Utah Engineers Council

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2021

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Utah Engineers Council

JOURNAL

UTAH ENGINEERS COUNCIL
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utahengineerscouncil.org

Our mission statement:

The UEC advances the art and science of engineering for the general welfare of the people of Utah by promoting cooperation among and beyond our 18 member societies.

This journal is an annual publication of the Utah Engineers Council. The Utah Engineers Council Journal is produced for and by the engineering community in Utah. Copies are provided to each of the 18 societies that make up the UEC, other Utah engineers, high school students and counselors, members of the Utah Legislature, and interested corporate entities. The UEC invites your interest, participation and feedback in this endeavor. Contributions and advertisements for future issues are welcome. Statements or opinions expressed by contributors are not necessarily those of the UEC, its member societies, or the publisher. Likewise, advertisements in the journal are not to be considered an endorsement of the product or service advertised.

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Spencer J. Cox

Governor

Declaration

Whereas, engineers apply their skills and knowledge to further society's technological process, strength, health, and prosperity in creative and innovative ways;

Whereas, engineers work to solve major industrial challenges, improving our quality of life and revolutionizing the way we learn, work, and communicate;

Whereas, engineers encourage students in STEM fields to realize the practical power of their skill and knowledge to meet present and future challenges; and,

Whereas, we recognize the importance of engineers to our state's continued growth and prosperity, and express our appreciation for their efforts to engage our youth in the exciting, ever-expanding fields of science, technology, engineering, and math;

Now, Therefore, I, Spencer J. Cox, governor of the great state of Utah, do hereby declare February 21-27, 2021, as

Engineers Week in Utah

Spencer J. Cox
Governor

Chairman's Message

Paul White — INCOSE

Greetings from the Utah Engineers Council (UEC)! We invite you to become a part of the most dynamic organization in Utah. For almost 50 years, the UEC has promoted and strengthened engineering in our beautiful state. Our state has a rich history with contributions from Native Americans, pioneers, educators, and innovators. You should be proud to be in the state that brought the world the odometer, the television, the Frisbee, the traffic light, and the artificial heart. Truly, our state continues to be at the forefront of innovation across engineering: aerospace, defense, civil, infrastructure, health care, manufacturing, plumbing, and all domains in between.

When we held our annual engineers week banquet in 2020, no one could have imagined the great changes that would sweep across our nation and world. The COVID-19 pandemic affected every part of our lives. It affected the way we work — from working in the office to working from home. It affected the way we attended church — worshipping with each other from a distance. It affected the way we go to school — with online classes becoming widespread. It affected the way we lived our lives — from shopping to eating at restaurants to going on vacation.

Sadly, many of us watched or personally experienced the effects of COVID-19 on the health of those around us. Today, we grieve with those who have lost friends or family members to the devastating effects of COVID-19. Our hearts go out to you.

During the COVID-19 pandemic, we imagined tomorrow and looked forward with hope to the future. We did what engineers do best: we came together and created innovative solutions to problems through technology. Our great people rose to the occasion, and we accomplished great things! We held our first hybrid banquet, with people attending safely in person at the Davis Conference Center in Layton and others participating virtually from within and beyond our state. We supported engineering college students across our state with generous scholarships. We recognized our local talent with awards: the MESA teaching award, the engineering educator award, the fresh face of engineering, and the engineer of the year award.

During our 2020-2021 year, we celebrated the important work of engineers and engaged the next generation of innovators. Engineers are changing the world and are inventing, designing, and creating things that matter. As we imagine tomorrow, engineers will be at the heart of combating climate change, securing cyberspace, developing vaccines, and making the world a better place for all of us. We invite you to celebrate with us and help inspire future engineers as we imagine tomorrow.

If someone had told me that we would conduct our 2020-2021 year during the global COVID-19 pandemic, I would have been incredulous, bewildered, or perhaps a little amused. Yet, we came together and pressed forward despite great adversity. We overcome challenges together and imagined tomorrow. I am proud of what we have accomplished this year. Moreover, I am proud of our UEC Leadership Team, The newsLINK Group, our students, and our local engineering talent. Above all, I am humbly grateful to our sponsors, whose generosity makes all of this possible.

We imagine tomorrow with hope and optimism toward our future. Our state has great people and especially exemplary engineers. Will you join us and help us promote and strengthen engineering for our future?

Member Societies

NSPE-UT Utah Society of Professional Engineers

AIAA Utah Section

UCEA INCOSE Wasatch Utah Chapter

Engineers Without Borders USA Great Salt Lake Professional Chapter

Structural Engineers Association of Utah

UCLS

ASHRAE Utah Chapter

swe Society of Women Engineers

ASCE Utah Section

Society of SAME American Military Engineers

sampe Utah Chapter

ite Utah Section

ASPE American Society of Plumbing Engineers Intermountain

ACEC American Council of Engineering Companies of Utah

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ASHRAE Utah Chapter

ASPE American Society of Plumbing Engineers Intermountain

MH Midgley Huber, Inc.

CHS Quality Service Integrity

The newsLINK group

UEC CELEBRATES ENGINEERS WEEK WITH
THE 2021 AWARDS BANQUET

IMAGINING TOMORROW

UEC Banquet Overview

The annual UEC banquet was held Feb. 27, 2021, at the Davis Conference Center in Layton, Utah. It was a hybrid event because of the COVID-19 pandemic, and members of the UEC either attended in person or watched a livestreaming video. The hybrid format meant people were able to participate from as far away as Connecticut. Scholarship students watched in real time with their friends and other students.

Those who organized, prepared and attended the event in person followed all COVID-19 protocols to ensure everyone's safety. The evening usually includes a delicious dinner, and this year's event was no different, but the organizers were careful to remember and include everyone who didn't attend in person. Virtual attendees received food certificates so they could order food and eat at home while watching the banquet. For them, the banquet was a party of their peers with food delivered by Uber Eats!

The most interesting part of the banquet is often the presentation by the guest speaker. Scotty Nowlin was a great speaker. He was very engaging, and after the banquet night, he helped UEC put together a narrative to go with the slides he presented. See page 16 for a close approximation of what he said; it will give you some idea of the ideas he discussed. It was inspiring. We appreciate his participation the night of the banquet and his cooperation in preparing material for the magazine later on.

Thank you to everyone who watched or participated during a memorable and enjoyable evening. It set a high standard for the future, but we are already looking forward to the 2022 banquet, and we hope to see you there.


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TOMORROW
Opening Remarks, Governor's Proclamation,
Member Societies, & Sponsors


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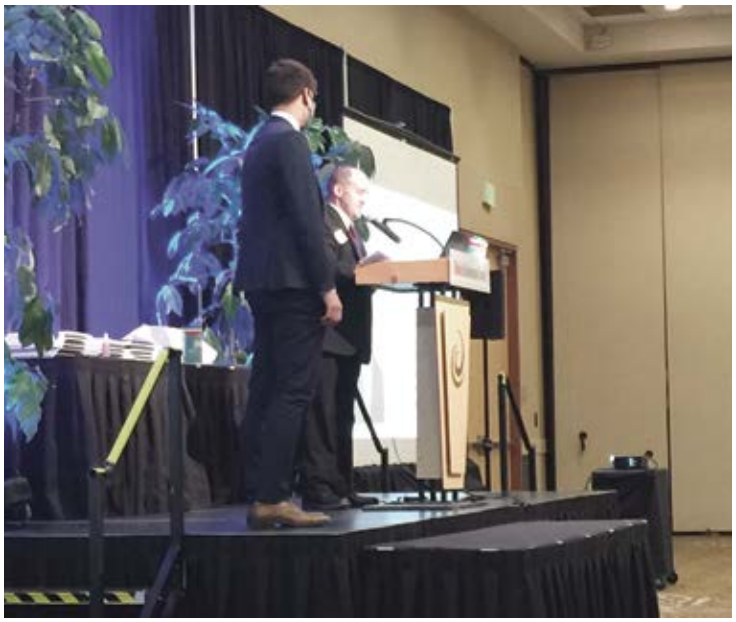


Featured Speaker of the Engineers Week 2021 Banquet

Dr. Scott Nowlin

Dr. Scott Nowlin was the featured speaker at the annual UEC dinner in February 2021. He grew up in Nevada, where his father introduced him to aeronautics and aircraft when he was fairly young. It became a shared interest.

Scotty holds a Bachelor of Science degree in aeronautics from the U.S. Air Force Academy, a Master of Science in aerospace engineering from the University of Texas at Austin, and a Doctorate of Philosophy in engineering science from Oriel College, the University of Oxford, U.K.

Scotty has lived in five different states and three different countries. He spent two tours teaching at the U.S. Air Force Academy. His last assignment before his military retirement was at Hill Air Force Base. He is currently a multidisciplinary systems engineer and career Air Force officer serving as the chief engineer of the Air and Space Force Solutions business area within the Intelligence and Security sector of BAE Systems, Inc.

At BAE Systems, Scotty holds engineering authority for a unit that provides the U.S. Air Force and combatant commands with innovative solutions to help acquire, modernize, maintain, test, and cyber-harden intercontinental ballistic missile and space systems.

He joined BAE Systems in December 2016 upon retirement from the Air Force, where he served 24 years as a developmental engineer. His career highlights include serving as an Airborne Laser Program flight test engineer, which involved multiple worldwide deployments. He also served as an assistant professor of Aeronautics, Systems Engineering program director, and Aeronautics Department Deputy Head at the Air Force Academy. His military career culminated at the rank of Colonel as the Military Director of Engineering for an Air Force Sustainment Center Operating Location supporting missile and aircraft depot maintenance activities.

Scotty's multifaceted community service includes current or past membership on the University of Utah, Utah State University, Weber State University, and U.S. Air Force Academy engineering industry advisory boards, as well as serving as a director on the Hill Air Force Base Aerospace Museum board, and the governor-appointed Utah STEM Action Center and Economic Development Coordinating Council boards.

Scotty met his wife, Joelyn, during junior high school. They met again at the U.S. Air Force Academy and were married a year after graduation; she served in the U.S. Air Force for five years. Scotty and Joelyn have four children: Faith, a senior at Weber State University; Christina, a sophomore at Colorado Christian University in Denver; Jonathan, a senior at the Northern Utah Academy of Math, Engineering, and Science (NUAMES); and Seth, a sophomore, also attending NUAMES.

Getting to Know Scott Nowlin

A family photo taken on Scotty's retirement day from the Air Force.
From left to right: Seth, Christina, Scotty, Joelyn, Jonathan and Faith.

Scotty (left) and his father building model rockets. Scotty's interest in all things rocket and aerospace was a result of his father's interest.

Scotty (10) on a family hike.

The Minuteman III ICBM. Scotty's current work supports the acquisition and sustainment of Air Force intercontinental ballistic missiles. The next ballistic-missile generation is called the ground-based strategic deterrent (GBSD).

Four T-37 subsonic jet trainers.

Three T-38 supersonic jet trainers.

During one of Scotty's last assignments, he managed people and money for the AF Research Laboratory while stationed at the Pentagon.

The front end of a C-135 specialized research airplane collected atmospheric data to improve the range and accuracy of lasers that knock down theater ballistic missiles. Gathered data was used to determine how far a laser could be shot and to what degree to pre-deform the laser to enable the atmosphere to focus it again. The work supporting this effort was done during the 1990s and early 2000s.

Cadets at the Air Force Academy's chapel. (The chapel is Colorado's No. 1 man-made tourist attraction.) Scotty included the photo because his real passion is teaching; he taught undergraduate aeronautical, mechanical and systems engineering there and served as the Department of Aeronautics Deputy Head.

Scotty and Joelyn on their wedding day.

Scott Nowlin's Banquet Presentation

Technology

When I was originally asked to speak, I thought I would talk about the U.S. Air Force's YAL-1A Airborne Laser aircraft because it was the engineering marvel of its time. But this year's theme for the annual UEC Banquet was "Imagining Tomorrow." We celebrated the engineering scholarship recipients and people who are advancing within their professional societies, so I decided to talk instead about a little bit of the technology changes I've seen in my lifetime and where I think we are going.

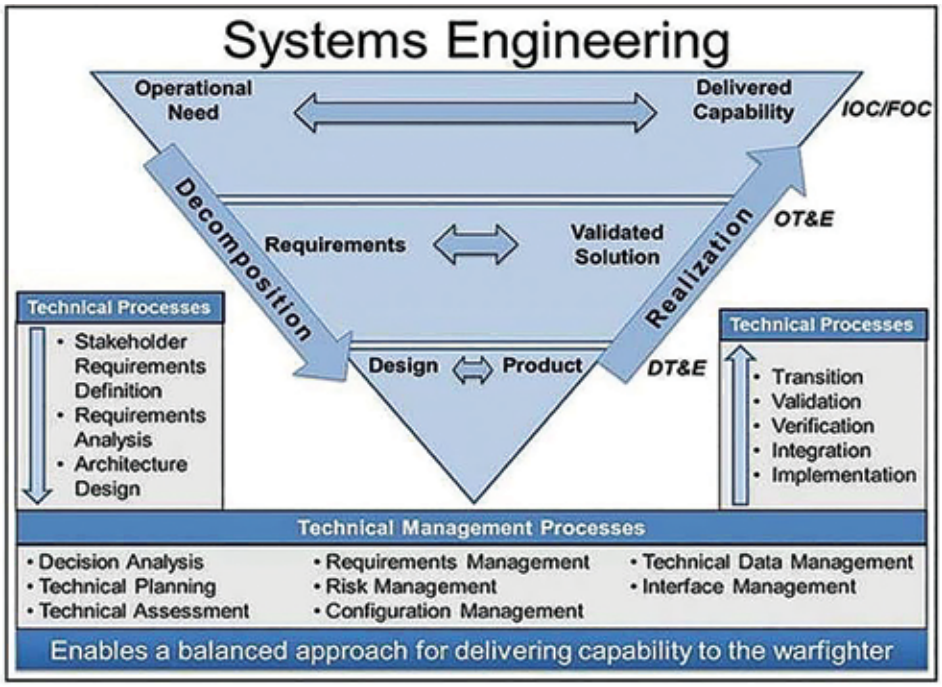
The first row's images (below) are about what has already happened during my lifetime. Typewriters, projectors, cameras and telephones all used to be separate devices. They were based on manual technology, such as large-scale video and digital formats, on individual equipment pieces. Now they have been replaced completely or partially by hand-held devices like cellphones, plus a lot of other functionality.

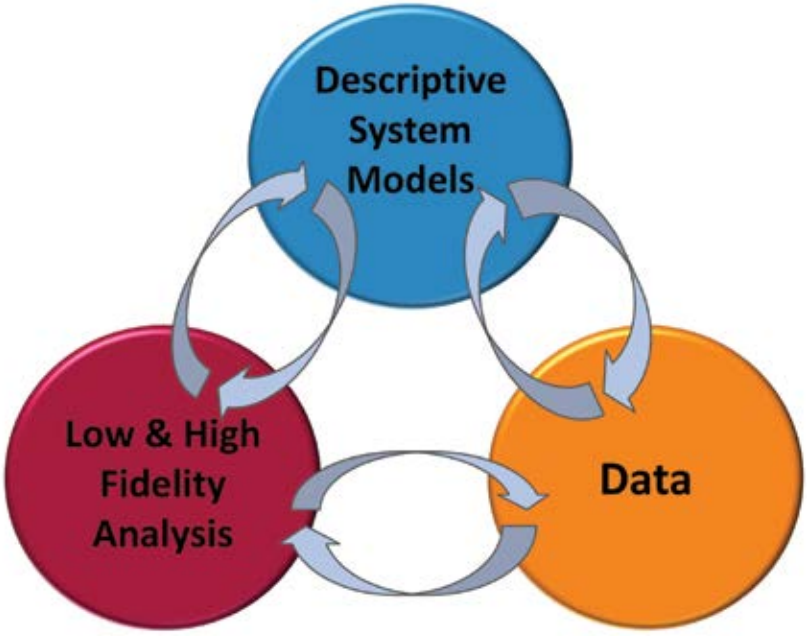
The second row's images are about the future and the growing importance of artificial intelligence (AI). We already have many apps on our phones. Increasingly, they will be driven by AI that knows what you will want to do next. The apps will rapidly fuse information about things we know we want with things we didn't know we want and then give us the results. For example, if someone calls me, one or more apps on my cellphone will know a call was on my calendar. It will know the purpose of the call; as a result, it might open a bio and a slide deck and then transcribe the conversation. If I refer to something, the app could inject the reference's internet link into the printed text or open an example of that reference on both of our devices for us both to see.

By the way, the image on the bottom right is wrong. I wanted a picture of a human hand holding a world, but the only picture I could find was of a robot hand instead. Humans can and will stay "in the loop" as need as a check-and-balance on the information. In my opinion, the challenge will be to keep the human unbiased with respect to the appropriate data to access, review, or modify, rather than keeping the machine from overreaching.

Systems Engineering

The graphic shows how the Air Force-defined system engineering processes and technical management processes are aligned and organized as part of the well-known systems engineering "vee" diagram. On a practical level, whether professionally or personally, we are all system engineers because we all manage systems. That includes us, our spouses or partners, and our children. We all make decisions and manage risks. Everyone thinks at least informally about requirements, including why the requirements are there and what the requirements mean, whether designing a building or setting up a home or business.





Model-based Systems Engineering

Systems engineers are now frequently engaging with model-based systems engineering. What does it mean to be doing model-based systems engineering? This form of engineering organizes engineering data and processes it within descriptive models.

These system models are large relational databases that are related to analysis tools. They capture requirements, risk, schedule and costs. Analysis tools take model information and analyze it, then create estimates and simulations. The system models, or architectures, contain more information than the "traditional" design-focused physical engineering model.

Analytical tools (red circle, bottom left) are changing faster than the models themselves (blue circle, top). Models and tools are fed by or archived in a data lake or data storage (yellow circle, bottom right). The models are always available through data management processes, analytical tools, and the inputs and outputs of analysis. The arrows between the circles show these critical integrating functions.

