university offers resources to support students in managing daily stress and self-care. Duke offers several resources for students to seek assistance on coursework and to nurture daily habits that support overall well-being, some of which are:

- **The Academic Resource Center (ARC)**, (919) 684-5917, theARC@duke.edu, or arc.duke.edu. The ARC offers services to support students academically during their undergraduate careers at Duke. The ARC can provide support with time management,

academic skills and strategies, course-specific tutoring, and more. ARC services are available free to any Duke undergraduate student, studying any discipline.

- **DuWell**, (919) 681-8421. This resource provides Moments of Mindfulness (stress management and resilience building) and meditation programming (Koru workshop) to assist students in developing a daily emotional well-being practice. To view schedules for programs please see https://studentaffairs.duke.edu/duwell. All are welcome and no experience is necessary.

If your mental health concerns and/or stressful events negatively affect your daily emotional state, academic performance, or ability to participate in your daily activities, many resources are available to help you through difficult times. Duke encourages all students to access these resources, some of which are:

- **DukeReach** provides comprehensive outreach services to identify and support students in managing all aspects of well-being. For concerns about a student's behavior or health, visit this website for resources and assistance: https://students.duke.edu/wellness/dukereach/.

- **Counseling and Psychological Services (CAPS)**, (919) 660-1000, https://students.duke.edu/wellness/caps/. Services include individual and group counseling services, psychiatric services, and workshops. To initiate services, walk-in/call-in 9-4 M, W, Th, F and 9-6 Tuesdays. CAPS also provides referral to off-campus resources for specialized care.

- **TimelyCare (formerly known as Blue Devils Care)**, bluedevilscare.duke.edu. This is an online platform that is a convenient, confidential, and free way for Duke students to receive 24/7 mental health support through TalkNow and scheduled counseling.

Schedule, Topics, and Readings Covered During Each Class

Any readings for classes will be separately communicated. The class schedule and topics are:

Class 1 (January 15, 2025) INTRODUCTION
Class 2 (January 22, 2025) DESIGN IN THE ANCIENT WORLD
Class 3 (January 29, 2025) DESIGN IN THE ANCIENT WORLD
Class 4 (February 5, 2025) DESIGN FAILURES
Class 5 (February 12, 2025) DESIGN FAILURES
Class 6 (February 19, 2025) DESIGN FAILURES & DESIGN SUCCESSES
Class 7 (February 26, 2025) DESIGN SUCCESSES
Class 8 (March 5, 2025) DESIGN SUCCESSES
[SPRING BREAK MARCH 8-16, 2025]
Class 9 (March 19, 2025) DESIGN SUCCESSES
Class 10 (March 26, 2025); DESIGN TO REFLECT INDUSTRY STANDARDS AND CERTIFICATIONS
Class 11 (April 2, 2025) DESIGN TO REFLECT INDUSTRY STANDARDS AND CERTIFICATIONS

Class 12 (April 9, 2025) DESIGN TO CONFORM WITH LAWS AND REGULATIONS
Class 13 (April 16, 2025) DESIGN TO CONFORM WITH LAWS AND REGULATIONS
[GRADUATE READING PERIOD STARTS APRIL 17, 2025]
WRITTEN ASSIGNMENT (due April 22, 2025 BY 11:59 P.M. EST)
April 23, 2025 Final individual presentations (all students)

Attachment: MEM Policy and Syllabus statement regarding class attendance

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MEM Policy and Syllabus statement regarding class attendance

Class Attendance

MEM's policy is that campus students are expected to attend class regularly and **in person,** adhering to Duke's Academic Calendar. Attending MEM classes is mandatory. MEM follows the Graduate dates within the calendar when applicable.

It is especially important that students attend the first day and the last day of class for **all** courses in which they are enrolled. Unless and until **all** coursework and examinations (whether comprehensive final exams, quizzes, or otherwise) have been completed for **all** courses in which a student is enrolled, a student is expected to remain at Duke **in person** through the end of final exam week as set forth on Duke's Academic Calendar.

In their first classes, faculty set course goals and standards, frame the course's subject matter, form student teams and begin to create the class community.

At the conclusion of the first class of each course, the faculty will report any unexcused absences to the MEM program administration. Thereafter, such students shall be dropped from the course. If students miss the first classes of the semester, they detract from their own educational experience and undermine that of their classmates. Furthermore, they create additional work for the professors and TAs.

Responsibility for regular and punctual class attendance rests with individual students. The course faculty shall refer a student to MEM's administrators in the event of excessive absences.

A student seeking an "excused" absence must work directly with her or his course faculty and must initiate the request in advance and as soon as possible. A student may be excused from attendance due to truly extenuating circumstances such as significant illness, personal/family emergency, or important religious observance.

Whether an absence is excused or not, a student will be held fully accountable for any in-class graded participation or assignments an absence caused the student to miss.