Continued on the following page

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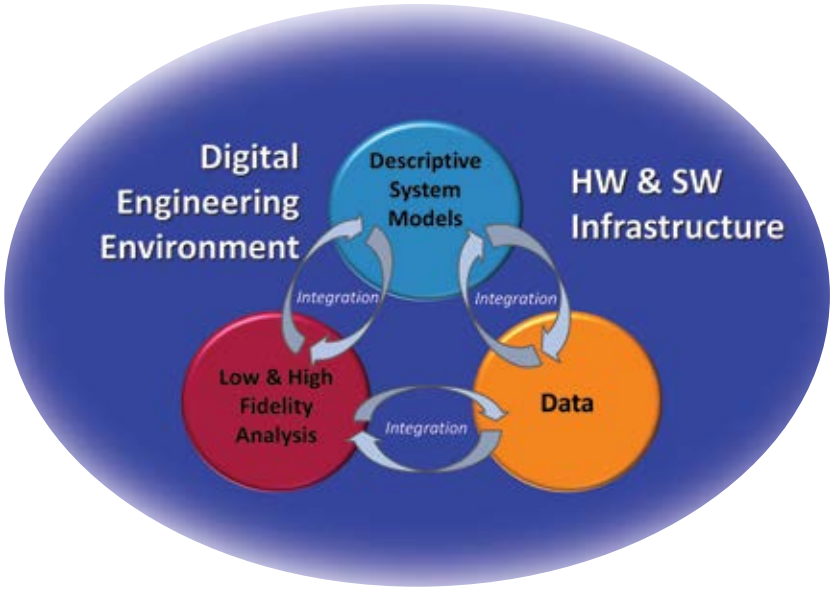
Digital Engineering (Versus MBSE)

Model-based system engineering sounds good in theory, but it's only useful in reality if you can access the data, models, and tools. Digital engineering mainly describes where that access takes place. It involves a hardware and software infrastructure where the IT experts behind the engineers define and implement the kinds of secure networks and efficient processors needed to do this computationally intensive work. When you have a lot of data, digital engineering helps organize it into models and analyze it rapidly to make decisions for designing, manufacturing, or sustaining.



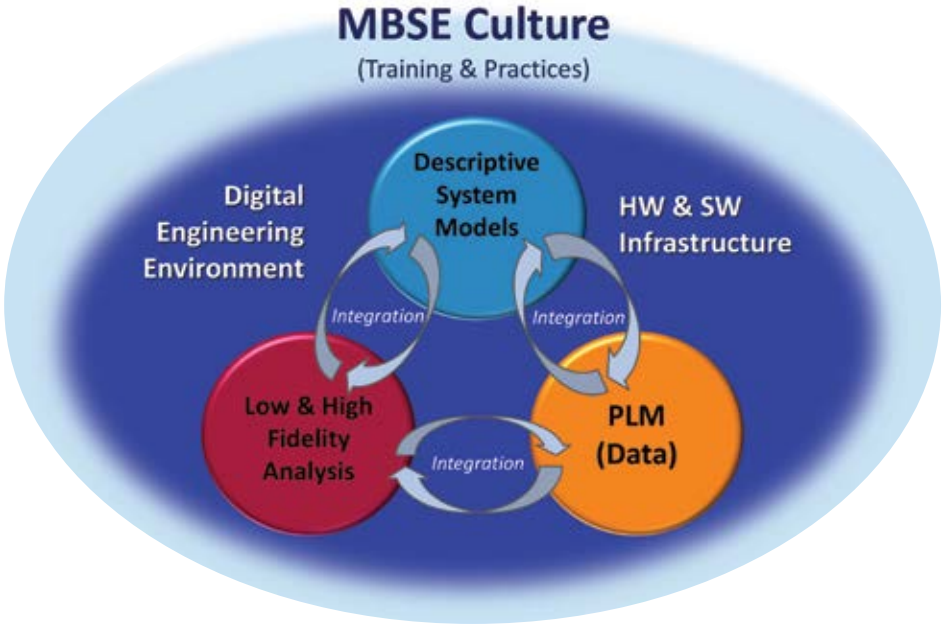
MSBE Culture

Everybody needs to get comfortable with digital engineering to the same degree as we are comfortable with software suites like Microsoft Office.

In the new model-based environment, where we have radical data integration and radical data availability, access will be nearly as transparent as using an app in Microsoft Office. In a model-based environment, we are already seeing models that capture and contextualize data almost transparently.

The process is already happening in the cloud — hence the graphic is "fuzzy" around the edges for a reason. The cloud can make data available to anyone anywhere through virtual machines. All you need to access data through a portal is a device and the right security controls.

The device's computational burden is "thin." You don't have a lot of computing power on your desktop or portable device because the computing power is in the cloud, and that is where the majority of the work occurs. The information generated and stored in the cloud then flows to us as decision-makers.

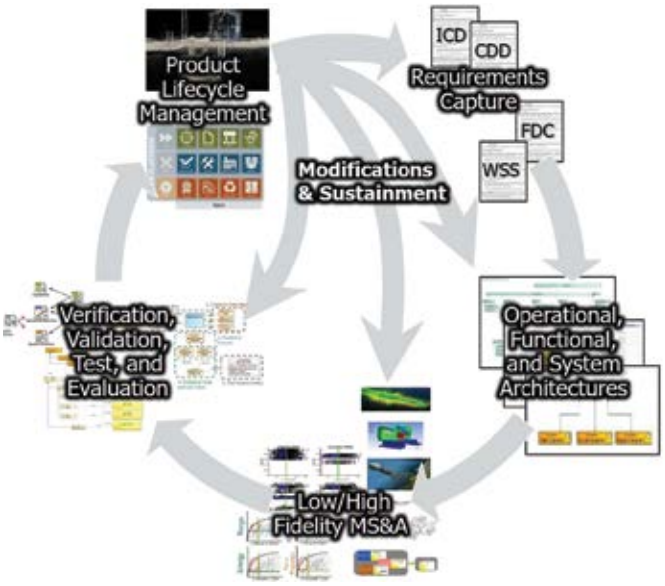


But I'm Sustaining Something Old!

I've been interested in model-based engineering at a design level and model-based systems engineering processes at a higher level for over 20 years because I saw how useful it was to have a digital twin when managing a program like the Airborne Laser.

Model-based systems engineering processes and their digital engineering infrastructure can apply to wherever you are in a product lifecycle. When you design, build, manufacture, sustain or update something, you either have an object in hand to operate and maintain or requirements for the work to be done. There is a great benefit to capturing information about your work early as you design and acquire a product. For example:

- Captured data allows you to test and evaluate so you know if an object will work when it is manufactured.
- If the object has already been built, you can make good decisions about updating or scrapping it.
- Models help you do performance simulations and run cost analyses. They help you manage the cost, schedule, and performance of any item designed, built or sustained.



One of the breakthroughs on the airborne laser project I worked on involved the required modifications to the Boeing 747 aircraft chosen to carry the system. We had to transition the paper-based design to a three-dimensional computational model because we took a 747 off the assembly line, basically took it apart, and rebuilt it in a highly modified way around the laser component.

The work involved was massive, but we did the digital parts first. We had data about pipes, conduits, chemical tanks, and electronics, and we made it all fit. We tracked cost, the weight of the airplane's modifications, and performance assessments. We wanted to know whether the 747 testbed could generate enough energy to propagate a laser as far as the Air Force wanted it to, with the required accuracy. The "digital twin" helped plan and execute this work to eventually reach a successful missile shoot-down test.

But I'm Not a Systems Engineer

I used the same picture here as on the previous section because all engineering disciplines can benefit from organizing data into models and aligning models against analytical tools. The tools change faster than the models, so engineers can use models to organize and analyze their data, then change the model content if the analytics dictate it. The models also enable improved integration with other engineering disciplines, keeping all subject matter experts referencing the same source of technical truth.

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So, What About Tomorrow?

What does this presentation mean to you practically? I propose a few specific areas for you to think about, and then go help advance the state of the art!

Legacy Data Migration

Migrating legacy data is very expensive. It requires time and investment in digital engineering infrastructure, especially if your starting point is completely paper and you want to create a detailed model from it.

The most important things to model early are those that represent high risk. For example, you should focus on modeling relationships, dependencies, interfaces, and aspects of the design that are most likely to change. As soon as you can complete even a partial model, it can help others execute their technical or program management responsibilities.

Mixed Reality

Virtual reality, or augmented reality, gives you the ability to immerse yourself in the data so you can understand it and how it interacts. The results can put modeling and simulation "on steroids"! For example, television shows like Star Trek showed us a holodeck where a simulation surrounded the actors. Other shows and movies have screens that can be pulled up and used by a hand gesture.

These applications are becoming more and more available and practical. It is already possible to be surrounded by a simulation that isn't just on a screen in front of you. You will be able to see how a very complicated system operates. You will also be able to examine a simulated object inside and out. Instead of being fixed in a cockpit, for example, you could go into an airplane wing and see how a hydraulic actuator is moving in flight and immediately see the impact on a change in design or in the system's operation.

There are very practical applications for mixed reality. Engineering used to be more about the operator and how the operator was going to interact. Engineering now is about system performance with or without the operator, and that's the direction the simulations are going. The work has become more concerned about the system itself.

Practical applications of a data-intensive, model-based environment are fairly self-explanatory. In a model-based world, you use system information to make products such as a Tesla sedan better and safer. The engineer is always looking ahead and uses the model-based environment to make continual process and product improvements.

Operating Locations

Engineers, from wherever they happen to be, can access data from many different operating locations. The pandemic has accelerated the process.

The Cloud

Information is ideally shared by a group of people who make decisions, but data growth has created the need for more intensive "data democratizing" capabilities.

Of course, cloud security has become increasingly important. If radically comprehensive and collaborative data exists, then your adversary or your competition can get a hold of it as well. Facebook has shown us how hard it is to keep private data safe.

Good data management and cybersecurity processes can ensure that people only see what they need to know.

Rapid Virtual Prototyping

The model-based world makes good engineers great and great engineers epic because they can see, comprehend, and act on so much data. They can look ahead, manage risks, see how to modify their work, and make and support decisions.

For example, an "Iron Man" exoskeleton suit allows you to do inhuman feats. In that same vein, we will have AI for data access on the same level as Tony Stark's AI system, Just a Rather Intelligent System (JARVIS), and we will be able to call up simulations very rapidly. For example, someone wearing a holo lens will be able to reach out and take apart a virtual system or look at its supply chain history.

We currently do physical testing when we want to validate and verify the models. As our skill increases, we will need to do much less physical prototyping and testing, just as NASA moved from having mathematicians like Katherine Johnson do calculations by hand to using actual computers instead.

Mathematicians continued to verify computations manually until NASA trusted computer accuracy. The same will be true for virtual simulations. We test when we need to anchor the model. The model drives simulations, but the simulations will become more powerful, and we will trust them more. Large virtual testing evaluations will become more common, and as it does, we will build fewer wind tunnels and test tracks. We will do fewer risky and expensive full-scale tests.

Just Imagine … and then, MAKE IT HAPPEN!

Data organized into models will be accessible to data tools, but this presentation about the expanding role of models and AI in engineering just scratched the surface. We will never reach a finish line, and the work currently being done — and your future work using these processes and technologies — is expanding human innovation. Go forward and innovate!

Congratulations UEC 2021 Award Winners!

2021 Engineer of the Year

Tait Ketchum, S.E.

Dunn Associates, Inc.
Nominated by SEAU

Tait Ketchum

Tait Ketcham has been a strong advocate for the structural engineering profession in Utah for over 25 years and has fostered improvements in design processes and given back to the practice throughout his career. He has served on the SEAU legislative committee, working closely with the Utah State Legislature to initiate the Structural Engineer's Practice Act, setting policy, and raising the bar for the entire profession. Tait has served his professional society in progressively increasing positions of responsibility and authority, on its Board and as SEAU President. He has provided mentoring and outreach though The Civil Engineering Academy, elementary schools, and SEAU Young Member events, promoting STEM learning and inciting an interest in engineering and math though his passion for the profession. Being the ultimate "Team-First" guy, Tait attributes his consideration for this award as the result of the esteemed mentors and industry associates he has collaborated with throughout the years, and the loving support of his wife and family.

Tait's many landmark projects include many award-winning structures that define the built landscape in Utah. He has been recognized for excellence in ENR Mountain States, Utah Construction and Design, and AIA Potomac Valley Excellence in Design. Notable achievements include:

- President of Dunn Associates, Inc.
- Professional structural engineer, Utah, and LEED Accredited Professional
- B.S. in Civil/Structural Engineering, University of Utah, with honors
- Eight publications and presentations, including journal publications in ENR, Construction and Design

He has received many notable awards:

- 2020 SEAU Engineer of the Year
- 2008 Utah Masonry Council, Excellence
- 111 S. Main
  - 2018 American Institute of Steel Construction, Ideas2 Award for Steel Construction
  - 2016 ACI Intermountain, Excellence in Concrete
  - 2016 Utah Construction & Design Magazine, Project of the Year
- dōTERRA Corporate Headquarters:
  - 2015 ENR Mountains States, Best Office/Retail/ Mixed-Use Project
  - 2014 Utah Construction & Design Magazine, Most Outstanding Commercial Office Project)
- Fairbourne Station: 2020 Utah Construction & Design Magazine, Most Outstanding Private Project Over $10 Million
- Hale Centre Theatre:
  - 2019 NCSEA Excellence in Structural Engineering Award
  - 2018 ENR Mountain States, Project of the Year
  - 2017 Utah Construction & Design Magazine, Most Outstanding Entertainment Project
- Lehi Tech:
  - 2019 ENR Mountain States Best Projects, Award of Merit for Office/Retail/Mixed-Use
  - 2019 Utah Construction & Design Magazine, Most Outstanding Office Project Under $10 Million
- One Empire Pass: 2018 Utah Construction & Design Magazine, Most Outstanding Hospitality/Resort Project
- Unified State Laboratories:
  - 2017 ENR Mountains States, Best Government/Public Building Project Award of Merit
  - 2017 Utah Construction & Design Magazine, Most Outstanding Public Project Over $10 Million
- The University of Utah:
  - 2017 ACI Intermountain, Excellence in Concrete Construction, University of Utah, Lassonde Studio
  - 2016 Utah Construction & Design Magazine – Most Outstanding Public Project Over $10 Million, Lassonde Studio
  - 2016 AIA Potomac Valley Excellence in Design Award, University of Utah, S.J. Quinney Law
  - 2015 ENR Mountains States, Best Higher Education Project, University of Utah, S.J. Quinney Law
  - 2015 Utah Construction & Design Magazine, Most Outstanding Green/Sustainable Project, University of Utah, S.J. Quinney Law
  - 2013 Utah Construction & Design Magazine, Most Outstanding Large Higher Education Project, University of Utah, David Eccles School of Business

2021 Engineering Educator of the Year

Dr. Doug Hunsaker

Utah State University

Nominated by AIAA

Dr. Doug Hunsaker

Dr. Doug Hunsaker has been teaching at Utah State University since January 2014. His research focuses on computational methods ranging from potential flow to full Reynolds-averaged Navier-Stokes computational fluid dynamics (RANS CFD) for two-dimensional and three-dimensional modeling and optimization. These research efforts support improved aircraft efficiency interests of NASA and the Air Force Research Lab and the rapid design and optimization needs of the emerging drone industry. Doug also has a strong interest in studying unsteady flows as they pertain to flapping flight.

His teaching experience and interests include aerodynamics, flight dynamics, flight simulation, optimization, and statistics. He has consistently improved the quality and depth of aeronautics instruction within the MAE Department. He is engaging when in the classroom and is inspiring to both undergraduate and graduate students. He is willing to do anything he can to encourage student participation in projects, publications, and professional meeting presentations. Doug's industry and academic collaborators often noted the quality and exceptional expertise of his students. This evidence of his teaching skill is particularly true of his work in the University Leadership Initiative. Many of those students are heading into advanced degrees and prestigious research and engineering positions in Utah's aerospace industry. Achievements include:

- Assistant professor, Mechanical and Aerospace Engineering, Utah State University
- CEO of Blucraft, Sandia National Laboratories and AeroVironment
- Nine honors, including this one, and 18 notable research awards
- 18 publications in peer-reviewed journals and 55 presentations, with impressive outreach

Career highlights include the following:

- He studied at Brigham Young University and USU.
- His research focused on improved aircraft efficiency (NASA and the Air Force Research Lab and drone industry).
- He is involved in AeroAcademy, an online aerospace learning platform with 1,400 visitors from over 70 countries and 190 users.
- His YouTube channel has 50 views per day.
- He participates in the University Leadership Initiative.

2021 Fresh Face of Engineering

Justin Wettstein

Northrop Grumman Corporation

Nominated by AIAA

Justin Wettstein

Justin Wettstein became a first-generation college graduate in 2015. He started as a product development engineer at Orbital ATK/Northrop Grumman in 2016, and he became an analyst for solid rocket motor performance. His work involves qualifying rockets through static tests, analyzed flight performance, and designed the performance of future rockets. While working full time, he pursued a Master of Science in Mechanical Engineering. Over the past few years, he has spent nearly every weekend following his passion for skiing, snowboarding, climbing, and mountain biking.

Achievements include:

- M.S. Mechanical Engineering, the University of Utah, cum laude
- AIAA Utah Young Professionals Chair
- AIAA Utah Solid Rocket Technical Committee member

Career highlights include the following:

- He is active in AIAA at the local and national levels.
- As a principal aeronautical engineer, he leads the design and analysis of solid rocket booster performance for the next generation of ICBM interceptor vehicles.
- He designed efficient loading systems for air bag explosives charges.
- He is a volunteer bike tech for a nonprofit organization.

Congratulations UEC 2021 MESA Teacher of the Year!

MESA Teacher of the Year
Mark D. Jasumback

Each year, the Utah Engineers Council recognizes the Math Engineering Science Achievement (MESA) program Teacher of the Year, who is selected by the educational community. MESA is an award-winning K-16 organization that focuses on science, technology, engineering, and math (STEM). It engages students, parents, and alumni as advocates for equity and access to high-quality STEM education and training for students. This year, the **MESA Teacher of the Year is Mark D. Jasumback**, a physics teacher and MESA adviser at Skyline High School. Mr. Jasumback accompanied MESA students to the MESA National Engineering Design Competition at Temple University in Philadelphia, Pennsylvania, and the University of Arizona in Tucson, Arizona, where the team took first place both years!

Mark D. Jasumback

Mr. Jasumback wishes to thank:

- Paul Ross, Michelle Loveday, and Nathan Moore, the Granite School District Coordinators for the honor
- Utah Engineers Council for continued support and recognition

The Utah Engineers Council thanks the American Society of Plumbing Engineers. Its members supported this award with a generous donation.

Congratulations UEC 2021 Distinguished Service Award Winner!

Distinguished Service Award Winner
Jacob Browning, FL Smidth

It is the tradition of the Utah Engineers Council to recognize the First Past Chair with the Distinguished Service Award for contributions to the engineering practice through many years of service to the council.

Jacob Browning

Congratulations UEC 2021 Engineering Educator of the Year Nominees!

For the 2021 Engineers week awards recognition, four UEC-member engineering societies submitted nominees for Educator of the Year. The following societies submitted nominees, who were then judged by a panel of four volunteers from the UEC Board.

- The American Institute of Aeronautics and Aviation Engineers (AIAA)
- The American Society of Civil Engineers (ASCE)
- The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
- The International Council on Systems Engineering — Wasatch Section (INCOSE)

The UEC awards evaluation criteria focus on measurable and meaningful contributions to the engineering profession and achievements in the areas of technical excellence, service to the profession through professional society engagement, and mentoring and outreach.

Engineering Educator Nominee

Dr. Nicole Batty

Weber State University
Nominated by INCOSE

Dr. Nicole Batty

Nicole Batty is a full-time instructor in the Manufacturing and Systems Engineering Department at Weber State University. Her expertise is in complex manufacturing systems and processes, focusing on the system's entire lifecycle and incorporating environmentally benign manufacturing techniques. Most of her industry career was spent in Aerospace in Operations Management, focusing on business intelligence and analytics. More specifically, she worked on descriptive and prescriptive analytics. Her achievements include:

- Bachelor of Science and Master of Science from The University of Michigan, Ann Arbor, in Industrial Engineering and Operations Research
- Postgraduate Certificate (PGCert) in Leadership and Management from Cornell University
- Six Sigma Black Belt

Career highlights include the following:

- She taught courses in systems engineering and systems thinking.
- She has esomotive, pharmaceutical, and semiconductor industries.
- She worked at Williams International (Ogden and Sonora, Mexico) and Applied Value Consulting (Detroit).
- She participates in diversity engagement through a monthly Economic Development Meeting, Parent Daughter Night Out/Outreach, East Diversity Committee, Women and Gender Studies Board Meeting, and Women's Center Speed Femtoring.
- She was involved in a Girl Powered! event at Syracuse Junior High.

Engineering Educator Nominee
Dr. Nick Roberts

Utah State University
Nominated by ASHRAE

Dr. Nick Roberts

Professor Roberts started at Utah State University in the Mechanical and Aerospace Engineering Department in 2013. He conducts research and teaches in the Thermal/Fluids Area, including Heat Transfer, Thermodynamics, and Advanced Thermal/Fluids, and he has secured more than $1.5 million in external funding as a principal investigator or co-principal investigator.

Professor Roberts enjoys research. However, he was driven to pursue a position in education because he wanted to work with students as a teacher and mentor. Professor Roberts is also very active in professional service as a member of ASHRAE, ASME, and ASEE. He has been a member of two technical committees, has acted as the chair of one technical committee, and been an organizer and session chair for 15 separate national and international conferences. Achievements of his career include:

- Ph.D. in Mechanical Engineering, from Vanderbilt University, Nashville, Tennessee
- B.S. in Mechanical Engineering, George Institute of Technology, Atlanta, Georgia
- Six awards and patents
- 29 Journal Publications
- 19 Conference Publications
- 65 Presentations at Conferences and Research Institutions

Career highlights include the following:

- He passed the EIT (FE exam) in Mechanical Engineering in Georgia.
- He has published over 48 research articles and given over 65 professional research presentations.
- He is a member of the NSF-funded ASPIRE ERC Team ($26 million over the next five years, renewable up to 10 years at $56 million) to research and develop sustainable electrified transportation.
- He established the USU ASHRAE Student Branch.
- He has taught more than 1,000 students in a traditional classroom setting, and he has mentored four Ph.D. students, 12 Master's students, and 25 undergraduate students in research projects.

Engineering Educator Nominee
Dr. Christine Pomeroy

The University of Utah
Nominated by ASCE

Dr. Christine Pomeroy

ASCE nominated Dr. Pomeroy to recognize her contributions to engineering students both inside and outside of the classroom. Her accomplishments include restructuring the introductory civil and environmental engineering course curriculum to improve student retention and revitalizing the ASCE Student Chapter. Notable achievements include:

- Ph.D. and Master of Science in Civil Engineering from Colorado State University
- Bachelor of Science in Civil Engineering from Michigan State University
- Professional Engineer, State of Michigan
- Associate Professor, Department of Civil Engineering, University of Utah
- 11 awards for outstanding teaching, advising, mentoring, leadership, and scholarship
- 12 research projects in Civil Engineering
- 15 publications and 36 conference presentations

Congratulations UEC 2021 Fresh Face of Engineering Nominees!

Fresh Face of Engineering Nominee
Mykel Vallerga

Colvin Engineering Associates
Nominated by ASHRAE

Mykel Vallerga

Project engineer Mykel Vallerga personifies servant leadership. Her technical skills, attention to detail, dedication to successful completion of projects, communication skills, and ability to work with people make her an effective and well-rounded engineer. Mykel demonstrates effective interpersonal skills with diverse industry groups, including vendors, contractors, architects, and owner's representatives. We look forward to her continued technical growth and professional success in the HVAC industry.

Achievements include:

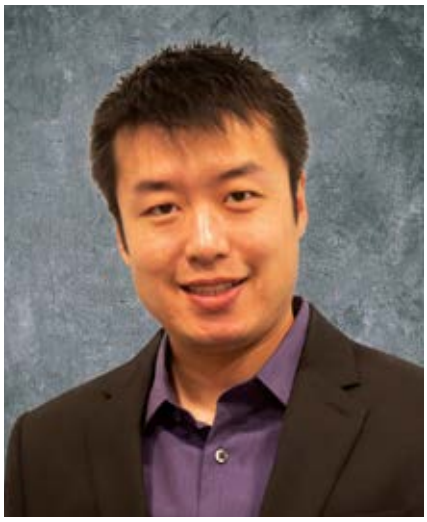
- B.S. in Mechanical Engineering, the University of Utah
- Project engineer, Colvin Engineering Associates

Career highlights include the following:

- She won the 2020 Engineered Systems, 20 to Watch: Women in HVAC Engineering Contest. She was featured in the January 2021 issue about her interests in sustainability, community impact, and the complexity of her skillset.
- Her project portfolio includes the Salt Lake City Airport, the BioFire 505 Colorow Road, BioFire Manufacturing Facility, and BioFire Administrative Building, the University of Utah Fieldhouse Theatre, and the Utah Valley University Keller Business Building.
- She is a member of the Society of Women in Engineering, ASHRAE, and ASHRAE Board of Governors, Utah chapter. She prides herself on seeking ways to leave a sustainable impact with every project she is assigned.
- She is a high school volleyball coach for a local high school girls' team.
- She tutors local middle and high school students in math and chemistry, and she hopes to inspire her students to become future engineers.

Fresh Face of Engineering Nominee
Lingkun Li

City of South Salt Lake
Nominated by ASCE



Lingkun Li

Lingkun has been involved with ASCE since 2014 when he joined as a student member. In 2017, he joined the ASCE Young Member Forum (YMF) and accepted the position of President in June 2018. During his term as President-elect, he arranged the Fall 2018 and Spring 2019 PE Review Course and volunteered to serve in a Ronald McDonald House event and assisted the President in YMF and Section board meetings. During his term as President, he oversaw the YMF budget and socials and successfully brought the Western Region Younger Member Council (WRYMC) Conference to Utah for 2022.

Achievements include:

- Master of Science in Civil Engineering, University of Utah
- Bachelor of Science in Mechanical Engineering, Tianjin University of Technology, Tianjin, China

Career highlights include the following:

- He investigated smog-eating concrete for UDOT.
- He served as the president of the American Concrete Institute, University of Utah Student Chapter.
- He volunteered at the Ronald McDonald House, helped during national engineering-week activities, and judged youth students through the University of Utah Science and Engineering Fair.
- He has been acctive in public and engineering organizations, including the American Society of Civil Engineers (ASCE), American Public Works Association (APWA), the American Concrete Institute (ACI), and the Utah City Engineer Association (UCEA).
- His professional work includes the following projects: the Provo-Orem BRT Asphalt Quality Assurance, the University of Utah Hospital expansion, the Ogden Library, Fitts Park, State Street Lighting Expansion, and the Fire Station 42 Parking Lot.

Fresh Face of Engineering Nominee
Breanna Whiteleather

Lockheed Martin
Nominated by INCOSE

Breanna Whiteleather

Breanna Whiteleather has been an electrical engineer for three years and interned for three years before that. She gained her bachelor's degree in December 2017.

Achievements include:

- B.S., Electrical Engineering with a minor in Mathematics, Weber State University
- INCOSE ASEP certification

Career highlights include the following:

- At BAE Systems, she was involved in the Acquisition Program for ICBMs. The program replaces and updates systems needed for the test launches at Vandenburg Air Force Base. She then transitioned to testing the new and current systems for the Minuteman III Missile. She also became involved with BAE System's model-based systems engineering (MBSE) initiative. Her goal was making digital engineering more mainstream within the intercontinental ballistic missile (ICBM) community.
- At BAE Systems, she won the Business Leader Award and the Air Force Quarterly Team Award.
- She is a systems engineer at Lockheed Martin. She works as the Survivability Task Team Lead, specializing in nuclear hardness and survivability.

Congratulations UEC 2021 Engineer of the Year Nominees!

Engineer of the Year Nominee
Capt. John McCrea

United States Air Force
Nominated by INCOSE

Capt. John McCrea

Capt John McCrea is the Lead Engineer, Flight Destruct System on the Minuteman III Flight Test, Telemetry, and Termination (FT3) system and the Lead Project Manager/Engineer for Minuteman III Digital Transformation. In his FT3 role, John is responsible for ensuring a safe flight destruct system during operational test launches out of Vandenberg Air Force Base in California to the Kwajalein Atoll. For the digital transformation, John is responsible for a team of 57 people taking over 70 systems of data and digital engineering tools for a 50-year-old weapon system and consolidating them in a cloud-based ecosystem. This modernization of a legacy system is a huge leap forward toward advancing the Department of Defense digital engineering objectives and making our national defense safer than ever. John also has a passion for STEM and service in building the wider engineering community, through organizations like INCOSE, AIAA, and NDIA, as well as participation in FIRST robotics competitions at multiple levels. Despite COVID, John has continued to enable quality engineering and education activities throughout 2020.

Achievements include:

- B.S. Aerospace Engineering (Astronautics), Arizona State University, 2016
- M.S. Engineering Management, Air Force Institute of Technology, 2018
- M.S. Systems Engineering, Air Force Institute of Technology, 2018
- Lead project manager/engineer for the Minuteman 3 (MMIII) digital transformation
- Five awards and patents
- Four publications at JHU/APL, NDIA, SciTech, and AIAA conferences
- 2020 UEC Fresh Face of Engineering

Engineer of the Year Nominee
Kerry Charles (KC) Shaw

Central Utah Water Conservancy District Nominated by ASCE

Kerry Charles Shaw

KC Shaw is a dedicated civil engineer with a distinguished 36-year career in the public and private sectors in Utah. He is the chief engineer for the Central Utah Water Conservancy District, where he oversees the planning, design, and construction of major critical infrastructure in Utah. Notable elements in his career include:

- Bachelor and Master of Science in Civil Engineering, Brigham Young University
- Director of Engineering at Anderson Geneva Department
- Management and leadership at Geneva Steel, Sunrise
- Engineering, and Comet Resources
- Utah State Water Quality Board, Member, 1995-2003
- Water Environment Association of Utah, Public Servant Award, 2003
- ASCE, President of Utah Section (1993-1994) and Central Utah Branch (1989-1990)
- Licensed Professional Engineer by State of Utah from 1986 to the present
- OSHA Hazardous Waste Operations and Emergency Response (HAZWOPER) Trained, 1989

Engineer of the Year Nominee

Roger Hamlet

Colvin Engineering Associates
Nominated by ASHRAE

Roger Hamlet

Roger is a professional engineer, project manager, principal, and partner at Colvin Engineering Associates, where he successfully manages a profitable project engineer team. Roger is an internal quality control supervisor and consistently sets the industry standard for sustainable design in higher education, municipal, manufacturing, utility distribution, laboratory, and office facility market sectors. He routinely leads the efforts to streamline processes, hosts in-house training programs, and coaches up-and-coming engineers. Roger can find the solutions for the most complex of project challenges. His 29-year career is a testament to his dedication to serving our community with design tailored to each client, owner, architect, and end-user. Our community benefits from his position as Code Commission Committee Member and his continued contributions to ASHRAE, CSI, and as a thought-leader in our industry.

Achievements include:

- B.S. in Mechanical Engineering, the University of Colorado
- Leadership in Energy and Environmental Design (LEED) AP BD+C
- Professional Engineering in the state of Utah
- Committee member, Uniform Building Code Commission Mechanical Advisory Committee, State of Utah
- Member of ASHRAE, Construction Specifications Institute (CSI), Swiss Association of Heating and Ventilation Engineers
- Region IX Technology Award, Salt Lake City Public Safety Building
- ASHRAE Utah Chapter Engineer of the Year Award
- BOMA Energy Symposium, presenter

Career highlights include the following:

- He volunteered as a teacher for an Agha Khan Foundation middle school in Pakistan.
- He consulted in Switzerland for five years. He designed research and manufacturing facilities for pharmaceutical and chemical manufacturers.
- His portfolio has 22 notable projects.
- His work at BioFire Manufacturing qualified for the Utah Construction and Design's 2020 Most Outstanding Project in the Manufacturing and Commercial category.

Engineer of the Year Nominee
Jessica Widrick

Northrop Grumman
Nominated by AIAA

Jessica Widrick

Jessica Widrick is an accomplished engineer who has spent the past 15 years working with large solid rocket motors for Northrop Grumman in Utah as a design engineer in the metal structures, joints, and seals group and as the design lead and technical expert responsible for metal hardware components, seals, and overall joint performance. She started her career working on the shuttle program with the reusable solid rocket motors and has since worked on government, commercial, and industry entities for both development and production programs. Jessica interacts and coordinates with multiple manufacturing centers and Design Engineers to ensure successful handling, manufacture, and assembly of metal hardware and joints. Jessica not only frequently works with different disciplines but also maintains a comprehensive knowledge of the production processes to ensure a successful design including an understanding of rocket motor ballistics, fluid mechanics, heat transfer, thermochemistry, and structures. Jessica is an expert of various seal material's capability, joint environmental conditions, potential changes during operation, seal integrity verification, and how to conceptualize and bound failure modes. Jessica maintains and develops engineering design standards within her discipline and teaches others good design practice by creating standards to help train others and create design process consistency.

Achievements include:

- B.S. in Aerospace Engineering, the University of Tennessee, Knoxville
- Sr. principal structural engineer, August 2007-Present
- System safety engineer, June 2006-August 2007
- Career highlights include the following:
- She spent 15 years working with large solid rocket motors.
- She worked on a shuttle program with reusable solid rocket motors.
- She interacts and coordinates with multiple manufacturing centers.
- She maintains and develops engineering design standards.
- She received a Northrop Grumman Innovation Systems and Propulsion Systems Achievement award, 2019.

Congratulations UEC 2021 Scholarship Winners!

Zakary Wankier

Zakary Wankier

Biomedical Engineering
University of Utah
Northrop Grumman Scholarship

- Interested in prosthetics — works in the University of Utah's Orthopedic Department doing research on percutaneous osseointegrated prosthetic attachments
- Co-president of a service oriented nonprofit organization called Maji
- Baseball fanatic and a die-hard supporter of the Boston Red Sox

Bryce Cheek

Bryce Cheek

Electrical Engineering
University of Utah
Northrop Grumman Scholarship

- From Charlotte, North Carolina
- University of Utah Honors College
- Officer for the University of Utah National Society of Black Engineers
- Student Athlete on Men's Lacrosse Team
- 3.816 GPA while maintaining athletics
- Executive leader for the United Together Against Hate Group (U.T.A.H.) for Student Athletics
- Two-time Athletic Director's Honor List
- Four-time Dean's List Qualifier

Andrew Meldrum

Andrew Meldrum

Chemical Engineering
University of Utah
FLSmidth Scholarship

- From Olympia, Washington
- Energy Industry Experience:
  - Industrial Assessment Center — 2019-current
  - BP – Summer 2020
  - Marathon Petroleum — Spring 2020, Summer 2021
- Engineers Without Borders: Tech Team Co-Lead
- Big Brothers Big Sisters Volunteer Work
- Trilingual: Spanish, Portuguese, English
- Enjoys the outdoors — dirtbikes, hiking, camping

Jordan Whitlock

Jordan Whitlock

Mechanical Engineering
Southern Utah University
Applied Product Solutions Scholarship

- Raised in Nephi, Utah as the third brother in a family of four boys
- Loves everything to do with science, and was drawn to engineering specifically by the ability to model the world through math and physics
- Beginning a thermodynamic research project this summer that will continue through the next school year
- Plans on attending graduate school after graduating from SUU and pursuing a career in aerospace
- His high school soccer team didn't win a game in the four years he played.

No photo available

Nathan Robertson

Mechanical Engineering
Utah Valley University
Midgley-Huber, Inc. Scholarship

- Top rank in school and recommended by faculty
- Works in quality control to improve processes between engineering drawings and the manufacturer of completed parts and design improvement
- New father supporting family and finishing school without debt
- Enjoys math, science, physics and learning how things work
- Hopes to be involved in the design of new products that will improve the world in some small way

Tanner Short

Tanner Short

Mechanical Engineering
University of Utah
VBFA Scholarship

- From Coeur d'Alene, Idaho
- Dean's list, four semesters
- National Aerospace Scholars Recognition
- Currently a Mechanical Engineer Intern designing and building machines that manufacture dental products for Ultradent Products Inc.
- Co-founder and treasurer of the University of Utah Film Production Club
- Emphasizing in Robotics, planning to earn an MBA
- Loves directing and producing films, and dreams of integrating robotic engineering into film production

Tyler Jackson

Tyler Jackson

Civil Engineering
Utah State University
Charlie and Nita Voto Scholarship

- Works as a Math Teaching Fellow for Multivariable Calculus courses
- Recently started an internship at Gerhart Cole, a Utah geotechnical engineering firm
- When he's not working on school, he likes to play music. He's been teaching himself the guitar and banjo since the pandemic began.
- Planning on completing his Master's in Geotechnical Engineering at Utah State University after getting his Bachelor's degree

Emilee Rickabaugh

Emilee Rickabaugh

Biological Engineering
Utah State University
Charlie and Nita Vono Scholarship

- Loves her research in Dr. Elizabeth Vargis's Lab
- Currently researching creating an in vitro model of the subretinal tissue using recombinant hagfish slime proteins
- Enjoys her volunteer work with LGBTQ+ organizations in Logan
- In her spare time, she likes reading, rock-climbing, and trying new coffee recipes.

Emily Quan

Emily Quan

Computer Engineering
Brigham Young University
Northrop Grumman Scholarship

- Cyber Analytics Internship with Northrop Grumman in the Mission Systems sector — working on a Java prototype from scratch of a user interface model that was presented to the customer
- Research assistant for the Brigham Young University Network Embedded Technologies Laboratory — working with air quality data analysis using Python, Jupyter Notebook, and was a BYU RA fabricating novel multicolor gratings on a holographic chip using photolithography in a class 10 cleanroom
- Ballet pianist for Brigham Young University's ballet classes and 2017 Knabe Young Artist Senior Piano Competition Winner, among other piano accolades
- $1,000 Fellowship for TreeHuggr in the CalHacks Hackathon
- 2019 National Merit Finalist
- 2018 FIRST Robotics Competition SW Virginia Division Winner

Blayze Ashurst

Blayze Ashurst

Electrical Engineering
University of Utah
BAE Systems Scholarship

- From Logan, Utah
- Involved in the IEEE club at the University of Utah, which helps introduce college freshman and K-12 students to STEM related field.
- Loved electronics for many years, and greatly enjoys spending spare time designing electrical circuits based upon what has been learned in coursework
- Works as a tutor in the Electrical Engineering department, and enjoys helping others learn concepts related to electrical engineering

Gaby van Brunt

Gaby van Brunt

Mechanical and Aerospace Engineering
Utah State University
BAE Systems Ben Van de Graaff 2021 Memorial Scholarship

- Worked as an intern in the aerospace industry during the summer of 2020 and continues in 2021
- Undergraduate researcher in computational fluid dynamics
- Supplemental instructor for USU Math Department
- Active in Utah State University Chapter of Society of Women Engineers — Outreach officer (2019-2020), President (2020-2021)
- Utah State University College of Engineering Ambassador
- Member of Tau Beta Pi Engineering Honor Society
- Passionate about STEM outreach and wants to ensure that all young people have exposure to opportunities in the engineering field

James Mullen

James Mullen

Mechanical and Aerospace Engineering
Utah State University
Northrop Grumman Scholarship

- From Pocatello, Idaho
- Currently researches with Dr. Roberts in the Utah State University Nanoscale Thermal Energy Lab
- Works for a local aerospace engineering company, Thermal Management Technologies
- Passionate about research and development and intends to pursue a future in patent law after graduating with his engineering degre[e]

Jason Hall

Jason Hall

Material Science and Engineering
University of Utah
AIAA Utah Section Scholarship

- University of Utah Material Science and Engineering Ph.D. Candidate
- Researching machine learning applications of multimodal particle packing and optimizing the mechanical properties of aging solid propellants by maximizing ballistic performance
- Principal Material and Process Design Engineer at Northrop Grumman, Promontory, Utah
- Registered Utah Professional Engineer
- Volunteers for youth STEM activities

Dellan Fielding

Dellan Fielding

Mechanical Engineering
Utah State University
ASHRAE Utah Chapter Scholarship

- Utah State University, Sophomore, Mechanical Engineering
- 2021 Reuben Trane national ASHRAE Society scholarship
- Utah State University ASHRAE Vice President, 2020-present, Student Branch, Treasurer, 2019-2020
- Two years experience, HVAC Controls Intern, Utah State University
- Projects include: Configuring the Air Handler Unit damper control and revamping building HVAC controls with upgraded PLCs and VAVs
- Fluent in the Hmong language.
- Enjoys sport climbing, playing guitar, and being outdoors

Interviews With UEC Leadership

An Interview With Paul White, Chair, and Roberta Schlicher, Second Past Chair

Our story starts way back.

The Utah Engineers Council (UEC) has been supporting local Utah chapters and societies for over 70 years. We are the umbrella organization for 15 local chapters and societies within the many engineering disciplines. Our purpose is to advance the art and science of engineering and to provide a forum for communication between the varying engineering societies.

We are a 501(c)(3) non-profit organization that is fully run by volunteers.

utahengineerscouncil.org/about-us /#aboutUEC

IMAGINING TOMORROW

ASHRAE

Early Design Phase Energy Modeling and Multiobjective Optimization

In the U.S., buildings have an average life span of 70-75 years (DOE, 2011) and represent 40% of the country's annual energy use (Energy Information Administration, 2012). Consequently, design choices related to new buildings have a significant and long-lasting impact. In general, it is important to consider energy consumption and cost for the design of every building. However, when buildings are part of a larger campus, a single-building perspective can fall short of identifying how the buildings can interact to reduce their overall energy consumption, cost or emissions. This reduction is only achievable through a multibuilding analysis simulation. One difficulty of performing a multibuilding simulation is that each building is probably only defined conceptually during the early design phase of a large campus. This article will go through one way to simulate, analyze and optimize the mechanical system types for a campus when only building function type, quantities of buildings, and size is known.

A good starting point, and excellent overall resource, for modeling building energy consumption from a high-level perspective are the DOE Prototype Building models (Commercial Prototype Building Models, 2021) created by researchers at Pacific Northwest National Laboratory (PNNL). There are 16 commercial building types available for 19 different climate locations that represent 75% of the commercial building stock in the U.S. The prototypes were created using data from the Commercial Buildings Energy Consumption Survey (CBECS, 2015), which in 2003 included data from 5,215 buildings. The CBECS database is thorough and includes information such as floor area, occupancy, and envelope construction. For information not readily available in the CBECS survey, the PNNL prototype buildings use guidelines outlined in ASHRAE 90.1 for criteria such as operating schedules, infiltration, and lighting power densities. The prototypes are available for efficiency requirements outlined in ASHRAE 90.1 and the International Energy Conservation Code from 2004 through 2019. These prototypes are specifically designed for use with EnergyPlus, a building energy analysis and thermal load simulation program developed by the Department of Energy. EnergyPlus is free to download and use. It may be accessed here: https://www.energy.gov/eere/buildings/downloads/energyplus-0.

Even though these prototype models won't be an exact match for every project, they are a very useful template. They can be used as a consistent starting point for evaluating design choices such as the HVAC system type. For example, consider a project where a developer would like to construct a six-office building campus. They intend to have two 580,000 square-foot, 14-story office buildings with data centers and four 110,000 square-foot, 6-story office buildings. Countless possibilities can be considered, but for the sake of this exercise, the following options will be evaluated: typical HVAC systems, all-electric HVAC systems, a blend of any system, and then a central plant that services the entire campus. The central plant's underlying purpose is to capture the waste heat from the data centers to heat office spaces in the winter.

The overall procedures for evaluating these different scenarios are listed below:

1. Review the DOE building prototype database and select buildings of similar functional use.
2. Select the building template file for the correct code version and correct climate zone and download the appropriate TMY3 (Typical Meteorological Year) weather file.
3. Adjust room multipliers and floors to align the template building file with the campus's proposed functional usage.
4. Modify and/or add HVAC systems to align with the different mechanical systems considered in the assessment.
5. Run the simulations and normalize energy use and emissions on a square foot basis.
6. Evaluate the solution set to select the system types that best align with the project objectives.

Scenario	Large Office	Medium Office
Base Case	- Water-source heat pumps are tied to a fluid cooler for the data center - Uses VAV air handlers and VAV-reheat boxes for offices - Has a gas-fired boiler	- The DX air conditioning unit is packaged with the gas furnace - Uses VAV reheat boxes with electric reheating coil
Central Plant	- Has water-source heat pumps tied to a fluid cooler for the data center - Uses VAV air handlers and VAV-reheat boxes for offices - Uses two water-cooled centrifugal chillers for building - Has a gas-fired boiler	
Central Plant	- Uses water-to-air heat pumps for all zone - Has a central condenser loop with a gas-fired boiler and cooling towers	
Electrification	- Has an air source VRF condenser - Has fan coil units	Has an air source VRF condenser
Hybrid	- Has water-to-air heat pumps for all zones - Uses a central condenser loop with a gas-fired boiler and cooling tower	- Has an air-source VRF condenser

The template files can be simulated without modification to evaluate the base case. The large office and medium office HVAC systems are changed to air-source VRF to evaluate the electrification scenario. Lastly, the large-office template is modified for the central plant scenario so that the ratio of office space and data center square footage is equivalent to the total ratio of the eight buildings. This modification is done by adjusting the number of occurrences for each zone or adding floors to the buildings. Lastly, the HVAC system type is changed to water-to-air heat pumps with a central condensing loop.

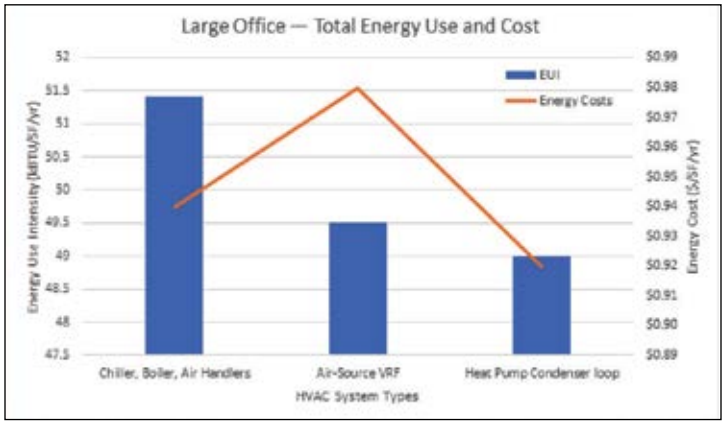


Figure 1. Large Office Energy Use Intensity and Energy Costs

Building simulation results (see Figure 1) show that for the large office, the traditional HVAC system, or base case, has a higher energy use intensity (EUI) compared to either of the alternative system types. It is interesting to note that for the large office, an Air-Source VRF system has a lower EUI, but the annual operating cost is higher. The higher operating cost is due to wintertime electricity charges for running the VRF system in heating mode and the reduced efficiency with using Air-Source VRF to cool the data center compared to heat pumps tied to a fluid cooler. The lowest EUI and operating cost system for the Large Office is the heat pump system.

A water-to-air heat pump system is well suited for large offices in the Salt Lake City climate because the data center's waste heat can be recovered and used to heat office spaces. Furthermore, when the heat from the data center is insufficient to heat the entire building, the central boiler can operate in the condensing mode since the return water temperature is much lower for a heat pump condensing loop than a standard heating water system. Finally, the heat pump system has a lower EUI than the air-source VRF because the cooling tower rejects heat at the wet-bulb temperature, whereas the air-source VRF system rejects heat at the dry-bulb temperature. In the Salt Lake climate, the wet-bulb temperature is significantly lower for the majority of the year.

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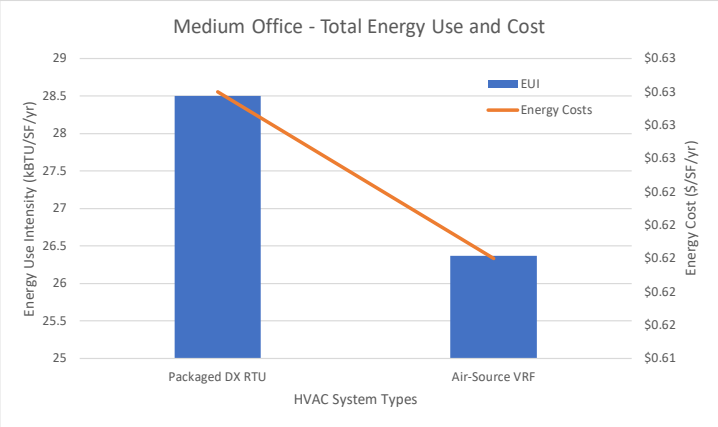

Figure 2. Medium Office Energy Use Intensity and Energy Costs

In contrast, the medium office is best served by an air-source VRF system, as shown in Figure 2. The VRF system allows for load sharing between different spaces and is more efficient with a smaller EUI than the packaged DX rooftop unit with a gas furnace. Given that the medium office has a much lighter heating and cooling load than the large office, the VRF system doesn't cause significant electrical demand charges, reducing the annual operating cost compared to the VRF system serving the large offices.

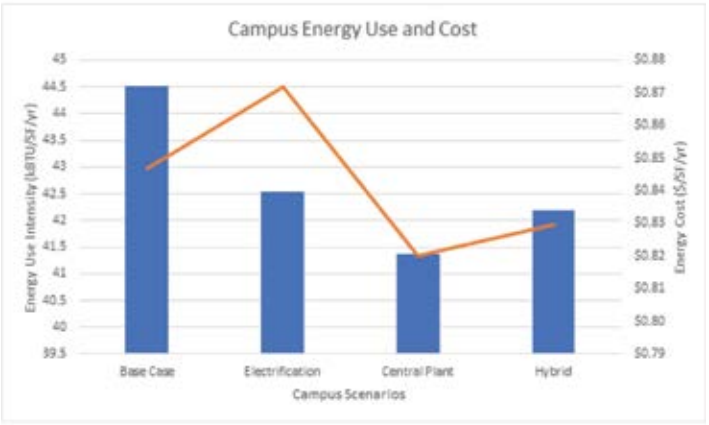

Figure 3. Campus Level Energy Use Intensity and Energy Costs

When viewed as a wholistic campus, the base case scenario has the worst EUI and operating costs, followed by the electrification scenario and, finally, the hybrid scenario. (Figure 3) By far, the best performing system type for the campus is a central plant because the waste heat from the data centers can be recovered and reused throughout the campus. Furthermore, the water-to-air heat pumps have a higher efficiency than air-source VRF because the condenser loop is maintained at a moderate temperature year-round.

This article describes a high-level energy modeling technique for evaluating campus buildings during the early design phase. Utilizing the PNNL template files makes it possible to quickly evaluate different HVAC systems for multiple buildings in an office campus. This approach can be beneficial during the design phase because it makes it possible to simulate different building types without creating full building energy models from scratch. Additionally, it is possible to simulate multiple buildings from a campus-level perspective to see if there are opportunities to reduce energy consumption and cost by interconnecting buildings with complimentary load profiles. It is important to note that this high-level approach is best suited for eliminating design choices early on. If different scenarios have relatively similar EUIs or operating costs, then detailed energy modeling should be conducted once the project is more fully defined.

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Gabriel Legorburu, P.E., Ph.D.

Gabriel Legorburu specializes in energy modeling, optimization and mechanical design for Industrial facilities and campuses. He is enthusiastic about designing robust, cost-effective, and efficient mechanical systems that meet client expectations. He is currently a senior mechanical engineer and mechanical team leader at Food Tech, a nationally recognized design builder that constructs food and beverage companies' facilities.

Gabriel has worked in the construction industry for 17 years and currently holds licenses in states across the U.S. He received his Ph.D. in Mechanical Engineering from the University of Utah, a master's in Mechanical Engineering from Ohio University, and a bachelor's degree from the University of Nevada, Reno.

INCOSE

The Hitchhiker's Guide to the Digital Engineering "Galaxy"

THE ULTIMATE ANSWER IS "42." WHAT IS THE QUESTION TO THE ULTIMATE ANSWER?

Thomas Lockhart, Director of Engineering and Technical Management,
Air Force Nuclear Weapons Center, Hill Air Force Base, Utah

Many of us can relate to Arthur Dent (the main character in The Hitchhikers Guide to the Galaxy). He is a mild-mannered guy trying to protect his house when he is plucked from the earth just before it is demolished to make way for a hyperspace bypass. I, myself, felt like "poor Arthur Dent" while writing this article on digital engineering.

Like many of you, I am seeking to understand and embrace digital engineering. To many of us, digital engineering is like that "tantalizing galaxy" outside our world … exciting, thrilling, and just waiting to be discovered and explored. This article will engage in a sharply humorous relation between the United States Air Force Digital Campaign and The Hitchhiker's Guide to the Galaxy. Be prepared to learn more about the innovative realm of digital engineering and what possibilities lie beyond our grasp. Most of all, enjoy this article, share it with your friends, and have fun!

Body of Knowledge No. 1. The Integrated Digital Environment

Like Arthur Dent, I had to grasp that so much more exists beyond my house (the United States Air Force) and backyard (the United States Department of Defense) that beckons to be studied and understood as we move into the Digital Engineering Galaxy.

The first body of knowledge I would share is an integrated digital environment. An integrated digital environment is a compilation of data, models, and tools for collaboration, analysis, and visualization across all functional domains. The integrated digital environment includes the methodology and specifications for data, models, and tools arrangement with processes and procedures to exploit informational results.

The Air Force Digital Campaign needed categorization/taxonomies for the body of knowledge tools and models being proposed to perform various lifecycle phases of system research, design, development, test, sustainment, and disposal. During the Air Force Digital Campaign tools sprint, it was generally acknowledged that the Air Force owns and manages over 700 tools and applications, plus thousands of independently developed models that perform on:

- Personal computers
- Client-servers
- High-performance computers
- On-premise clouds, and
- State-of-the-art enterprise clouds

In other words, the tools, applications, and models form a very complex digital galaxy. With the size and complexity of tools available on the market, the team arranged this galaxy of tools into four areas of prominence:

- Model-based System Engineering
- Product-Lifecycle Management
- Analysis
- Visualization

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To understand this digital galaxy transformation, we have presented Figures 1.0 and 2.0. Figure 1.0 is system engineering and management from the past. Figure 2.0 moves product lifecycle management into the future model-based digital engineering galaxy (beyond the clouds, the integrated digital environment, and crowd-sourced thinking).

For myself, my understanding was defined as moving from a paper to a virtual three-dimensional environment, as visualized in Figure 2.0.

Arthur (I) began his (my) journey by getting snatched from earth. I needed definitions to tether me to earth while on my journey.

I worked from the international landscape using definitions from the International Council on System Engineering (INCOSE).[1] INCOSE will be the primary source of these definitions and understanding. I also referred to the Office of the Secretary of Defense Digital Engineering Strategy,[2] System Engineering Research Center,[3] and the Air Force System Engineering Center.[4] After that, I went into open-source literature — the big blue digital galaxy. In keeping with the theme, I highlighted the proposed definitions for the **Air Force Digital Campaign guide** in blue.

Model-based Systems Engineering

Feb. 26, 2020: INCOSE defines model-based systems engineering as ***"the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases."***[1]

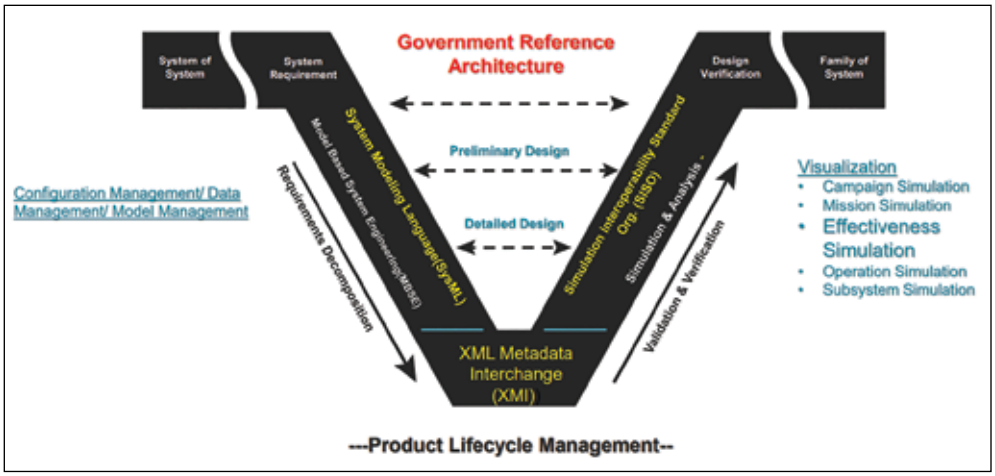


Figure 1.0 System Engineering

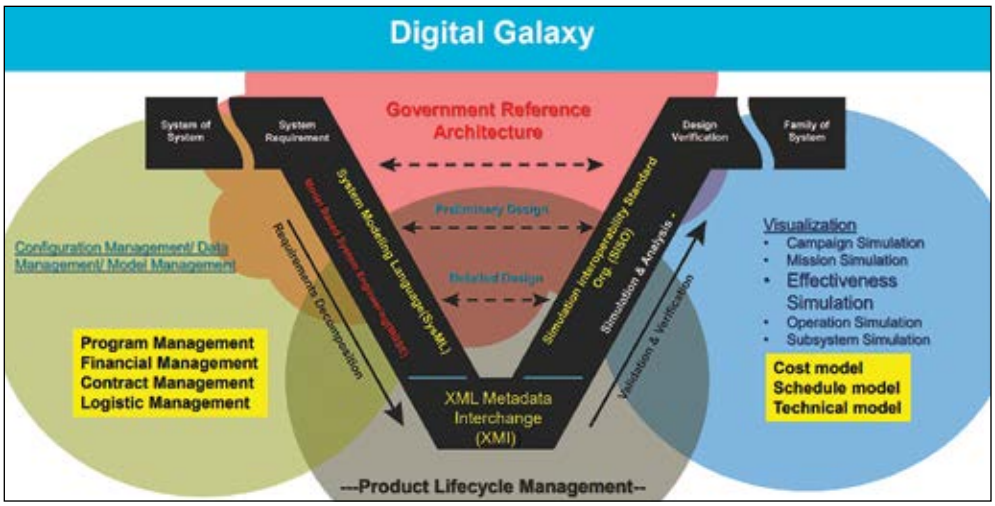


Figure 2.0 Future Model-based System Engineering (Cloud, Integrated, and Collaborative)

Digital model-based engineering is the use of digital artifacts, digital environments, and digital tools in the performance of engineering functions.[2] For a list of popular MBSE tools, please visit https://mbse4u.com/sysml-tools/.[4]

Product Lifecycle Management

Using product lifecycle management is not a new concept and has been part of system configuration management and data management processes; however, digital emphasizes the continuity of models across the lifecycle with the mission owner, acquirer, and product development.[2]

Product lifecycle management is ***"a systematic approach to managing the series of changes [and models] that a product goes through, from its design and development to its ultimate retirement or disposal."*** [5]

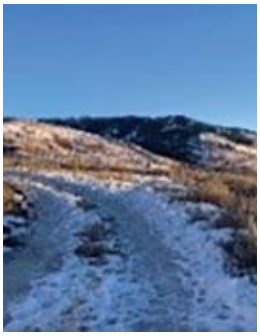
Analysis

Formalize the development, integration, and use of models to inform enterprise and program decision-making. This support combines model-based systems engineering and product lifecycle management with consistent analysis and decision-making for programs across the enterprise.[2]

"Analysis is the examination of anything complex in order to understand its nature or to determine its essential features." [6]

Visualization
Visualization techniques and tools are used to display the results in various visual forms to be processed so they can be presented to the users in a meaningful way.[7]

"Visualization is the act or process of interpreting in visual terms or of putting an object, situation, or set of information into visible form." [6]



Body of Knowledge No. 2. Framing the Integrated Digital Environment for Acquisitions

We are in the throes of understanding the Digital Galaxy, which might look different and have different turns depending on your programs, knowledge, and, more importantly, your knowledge of the digital universe.

One notional body of knowledge example is in the graphic below (Figure 3.0), which shows a simple government integrated digital environment with multi-levels of security communities exchanging knowledge, models, and data from a contractor's integrated digital environment, also at multi-levels of security. The two-dimensional graphic does not do the relationship justice since that bidirectional arrow happens at quantum speeds in the new digital galaxy.

One note of importance is that the integrated digital environment includes integrating programmatic information (such as the program manager, financial manager, logistics manager, and so on) with the engineering models and data, resulting in an environment that is a truly integrated acquisition program. It is not a paper-based product anymore, but a digital galaxy.

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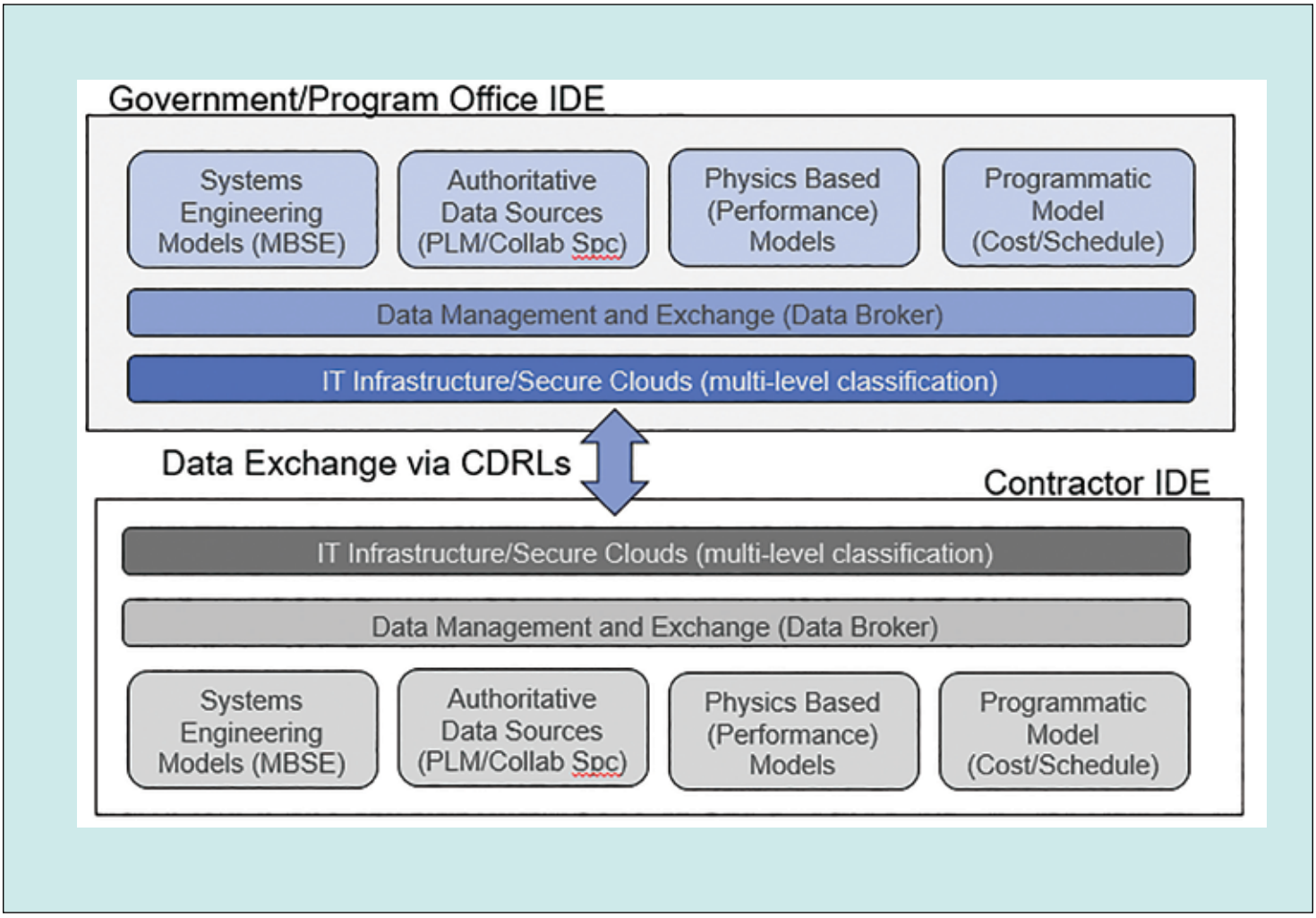

Figure 3.0 Integrated Digital Environment Example

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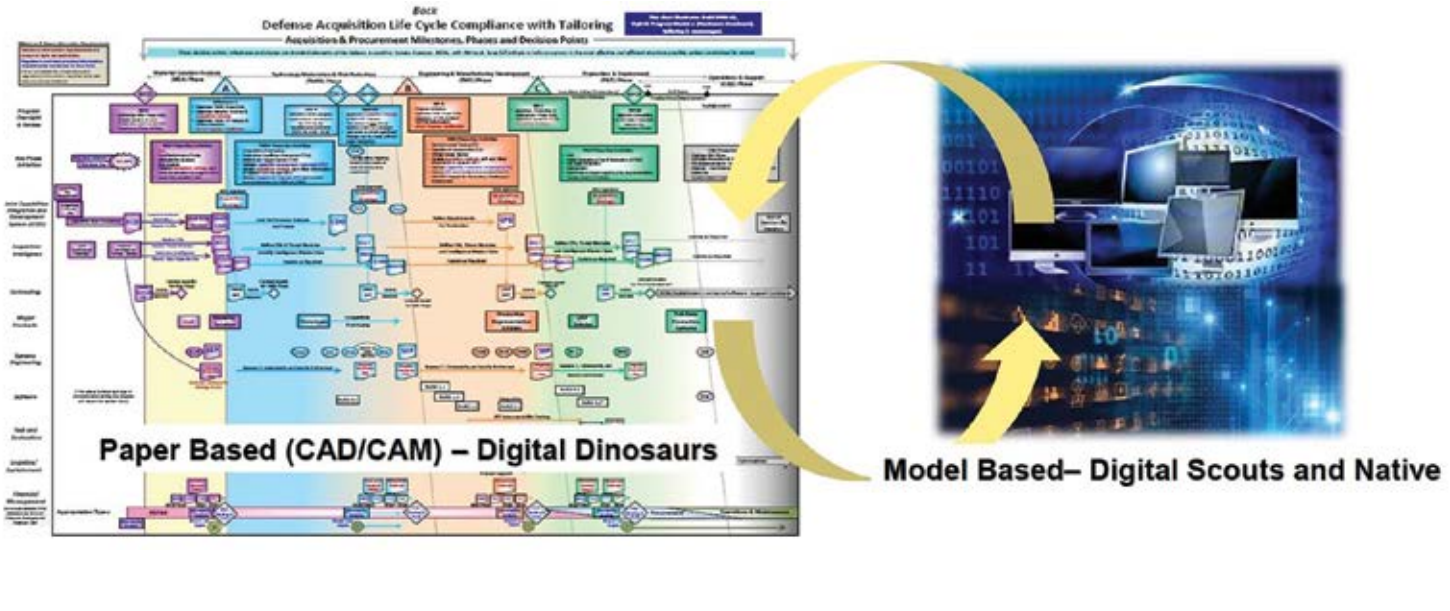

Figure 4.0 The Transition From Paper-based Management (1960) Through Computer Added Design Products (1980) Into Today's Digital Galaxy

It is great to see defense acquisition laid out so clearly. It made complete sense to me. However, the step from a local understanding to understanding the galaxy was a giant and very complex leap for me. To develop my understanding, Arthur (I) ended up breaking it down into the chapters that have led into the digital galaxy:

#0: Integrated Environment — IT Infrastructure

Provide overarching guidance to influence corporate IT improvement investments and enable a robust, secure infrastructure for the enterprisewide Digital Campaign.

#1: Integrated Environment — Models and Tools

Provide an integrated digital environment of models and tools for collaboration, analysis, and visualization across the functional domains of Air Force users.

#2: Standards, Data and Architectures

Provide overarching guidance on using government reference architectures and related standards and datasets in an integrated digital environment to be applied at the enterprise and system levels.

#3: Lifecycle Strategies and Processes

Develop life cycle strategies and processes for technology transition, system acquisition and product support using an integrated digital environment, supporting lifecycle activities from concept development to disposal.

#4: Policy and Guidance

Assess and define the required policy and guidance updates or changes to enable digital transformation's full implementation.

#5: Workforce and Culture

Drive cultural change across the Air Force Materiel Command enterprise through training and change management, enabling a workforce well-versed in digital engineering.

Body of Knowledge No. 3. Cultural Natives, Scouts, and Vagons (Dinosaur-Like Creatures)

Another knowledge point in body of knowledge 3 that Arthur (I) had to grasp was culture and cultural acceptance within the digital galaxy. As we explore culture, we take another detour around the galaxy, understanding people, pathfinders, and acceptance.

This section isn't specifically about the previously discussed framework of the integrated digital environment. This section is a reflection of the Air Force Digital Campaign evaluation of the Air Force Digital Campaign community in the digital galaxy. As we gallivanted about the galaxy with its 10,000 people, industry, pathfinders, and programs, several common themes were revealed.

- **Observation 1:** There were digital natives in the galaxy. These natives accepted that the network, connections, and applications were always available. They just accepted this digital ecosystem as part of their daily life.
- **Observation 2:** Scouts were experiencing parts of the digital ecosystem (as they looked into clouds, microservices, agile software, and so on.). As a group, they were trying to utilize this new environment to the best of their ability through crowdsourcing models and ideas.
- **Observation 3:** I saw a third group that I termed "Vagons" (not a negative term) that were not as comfortable as the scouts and natives. They are cautious at every step as we see and experience more of the universe and as the digital galaxy starts to expand.

Don't worry if you fit into any of those categories. Arthur continued to ask "Why?" in The Hitchhiker's Guide to the Galaxy. You can, too.

So Long, and Thanks for All the Fish

Arthur and I hope you enjoyed The Hitchhiker's Guide to the Digital Engineering Galaxy. The journey doesn't stop here. We have a long way to go, and it is going to be a fantastic future!

Let's recap some of the journey.

In body of knowledge No. 1, we learned the basic elements that make up the Digital Galaxy, such as model-based system engineering, product lifecycle management, analysis, and visualization. We also ran through the element descriptions to better understand this very complex, very integrated $\iint_{MBSE}^{PLM}$ Analysis Visulization. The expansion of the sum of those four critical elements is larger than the individual elements:

$$(1+x)^n = 1 + nx + \frac{(n(n-1)x^2}{1!} + \frac{}{2!} + \ldots$$

For me, concluding that those four elements are the only or completely correct four elements is just ludicrous at this stage of our digital galaxy journey.

In body of knowledge No. 2, we learned how to frame our understanding of this integrated digital environment relative to the further advancement of acquisition knowledge processes. We should embrace our legacy but recognize that our legacy should not restrict our advancement and adaptation of new truths thrust upon us as the complex digital galaxy is unveiled.

In body of knowledge No. 3, we recognized that everyone would not advance at the same pace while traversing the galaxy. We will recognize digital "Natives, Scouts, and Vagons." We should strive to understand their cultures, perspectives, and backgrounds and leverage all these aspects as we moving into the new digital galaxy.

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The Hitchhiker's Guide to the Digital Galaxy finishes with body of knowledge 3.14 (Pi). If you remember, The Hitchhiker's Guide to the Galaxy had two mice. They studied while the dolphins (the smartest mammals on the planet) were off playing and having fun.

As our Air Force Digital Campaign has studied the digital galaxy, we have concluded that:

- We are only starting our journey.
- We should pay attention to the fish. (The fish are the digital galaxy's computer gamers who seem to have a lot of fun.)

The Air Force Digital Campaign has benefited from collaborative interactions and continues to gain from lessons learned from digital pathfinders, industry, and academic advisers. The Air Force Digital Campaign is expanding every day because of these collaborations and observations.

There is a long way to go seeking to understand the potential of this complex Digital Galaxy. The Galaxy is being realized through:

- The centralized computational power of the clouds
- The need for high-speed communication networks
- The important integrated environments, and
- Pilot understanding of improvements through machine learning and artificial learning

We know the ultimate answer is "42." Now we need to find the ultimate question to the ultimate answer. So please, Marvin (a paranoid android): "Don't panic."

Special thanks to Mr. Paul White and Mr. Mark Kassan for guidance and consultation on this project.

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This Article was inspired by the following books by Douglas Adams:

- *The Restaurant at the End of the Universe, Douglas Adams, 1980*
- *Life, the Universe and Everything, Douglas Adams, 1982*
- *So Long, and Thanks for All the Fish, Douglas Adams, 1984*

Thomas A. Lockhart, Jr.
Thomas A. Lockhart, a senior executive service member, is the Director of Engineering and Technical Management, Air Force Nuclear Weapons Center, Hill AFB, Utah. He enhances warfighter support as the center's lead for nuclear systems and digital engineering, weapon system integrity, cybersecurity, test and evaluation, workforce development, technology insertion, and multi-domain system support for Minuteman III, Air-Launched Cruise Missile, and Command and Control (C2).

Prior to his current assignment, Mr. Lockhart was the Air Force Research Laboratory's director for both its Plans and Programs Directorate and its Strategic Development Planning and Experimentation Directorate, managing the processes that define Air Force Research Laboratory's $2 billion annual investment in technologies for future Air Force systems and enable the alignment of Science and Technology resources.

Mr. Lockhart has had two tours in Iraq and Afghanistan. In his last tour as the NATO Resolute Support Essential Function for Sustainment, Kabul, Afghanistan, he exercised oversight of Afghanistan National Defense and Security Forces sustainment for 385,000 Ministry of Defense and Interior military and police forces' yearly budgets of over $3.2 billion.

Mr. Lockhart began his career in 1987, working as a journeyman engineer in training and simulation at Hill Air Force Base, Utah. He has served as an engineer, chief engineer, acquisition program manager, group director, combatant command financial manager, deputy program executive officer (PEO) and security cooperation director.

A Community Wake-Up Call:

The Surprising Power of a Moderate Earthquake in Magna, Utah

Jessica Chappell, S.E., LEED AP

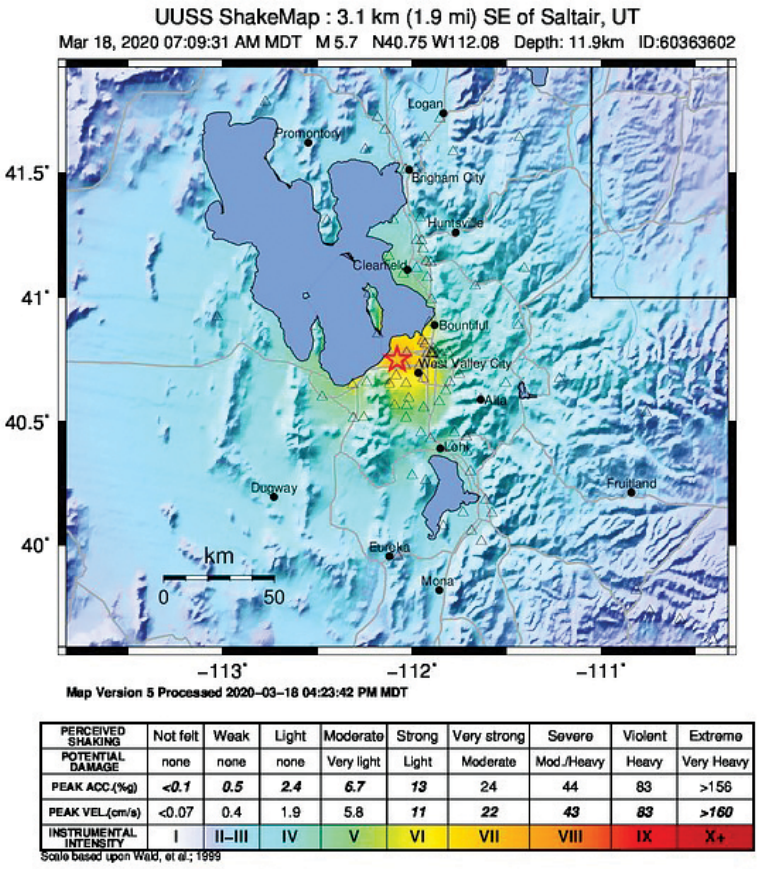

Figure 1. Magna Earthquake ShakeMap https://earthquake.usgs.gov/earthquakes/eventpage/uu60363602/shakemap/intensity

On the morning of March 18, 2020, life was already a bit surreal. Due to the rapidly developing COVID-19 pandemic, local schools had abruptly closed to in-person learning, keeping our two elementary school-aged children home. We voluntarily sat out day care for our youngest child, and my husband's office closed completely the day after the infamous Rudy Gobert incident that triggered the shutdown of the NBA. At Reaveley Engineers, we had a partial exodus of staff under a voluntary policy. I opted for a hybrid. With deadlines on a large hospital project looming, I intended to split my time between the office and my dining room table — not wanting to put the entire burden of taking care of three children on my spouse.

I stood in the kitchen, waiting for my coffee to brew, when the earth moved at 7:09 a.m. The shaking at my home in Cottonwood Heights was significant enough to cause me to brace myself with the counter. I looked out the window toward Holladay and Salt Lake City, where the sparking transformers looked like flashes of lightning. This earthquake was only the third one I had felt in Utah since moving home after college. The first was a foreshock in Bluffdale, Utah, in 2019 that awakened me enough to have my mobile in hand looking for U. S. Geological Survey (USGS) updates when the magnitude M_W 3.7 mainshock hit. This time, as in 2019, I went first to the USGS website to submit my citizen science report of what I felt.

In the next few minutes, I was surprised to learn that the magnitude M_W 5.7 event occurred in Magna. I made sure my family was settled after the excitement, reached out and responded through text messages with family and friends, and headed to the office to face what was inevitably going to be an interesting day.

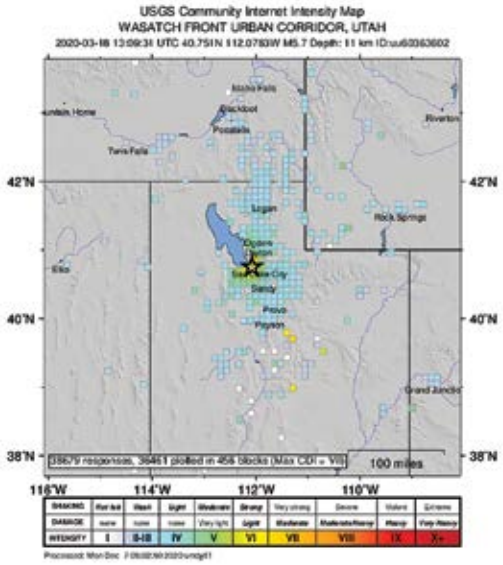

Figure 2. Did You Feel It? https://earthquake.usgs.gov/earthquakes/eventpage/uu60363602/dyfi/intensity

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The Wasatch Front has long been known as earthquake country to scientists and engineers. The grand mountain ranges frame our cities and towns and create the vibrant outdoor recreation that often draws people to our state. They also stand as evidence of the thousands-to-millions of years of uplifting geologic activity that created them. As a community, however, we all seem to be lulled into complacency by the very fact that we have never had catastrophic earthquake damage here. There has never been a building collapse resulting in extreme casualties or a clear "near miss" similar to the 1933 Long Beach, California earthquake.

Looking back on the Long Beach event, it is easy to see why it was such a catalyst for changes to building standards in California. More than 230 unreinforced masonry (URM) school buildings were destroyed, suffered major damage, or were judged unsafe to occupy following the earthquake.[1] The magnitude M_W 6.3 event shook the ground with a maximum Modified Mercalli Intensity (MMI) of VIII (severe) at 5:54 p.m. If the event had occurred mere hours before, while school was in session, Long Beach would have experienced a devastating loss of school-age children. California prohibited the construction of URM schools the following month, and the Riley and Field Acts followed within the year.

The Riley Act required all California local governments to have a building department and inspect new construction, mandating that all state structures be designed to withstand a horizontal acceleration of 0.02 times the building mass. The Field Act mandated that schools be designed to 0.03 times the building mass by registered architects and engineers. URM building failures were among the leading causes of casualties in many California seismic events. The failures led to widespread retrofitting ordinances.[2]

Casualties and economic losses in California's significant earthquakes (M_W 5.3 to M_W 7.8) have formed the foundation of modern seismic provisions in building codes in the United States. By contrast, Utah's largest modern earthquakes occurred in rural parts of the state. Both Hansel Valley (1909) and Elsinore (1921) experienced events estimated at magnitude 6+ with no casualties.[3] Given the relatively modest community impacts of these events, it becomes more understandable that unreinforced masonry buildings were constructed in Utah through the 1970s. It is common to estimate that prohibition of this construction type was enforced by 1975 with statewide adoption of the Uniform Building Code (UBC). However, some URM construction may have continued for a few years where permitting may have already occurred.

Utah would go over 20 more years before building codes would fully recognize the significant earthquake risk and raise the seismic demand for which buildings would be designed by adopting the 2000 International Building Code. The previous seismic provisions of the 1997 UBC categorized the Wasatch Front and surrounding areas as Zone 3. In contrast, the updated provisions would be approximately equivalent to UBC Zone 4, roughly a 1/3 increase for parts of the Wasatch Front. It bears restating that buildings constructed under the old provisions (anything permitted before 2001) were likely designed at roughly 75% of the seismic design forces in place now. A map of the 2018 national seismic hazard in Figure 3 shows the highest seismic hazards along the urban Wasatch Corridor.

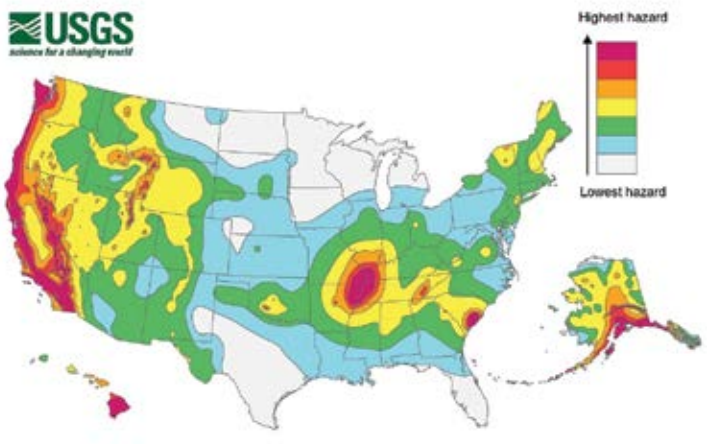

Figure 3. 2018 Long-Term National Hazard Seismic Map Showing Peak Ground Accelerations Having a 2% Probability of Being Exceeded in 50 Years, for a Firm Rock Site. https://www.usgs.gov/media/images/2018-long-term-national-seismic-hazard-map

With knowledge of Utah's seismic risk, various communities and organizations have been retrofitting critical structures.[4] In 1987, the Salt Lake City and County Building was one of the world's first buildings to be retrofitted with base isolation.[5] FEMA programs and grants such as the 1997 Project Impact initiative have been critical to addressing URM parapets and retrofitting schools in Utah.[6] Other notable seismic retrofits in the state include the Utah State Capitol, the Wallace F. Bennett Federal Building, the Salt Lake Tabernacle, the Marriott Library and, currently underway, the Salt Lake Temple.

While the voluntary retrofitting projects are significant, especially by health care organizations, they do not come close to eliminating the risk to all Utahns. In 2008, at the Utah legislature's urging, the Utah Seismic Safety Commission (USSC) compiled an inventory of unreinforced masonry buildings. The commission found that in the Salt Lake Valley alone, there are over 185,000 such structures.[7] Most URMs are single-family residences ranging from historic bungalows to midcentury multilevel tract homes. Other common URM building types include apartment buildings up to three stories above grade and commercial buildings up to five or six stories tall. Additionally, many historic midrise steel structures have unreinforced masonry infill that may fail in a moderate-to-large magnitude earthquake.

Notably, in 2011, the USSC and Structural Engineers Association of Utah (SEAU) published a preliminary survey of K-12 schools.[8] This report highlighted the risk to students' safety in school buildings and requested funding for additional study from the Utah Legislature. This call for funding went unanswered by the legislature, but the governor's office offered partial funding in 2015. The effort to find funding to complete the school building survey is ongoing now, 10 years after the report.

Leading up to the 2020 Magna earthquake, the largest recorded by modern technology on the Wasatch Fault, the seismic risk to our community is characterized by a few things unique to the Wasatch Front Region:

- Unretrofitted unreinforced masonry buildings are common.
- National building codes were not enforced reliably across the state until 1980.
- The UBC underestimated design forces for the Wasatch Front compared to other high seismic regions such as California (in place until 2001).
- Utah is politically averse to regulation; even the state's parapet bracing ordinance has been subject to attack (Utah Code Section 15A-3-801).
- The state does not have any statewide geologic-hazard ordinances related to earthquakes and secondary effects (e.g., surface fault rupture, earthquake-induced landslides, and liquefaction).

Misperceptions surround what our building code life-safety standards really deliver to our communities regarding seismic design.

Life safety standards aim to provide the likelihood that occupants will be able to escape a building unharmed during an earthquake but do not aim to eliminate damage to the building itself. Any reduction in damage beyond preventing building collapse to the building is a byproduct. In other words, a life safety standard saves lives during an earthquake but does not save the building, nor the meaningful life and the livelihoods we build within those buildings.

Our building codes and seismic design are also predicated on the idea that a building's useful life is 50 years — factoring in the probability the "big" earthquake will happen at a certain location in the next 50 years. Interestingly, though, I have not yet seen a bulldozer show up on-site when a building reaches that age. We should remember what Dr. Lucy Jones, a seismologist and science communication expert, frequently says: it is not a question of if the Big One will occur, but when. Give a building enough time, and an earthquake will affect it. The real question becomes whether we should be building a community that will recover adequately from a potential strong (M_W6.0-M_W6.9) or great (over M_W7.0) earthquake,[9] if not just for our sakes, but also for our children and grandchildren.

Upon arriving at my office in Salt Lake on March 18, I felt the parking deck roll underneath me as an MW 4.4 aftershock hit. It was the first of three significant aftershocks I would feel throughout my workday. The office was buzzing with activity — even with less than half of the staff in the office. We received phone call requests for building inspections, and a coordinated effort was established to dispatch our engineers quickly to meet the most pressing needs. Structural engineers all over the county were busily visiting buildings and, in most cases, explaining the extensive damage was largely limited to nonstructural elements.

The mainshock, as mentioned earlier, was the largest recorded by modern instruments on the Wasatch Fault. Even though seismologists classify anything from MW5.0-5.9 as a moderate earthquake, shaking intensity registered VII (very strong) on the Modified Mercalli Intensity (MMI) scale. USGS estimates it was experienced by 139,000 people (see Figures 3 and 4). This shaking intensity is a higher one than anticipated for this size event. Seismologists met the first week of February for the 2021 Virtual Utah Quaternary Fault Parameters Working Group Meeting.[10] Participants discussed the causes of the higher shaking intensity, along with the data and research that were generated by the community in the wake of the Magna sequence. According to one seismologist, Ivan Wong, P.G., the event was the best one ever recorded in the Basin and Range Province in terms of the strong motion. Due to extensive instrumentation and data collection, areas of greatest damage can be correlated with the strongest ground shaking. [11]

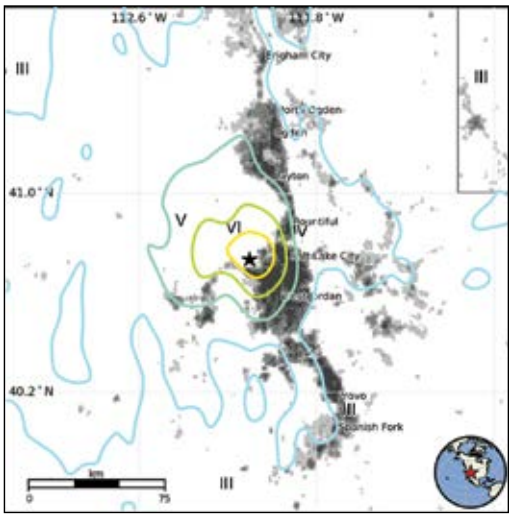

Figure 4. Population per ~1 sq. km. from LandScan https://earthquake.usgs.gov/earthquakes/eventpage/uu60363602/pager

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MMI	Shaking	Population
I	Not Felt	0 k*
II-III	Weak	383 k*
IV	Light	1,270 k*
V	Moderate	599 k
VI	Strong	271 k
VII	Very Strong	139 k
VIII	Severe	0 k
IX	Violent	0 k
X	Extreme	0 k

*Estimated exposure only includes population within map area (k = x1,000)

Figure 5. Population Exposure Modified Mercalli Intensity (MMI) Scale https://earthquake.usgs.gov/earthquakes/eventpage/uu60363602/pager

Damage from the Magna earthquake was widespread in Salt Lake County. While the total economic losses are distorted due to ongoing business disruption from the COVID-19 pandemic, property damage and loss totals will likely be generated based upon insurance claims and FEMA assistance programs in the future.

Photograph 1. Partial Unreinforced Bearing Wall Collapse in Salt Lake City. Photo: Corey Price, Reaveley

Structural damage included connection failures at masonry and concrete walls to floor and roof decks — some with a partial collapse at decks, and a partial collapse at a URM bearing wall (Photograph 1), and URM in-plane shear cracking with telltale x-patterns and twisting at corners. At least one instance of a prefabricated metal building connection failure was documented in the EERI Virtual Earthquake Reconnaissance Team report.[12] Many unreinforced masonry chimneys and parapets fell onto the sidewalks and lawns below them from commercial and residential buildings.

In the early stages after the earthquake, the Red Cross opened evacuation centers at nearby schools that were ultimately unneeded. Forty-nine homes in the community at the Western Estates mobile home park were placarded as unsafe (red-tagged per ATC-20 evaluation criteria) due to failure of the unit supports (see Photograph 5). Bruce Maison reports that this is notable because each had been anchored, but the anchorage failed during the earthquake.[13] While the collapsed foundations did not result in gas leaks or fire, the overall damage to this community raises an important point of concern for local disaster mitigation efforts. Manufactured housing, which includes mobile homes, is the single largest unsubsidized, affordable housing source in the U.S. It represents over 6% of the country's housing stock. Protecting these communities from disaster impact is critical to protecting the lives and livelihoods of some of our most socioeconomically vulnerable neighbors.

Photograph 2. Unreinforced Masonry Wall Failure in Downtown Salt Lake City. Photo: Spenser Heaps, KSL

Photograph 3. Unreinforced Masonry Apartment Building With Collapsed Parapets and Damaged Chimney. Photo: SHPO

Photograph 4. Damage to a Mobile Home at Western Estates. Photo: Jefferey D. Allred, KSL

Photograph 6. Ceiling and Light Failure in a Salt Lake Business. Photo: Jessica Chappell, Reaveley

Photograph 7. Water Leak in the Salt Lake International Airport. Photo: KSL News

The nonstructural damage was extensive in buildings of all types in the areas where the shaking intensity was highest. Many buildings had damage to cladding systems. Separations at window frames, broken glass, and fallen unreinforced masonry were common at Main Street businesses in Magna (Photograph 6). Interior glass partitions shattered in some Salt Lake City businesses, and ceilings and lights swung from compromised supports (Photograph 7). Water leaks rained down from ceilings in building systems that have not been detailed for building movement. One such water leak shut down the Salt Lake International Airport (Photograph 8). Entire sections of mechanical ducts or diffusers fell in some buildings. New buildings experienced extensive partition wall damage, even if other systems were uncompromised. Damage to building contents included collapsed storage shelves, toppled monitors, and fallen wall clocks.

Photograph 5. Wall Damage, Colosimo's Store, Magna. Photo: Steve Cornell, SHPO

As of March 26, 2020, the Utah State Historic Preservation Office (SHPO) had identified 145 damaged historic buildings with a preliminary windshield survey. While three were determined to be unsafe to occupy for observed residual instability, none required demolition.

Continued on the following page

Photograph 8. West Lake Junior High URM Wall Collapse and Ceiling Damage, Photo: Reaveley

Continued from the previous page

Three Salt Lake County schools had notable damage: Cyprus High in Magna, West Lake Junior High in West Valley, and Silver Crest Elementary in Herriman. The most significant damage at Cyprus High occurred near the swimming pool and the library. The school is being repaired for use until the opening of the replacement structures, estimated to be completed in 2024.[14] West Lake Junior High, the hardest-hit school building, is a concrete frame building with URM interior walls. Damage at the entry corridor is shown in Photograph 8. The school district is currently determining whether to repair or replace the structure. The International Existing Building Code 2018 (IEBC 2018) includes a disproportionate earthquake damage clause that can trigger a comprehensive seismic upgrade. This provision will probably be cited often in future moderate earthquakes along the Wasatch corridor. Damage to 10-year-old Silvercrest Elementary School, a more modern school, may indicate larger community problems in new construction. Silvercrest is approximately 18 miles from the epicenter of the Magna earthquake. Shaking from the earthquake was strong enough to cause masonry veneer debris to fall from archways directly over school entrances. Due to the nature of the school building's damage, it is reasonable to conclude that injuries would have occurred if the school had been in session that morning.

Health care facilities were largely unaffected by the earthquake, although certain older health centers were temporarily closed for building evaluations. The Utah Coronavirus hotline was shut down due to an evacuation of the call center building. The state public health office stopped processing COVID tests but resumed in less than 24 hours.[15]

Infrastructure impacts were largely limited to power outages from the blown transformers. By 8:08 a.m. the morning of the earthquake, Rocky Mountain Power reported 55,000 customers without power. Service was reportedly restored to all customers after midnight.

Due to the unprecedented circumstances of the ongoing pandemic, earthquake recovery is occurring largely in the background. Another disaster was declared as Salt Lake County suffered more damage in neighborhoods from downed aging trees and power lines when hurricane-force winds accompanied a storm in September.

The damage from the Magna earthquake sequence, a moderate event, was significant. Dr. Keith Koper of the University of Utah Seismograph Station noted that the largest earthquake that experts determine could be generated from the Wasatch fault system is up to an M_W7.1. The energy released from an event of that size would be approximately 90 times Magna's energy release.[16] The EERI Scenario document, published in 2015, delineates the damage due to an event of that magnitude in Salt Lake.[17] The HAZUS results are staggering. Updated economic losses have been revised upward to an estimated $52 billion since this document's publication. State emergency managers will be recalibrating these models with information gathered in the Magna event.

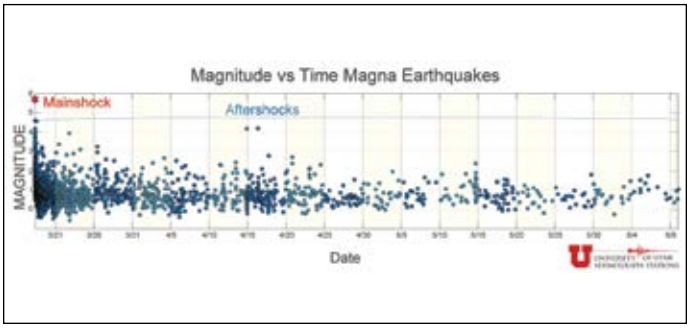

Figure 6. Magna Earthquake Sequence https://quake.utah.edu/monitoring-research/2020-magna-earthquake-sequence

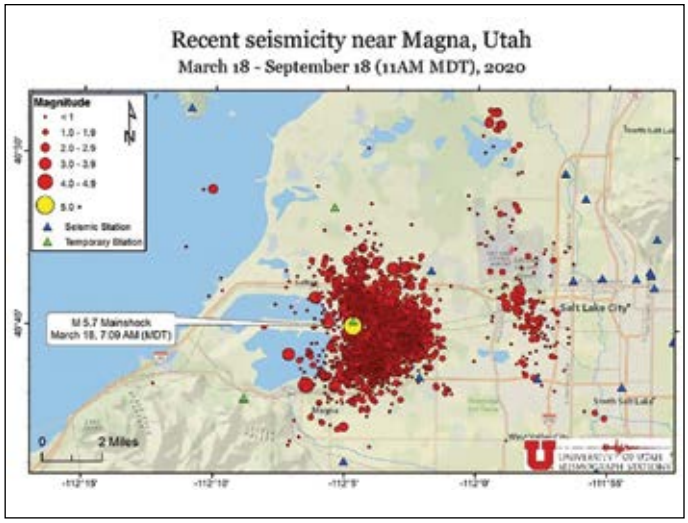

Figure 7. Magna Earthquake Sequence https://quake.utah.edu/monitoring-research/2020-magna-earthquake-sequence

The disaster risk we face as a community has not gone unnoticed. The Utah Division of Emergency Management teamed up with FEMA Region VIII to hold a two-day summit on unreinforced masonry buildings in Utah in June 2019.[18] This gathering of experts, government officials, and community organizations highlighted the needs of our community. The summit led to a large collaborative effort to generate the Wasatch Front URM Risk Reduction Strategy — a program intended to implement the federal National Mitigation Investment Strategy (NMIS), with goals to invest in ways that benefit the whole community. The final strategy document, published on the Magna quake's anniversary, presents ideas to meet three goals: 1) show how mitigation investments reduce risks, 2) coordinate mitigation investments to reduce risks, and 3) make mitigation investment standard practice.

FEMA Region VII has identified the Wasatch Fault as "one of the most probable catastrophic natural threat scenarios in the U.S.," noting that experts project that a major earthquake on the Wasatch Fault would be among the deadliest disasters in U.S. history. A national-scale FEMA

earthquake exercise is planned for 2021: The Great Salt Shake. This event will highlight the impact of a Utah disaster on the region and country and bring attention to what can be done to make our community more resilient.

The USSC is working on funding, updating, and completing the survey of Utah K-12 schools that a lack of funding has dogged. USSC is collaborating with FEMA Region VIII and the Applied Technology Council (ATC) to fund and execute the work without funding from the state.

Envision Utah has convened a disaster resilience project with the following stated goals: 1) reduce the number of people who would be killed, injured, or displaced in a disaster; 2) reduce the disruption and damage a disaster would cause and the time needed to recover (such as restoring utilities, rebuilding structures, and reopening businesses); and 3) reduce the number of people who must leave Utah (e.g., lost job, no shelter, no water/sewer, etc.) after a major earthquake.[19]

In the 2021 Utah legislative session, Rep. Andrew Stoddard (HB0214) and Rep. Clare Collard (HB0366) sponsored two seismic safety bills. The first called for disclosure of unreinforced masonry at a real estate transaction, similar to lead paint, radon gas, or floodplain disclosures. At the end of February, the House Business and Labor Committee elected to hold the bill after the real estate lobby expressed opposition. Rep. Stoddard intends to continue to work on the issue. The second would have provided funds to the USSC for more public education and homeowner resources about URM. The bill made it out of committee but was voted down on the floor of the house.

Ultimately, it is up to our professional communities to engage with our policymakers at the state and local level to ensure that investment in our seismic resilience is a priority. There is a great deal of work to do, but as every disaster researcher will tell you, hazards are natural, and disasters are made. Together, we can work toward a community and a state that will see less destruction and disruption in a major earthquake and one that is ready to recover quickly.

Jessica Chappell, S.E., LEED AP
Jessica is a principal at Reaveley Engineers. She is a licensed structural engineer in Utah and Alaska and has worked in structural consulting for over 17 years. She serves as the vice-chair of the Utah Seismic Safety Commission (USSC), is a member of the Envision Utah Disaster Resilience Steering Committee, and is a certified rater with the United States Resilience Council (USRC). Jessica has participated in organizing the EERI Utah Chapter Resilience Workshops and has represented Reaveley in a partnership with the University of Utah College of Architecture and Planning for their Community Resilience programs for the last two years. Jessica is also a newly appointed member of the Cottonwood Heights Planning Commission.

In addition to resilience and community-focused endeavors, Jessica is on the NCSEA Structural Engineering, Engagement, and Equity (SE3) Committee, is a member of the SEAU Technical Committee and serves on the Education Committee for Utah Society of Healthcare Engineering. Jessica authored a paper about the Cedar City Temples spire's rocking mechanism and presented it at the 11th U.S. National Conference on Earthquake Engineering.

Her recent notable projects include Intermountain Primary Children's Hospital, Lehi (in design), Intermountain Alta View Hospital, and the Thanksgiving Point Butterfly Biosphere.

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ITE

Leadership ITE: My Experience

Lisa Miller, UDOT

The Institute of Transportation Engineers (ITE) is a worldwide organization with over 15,000 members. The Leadership ITE program brings together transportation professionals to network, learn and grow. I was accepted into the 2020 Leadership ITE program and found it to be an incredibly rewarding experience.

The program consisted of several in-person workshops. Due to COVID, a majority of those workshops were transitioned to virtual learning. The first session in January 2020 was in-person in Washington D.C. to coincide with the Transportation Research Board (TRB) annual meeting. TRB draws tens of thousands of transportation professionals from all over the world. TRB blends research and academia with real-world, transportation-focused case studies and allows transportation professionals to learn about best practices in the field. Kicking off the Leadership ITE Program in conjunction with TRB is a natural fit.

Applying to the Leadership ITE program consists of several steps. There are letters of recommendation, essays and other application components required for this competitive program. The Leadership ITE program began in 2014 and has program goals specifically ensuring that participants will take away skills to be high functioning communicators, be self-aware and confident in leadership roles, and become effective advocates for the transportation industry. To be eligible to participate in Leadership ITE, applicants must be an active student member or fellow in good standing, demonstrate contributions to it through volunteer activities, and be willing to work with their employer to receive financial support to cover the $3,000 registration fee.

I was immensely fortunate to attend the 2020 Leadership ITE session with 25 transportation professionals from all over the United States and Canada. The disciplines ranged from public and private sector individuals and academia. Some participants were newer in their careers, while some had 15 years of experience. There was involvement from ITE leadership, with Jeff Paniati presenting and sharing his ideas for our industry's future. Shelley Row, a professional engineer and former USDOT executive, leads the program. She developed it from the ground up to give transportation leaders the tools and leadership knowledge we need to be successful.

Following the initial sessions, participants are broken into small project working groups. Each working group was responsible for project ideas that solved problems or streamlined processes throughout the ITE organization. Our group sought to streamline student chapter involvement in order to maximize resources and encourage student members to continue participating in it once they graduate.

LITE Class of 2020

The Leadership ITE curriculum was unique in its content. Rather than focusing solely on effective leader's skills, Shelley discussed the DNA behind how human brains work. Knowing your brain, values, work style, and communication style are very important in a professional setting. To best coordinate in a team, it's important to know whether someone is information-oriented or goal-setting-oriented and if they prefer to make fast-paced or more carefully constructed decisions. Through the assessment that Shelley led, I determined that my values are logical, decisive, intuitive, direct, and efficient. My communication style preferences are direct with forward momentum. While that may suit my professional needs, it can directly conflict with other preferences on my working team. Shelley shared with us that sometimes what we consider our greatest strength can also be considered by someone else to be a weakness.

Another significant component of the training was an opportunity to network with the ITE International board of directors. This training is a once in a career opportunity to have high-level leadership all in one place, focused on interacting with the Leadership ITE participants with the sole focus of giving them feedback on how to become better professionals. Before this networking opportunity, Shelley encouraged us to create a networking plan to most effectively utilize our time with the board of directors. We answered questions such as: Who will you connect with?

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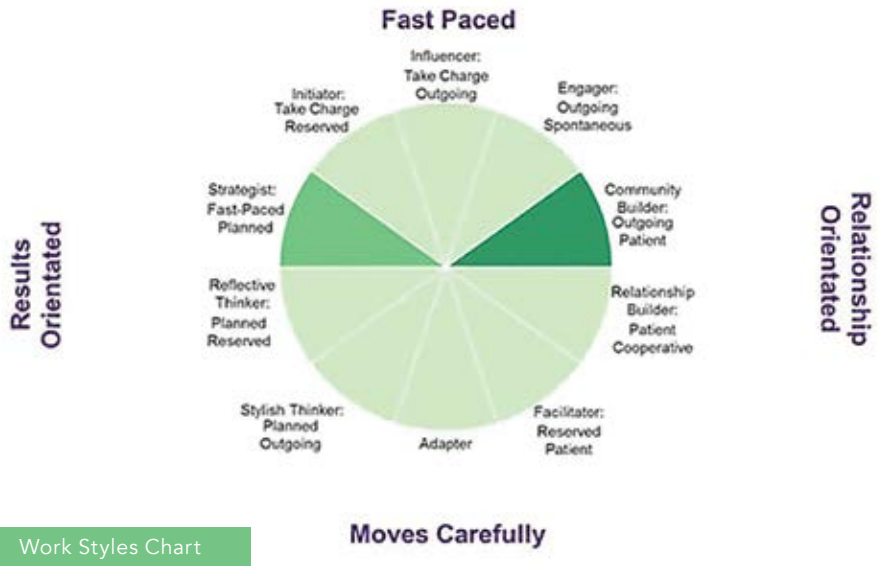

Work Styles Chart

What questions will you ask each person? How will you follow up, and when? I was able to network with several members of the board of directors and discussed how I could further the mission and the ITE goals when I returned to Utah.

During the international board of directors networking event, our groups participated in a "Shark Tank" style process where we were able to discuss our group projects and get feedback. The group projects focused on emerging topics within the transportation industry and were all very diverse. Each year, the groups are assigned project mentors from both the Leadership ITE alumni support network and the current International board of directors. These mentors are asked to support the teams and provide insight to enhance the project development process. During the Shark Tank presentations, each team had four minutes to pitch their project ideas to the room full of "sharks." At the end of each pitch, the "sharks" were given three minutes to comment publicly on the project ideas. After the event, the "sharks" are encouraged to discuss project ideas informally with Leadership ITE participants and to seek out groups that they may be interested in mentoring. While this process was somewhat stressful, our group's feedback was insightful and very helpful when it came to developing our project.

Engaging in leadership opportunities is an excellent way to stay abreast of current trends, topics and emerging ideas in any profession. There are different leadership classes and engagement opportunities at all different levels of a professional career. Some leadership opportunities are very labor-intensive and require a substantial time commitment, while other opportunities are available on a case-by-case basis as time permits. Mentorship is an excellent way to contribute to your profession and the time commitment is very flexible. Many professionals mention that when they were starting their careers, they wish they would have had a mentor who could have given them guidance about what to expect and recommendations on how to grow their career.

The Utah Engineers Council has a robust scholarship program funded from donations of individuals and businesses seeking to move initiatives forward in science, technology, engineering and math (STEM). There are always ways to engage and network within your profession. I would encourage all transportation professionals, not only engineers, to consider the Leadership ITE program. The networking opportunities provided to me through this program will be connections that I will utilize for the rest of my career. Participating in leadership programs can provide a wealth of knowledge and a better understanding of the nuances of any profession. The outcome I received from participating in the Leadership ITE program was well worth the time and effort invested.

To learn more about the Leadership ITE program, visit www.ite.org and search for Leadership ITE under the website's professional development section. To learn more about Blue Fjord Leaders and Shelley Row, visit bluefjordleaders.com.

Lisa Miller
Lisa Miller is the Traveler Information and Outreach/ Growth Manager at the Utah Department of Transportation. Lisa also acts as the Public Information Officer for the Traffic Management Division. Prior to her current position, Lisa was with TranSmart Technologies, Inc. and URS Corporation.

Ms. Miller is a past president of ITS Wisconsin and is the current secretary for the Utah Chapter ITE. In coordination with WTS, Lisa founded and is the chair for the UDOT/WTS Women's Mentorship Program. Lisa is also a three-time recipient of UDOT's Silver Barrel Award.

Ms. Miller holds a B.A. in Communications from the University of Wisconsin in Milwaukee and a master's degree in Journalism and Mass Communication from South Dakota State University.

SEAU

The "Big One" — A Wasatch Fault Earthquake and Its Effect on Buildings

Brent Maxfield, S.E. and Eric Hoffman, S.E.

Many of you reading this article experienced the shaking from the Magna Earthquake on March 18, 2020. You may have also wondered how it compared to what we would experience in the "Big One." During the Magna earthquake, the shaking was felt from Utah County to Cache County and beyond. If you experienced the earthquake, how would you describe the shaking that occurred where you were? Was it weak, light, moderate, strong, severe, violent, or extreme? How long did the shaking last? Each reader's answer to these questions will likely be different depending on where they were during the earthquake.

This article will discuss earthquake shaking, earthquake magnitude, and building performance for specific levels of shaking. It will also help paint a picture of the substantial effect on buildings from a Wasatch fault earthquake, which has the potential to generate shaking levels significantly higher than the building code requires new buildings to be designed for.

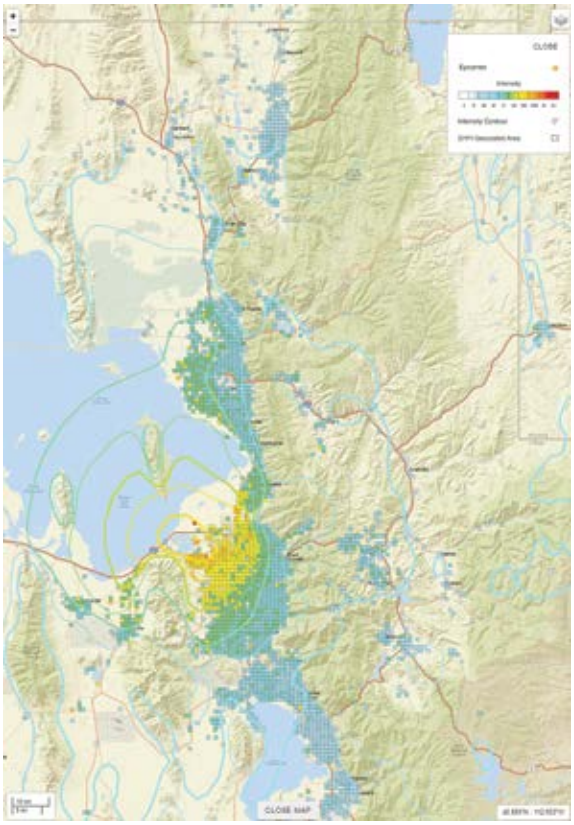

Figure 1

2020 Magna, Utah, M5.7 — Did you feel it? Responses: https://earthquake.usgs.gov/earthquakes/eventpage/uu60363602/map?dyfi-responses-10km=trueandshakemap-intensity=false, accessed March 23, 2021

Figure 1 maps how people who felt the shaking reported what they felt. The blue colors are weak to light shaking. The green colors are moderate shaking. The yellow colors are strong shaking, and the orange colors are very strong shaking. (See the key in Figure 2.) Notice how the yellows and orange colors are clustered close to the epicenter. We learn several things from this map.

1. Shaking varies in every earthquake. Every location does not experience the same shaking.
2. Shaking decreases with distance.
3. The shaking was not severe (dark orange), violent (red), or extreme (dark red).
4. Earthquakes cause the ground to shake, and it is important to understand the shaking intensity in addition to the magnitude of the earthquake.

Almost all the damage occurred in areas that experienced the yellow (strong) and orange (very strong) shaking. Most of the damage occurred to unreinforced masonry buildings (URM), which are very prone to damage or collapse in earthquakes. Figure 3 shows shaking intensities for various recent earthquakes, and Figure 4 shows the Magna Earthquake and a Scenario Wasatch Fault 7.0 earthquake generated by the U. S. Geological Survey (USGS). Notice the variations in shaking in each of these earthquakes. The scales and areas are identical in each of the images shown in the two figures.

Earthquake magnitude is important because it can tell us two very important pieces of information. The first is how large of an area was affected by the earthquake. The second is about how long the shaking lasted. The Magna Earthquake was a moderate M 5.7 earthquake. It was felt over a large area but only caused damage in a relatively small area. It also only lasted a few seconds. By contrast, a magnitude 7 or larger earthquake on the Salt Lake City segment of the Wasatch fault could cause shaking that lasts 60 seconds, and the area affected will extend well beyond

the Salt Lake Valley. More importantly, the intensity of shaking will be much higher than experienced in the Magna Earthquake. There will be large areas with severe (dark orange) and violent (red) shaking. The strong (yellow and orange) shaking will extend into surrounding counties. See Figure 4 to see the expected extent of the yellow, orange, and red shaking intensities from the USGS scenario. As you can see, a magnitude 7 Wasatch fault earthquake will not be a repeat of the Magna Earthquake.

A Wasatch fault earthquake will be very impactful. Which areas will see the strongest shaking, and how strong will that be? What level of shaking will your home or work location experience? These are great questions, but unfortunately, they are impossible to answer accurately. Earthquakes are similar to children. Just as children who are the same age vary in height, earthquakes can produce shaking levels that vary in intensity. In a Wasatch fault earthquake, you may be one of the lucky ones who experience a lower level of shaking than someone who lives nearby. A relative who lives several miles away may experience a much higher shaking intensity. To help you visualize shaking variability, think of a very short 5-year-old girl who is in the 16th percentile in height for her age. There is a low probability (16%) that when she meets someone her age that they will be shorter than she is. Most girls her age will be taller than she is.

Now visualize a very tall 5-year-old girl who is in the 84th percentile in height for her age. At 84%, it is very likely that when she meets a girl her age, the girl will be shorter than she is. It is still possible that she might meet a girl her age who is taller than she is, but it is not very likely.

Let us now relate this example to predicted earthquake shaking levels from a magnitude 7.0 earthquake on the Wasatch fault. Scientists can provide us the median predicted shaking level for each location. An actual Wasatch fault earthquake has a 50/50 chance of causing a shaking level at your location that will be lower than this median predicted level. Scientists can also predict what the 16th percentile shaking level will be at your location. There is a high likelihood that this level of shaking will be exceeded (84%) in a Wasatch fault earthquake. The 84th percentile shaking level has a low likelihood that the Wasatch fault will generate a shaking above this level (only 16%).

Just as children are not all the same height, the same is true of a Wasatch fault earthquake. Not all shaking intensities will be the same. However, just as there are short and tall children, shaking intensities will be higher and lower than the median predicted shaking levels. The lucky ones will have shaking intensities lower than the median predicted, and the unlucky ones will experience shaking intensities higher than the median predicted.

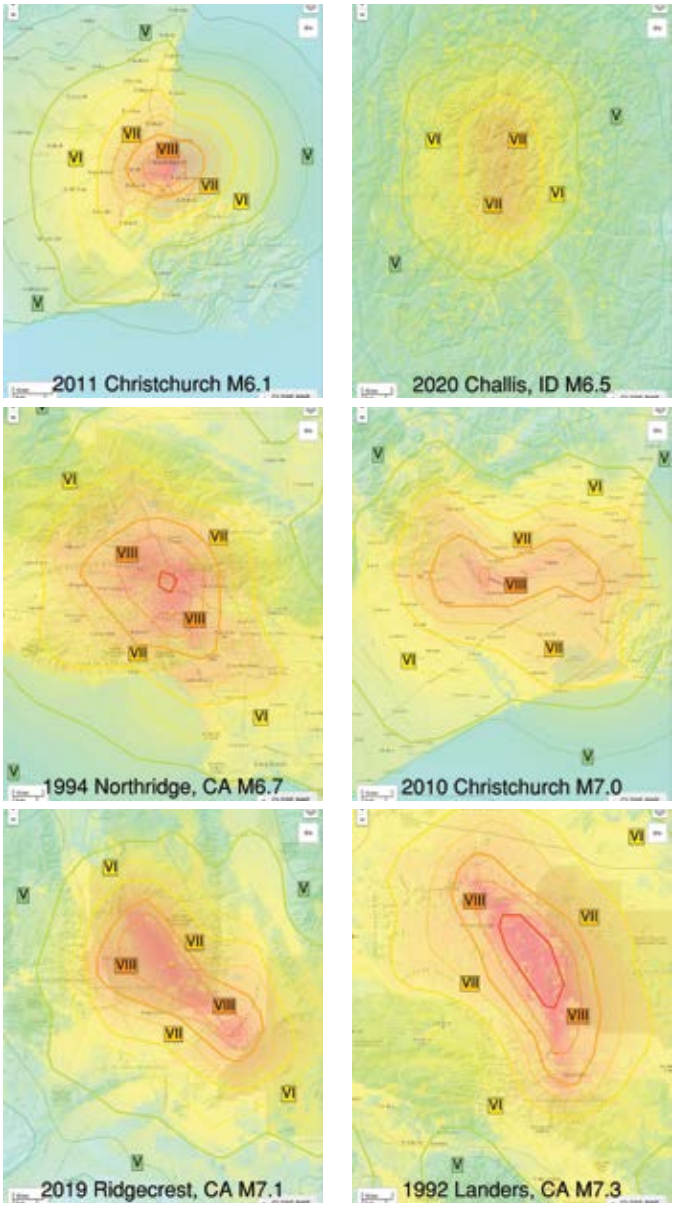

Figure 3

How do buildings respond to various shaking levels? We saw from the Magna Earthquake that old brick buildings (URMs) can be heavily damaged from yellow (strong) shaking.

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- *2011 Christchurch M6.1: https://earthquake.usgs.gov/earthquakes/eventpage/usp000huvq/map*
- *2020 Challis, ID M6.5: https://earthquake.usgs.gov/earthquakes/eventpage/us70008jr5/map*
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All accessed March 29, 2020, annotated.

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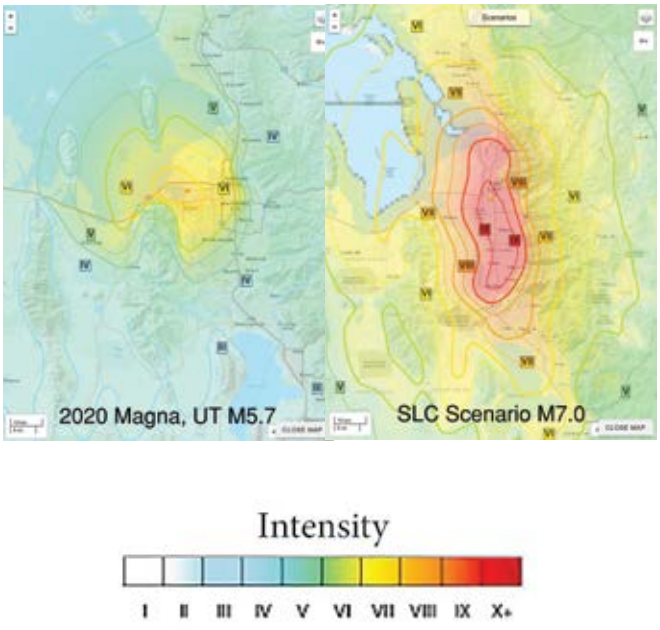
Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Figure 2

Modified Mercalli Intensity Scale:
https://www.usgs.gov/media/images/modified-mercalli-intensity-scale,
accessed April 1, 2021.

Figure 4



Well-engineered modern buildings were not affected other than some minor cracks and broken windows. As the shaking intensity increases to red (violent) or dark red (extreme) shaking, even well-engineered modern buildings can be heavily damaged and might even collapse. We will discuss how buildings could perform from a Wasatch fault earthquake, but first, we want to introduce the concept of code building performance.

We all want our buildings to be life-safe during and after "an earthquake." We also want our hospitals, fire stations and police stations to be functioning after "an earthquake." But what is "an earthquake," and what does life-safe mean? First, "an earthquake" is not specifically addressed in the building code and is not useful for engineers designing buildings. Instead, engineers use a shaking level at the building's site. The building code is very specific about what "Life Safety" means and even more specific about the level of shaking that engineers should use to achieve "Life Safety" for a building's design. We will first discuss two building performance levels discussed in the commentary to ASCE 7-16 (the portion of the building code that specifies earthquake forces). Per Section C11.5., "Collapse Prevention" means that a building will have a "suitably low likelihood of collapse," which is defined by the code as a 10% chance of collapse. "Life Safety" means that "life-threatening damage, primarily from a failure of nonstructural components, is unlikely." Buildings with damage in either one of these performance states could be heavily damaged, and it could be months before repairs are made to allow them to be reoccupied. In some cases, the cost of repairs will exceed the replacement cost of the building.

Building performance must be associated with a level of shaking for it to have any meaning. One cannot just say, "I want my building to be 'life safe,'" because there is always a level of shaking where the building will not be "life-safe." As previously stated, a "Life Safety" performance or a "Collapse Prevention" performance must be associated with a specific level of shaking. The code sets the shaking level at which a new building must have "Collapse Prevention" performance and "Life Safety" performance. The shaking level for "Collapse Prevention" is defined as the Maximum Considered Earthquake shaking (MCE_R). It is not the highest level of shaking that could ever happen at a location, but it is the highest level of shaking that the code requires engineers to consider. The value of MCE_R shaking for each location in the U.S. generally has a 1% probability of building collapse in 50 years (1/5000 chance per

- *2020 Magna, UT M5.7: https://earthquake.usgs.gov/earthquakes/eventpage/uu60363602/map*
- *SLC Scenario M7.0: https://earthquake.usgs.gov/scenarios/eventpage/uulegacyshakeoutff_se/map*
  Both accessed March 29, 2020, annotated.

year). (This article does not discuss the exceptions.) The code sets the level of shaking for which a building must have "Life Safety" performance at 2/3 the value of the MCE_R shaking.

The code value of MCE_R shaking along the Wasatch Front is heavily influenced by the long recurrence intervals (average time between large earthquakes) of the different segments of the central Wasatch fault, which are about 1200+/-100 years. The code does not consider the elapsed time since the last major earthquake. If the fault ruptured more often, reducing the recurrence interval, the code required MCE_R shaking level would be significantly higher along the Wasatch Front than it currently is, and buildings would be required to be stronger.

Let us now summarize and tie this discussion together. We know that a magnitude 7.0 earthquake on the Wasatch fault will cause a wide range of shaking intensities, some of which will be very large. We compared the predicted range of shaking to a short girl (16th percentile) and a tall girl (84th percentile). We introduced the code MCE_R shaking level and said that a building could have a 10% chance of collapse if it experiences this shaking level. We now need to compare where the code MCE_R shaking level fits along the range of potential shaking levels that could happen in a large Wasatch fault earthquake. Understanding this relationship will show that the building code does not protect the Wasatch Front from a Wasatch fault earthquake to the level that most people expect. Because of the methodology used to calculate the MCE_R value, as discussed above, MCE_R falls at about the median predicted shaking from a large Wasatch fault earthquake. The consequence of this is that there is a 50/50 chance that a site will experience a shaking level that exceeds the MCER. The 84th percentile shaking is about twice the value of MCE_R in most areas of the Wasatch Front (2.70 versus 1.48 for Ss and 1.16 versus 0.541 for S1 for a site in downtown Salt Lake City).

The scary thing about this factor-of-two difference is that the probability of collapse could jump from 10% to 45% if a building experiences the 84th percentile shaking intensity.

Luckily, most locations will not experience an 84th percentile shaking intensity in a Wasatch fault earthquake (about double MCE_R), but some areas could be hit with this shaking. Not all buildings that experience shaking levels twice the MCE_R will collapse, but almost all of them that do experience it will be severely damaged and near collapse. Many newly constructed buildings in areas that experience the median predicted shaking intensity will be severely damaged, and a few could collapse. The $2/3*MCE_R$ shaking level is in the range of the 25th to 35th percentile, which means that there is a high likelihood that most buildings will experience a shaking that exceeds the $2/3*MCE_R$ "Life Safety" shaking level. Since most buildings will experience damage that could exceed "Life Safety," there could be many deaths from falling hazards.

Why would the building code allow for so much damage and risk of collapse from a Wasatch fault earthquake? The code uses a specific methodology across the United States to calculate the MCE_R shaking level. The Wasatch Front is in a somewhat unique situation because there is one very large fault with a long recurrence interval and many smaller faults. This combination tends to lower the value of MCE_R compared to some other areas of the country that have multiple large faults with shorter recurrence intervals. The SEAU Technical committee wants to study the impact that a Wasatch fault earthquake could have on the Wasatch Front.

We want to quantify and compare the economic and life safety impact from staying with the current building code methodology, as described above, compared to enhancing the code to ensure that buildings that receive the 84th percentile shaking intensity have no more than a 10% chance of collapse. (The 84th percentile shaking level is required by the building code to be used in areas of the country where large earthquakes happen frequently. It is also often used when designing for a specific earthquake scenario.) We are seeking funding for this study.

The building code is based on an acceptable risk set by the code writers; however, the Wasatch Front's unique aspects may create higher potential consequences from a Wasatch fault earthquake than what many people expect or desire from the building code. Once the risks are quantified, we can have informed discussions about what to do about it. The code allows concerned owners to design and construct new buildings beyond the risk provided by the code. Please speak to your structural engineer about your desired building performance levels at specific levels of shaking, especially as it relates to shaking from a Wasatch fault earthquake.

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Brent Maxfield, S.E., is a member of the SEAU Technical Committee and the Seismic Subcommittee Co-Chair. He has been employed as a structural engineer in the Special Projects Department of The Church of Jesus Christ of Latter-day Saints for almost 29 years. In 2012, he was selected the Utah Engineer of the Year by the Utah Engineers Council. He loves spending time with his wife, five sons, and their families exploring Utah's great outdoors.

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ASCE

Adding "Depth" to Civil Designs With 3D Printing

Clint Merrell

In the last five years or so, you've probably come across a new and exciting technology known as "3D printing." It might surprise you to learn that 3D printing has existed in some form for around 30 years. Beginning in 2002, some of the earliest 3D printing patents began to expire. With the expiration of these patents and advances in the production of low-cost, easily programmed microcontrollers, 3D printing has exploded in popularity. Hopefully, this article will give you a glimpse of how this exciting technology can add a new "dimension" to our civil engineering designs and provide additional value to our clients and communities.

What is "3D Printing"?

3D Printing is a form of additive manufacturing where a three-dimensional object is built up one thin layer at a time. Many different processes and technologies for 3D printing exist. These processes are defined in ISO/ASTM 52900, but some of the most common include:

- Material Extrusion (Fused Deposition Modelling (FDM)): Material is selectively dispensed through a nozzle or orifice.
- Vat Polymerization (SLA and DLP): Liquid photopolymer in a vat is selectively cured by UV light
- Powder Bed Fusion (SLS, DMLS and SLM): A high-energy source selectively fuses powder particles.[1]

The most commonly available "consumer" 3D printer models are material extrusion models. If you've never seen one of these machines in action, picture a hot glue gun mounted on an old pen plotter. Now imagine that the glue gun "pen" (extruder) draws an object layer by squirting glue onto the paper (build surface). When one layer is drawn, the pen raises up (or paper lowers down) by the thickness of one layer and begins drawing another layer on top of the previous layer. The printer then repeats this process until all the object's layers have been drawn, resulting in a 3D object. A simple search for "3D printing time-lapse" will reveal hundreds of videos illustrating the process. Here are a couple of videos:

- 3D printed Eiffel tower time lapse[2]
- Baby Groot - 3D Printing Time Lapse[3]

3D CAD Revolution

Along with the explosion in 3D printing, the last 10 to 15 years have seen significant advances in the realm of computer-aided design (CAD). With CAD software tools like Autodesk's Civil 3D and Revit and Bentley's InRoads and OpenRoads Designer, our industry has seen an increasing shift to 3D design for buildings, roadways, bridges, pipe networks, earthworks and more. It's not hard to imagine a future where two-dimensional plan sheets — paper or electronic — are obsolete and replaced with 3D interactive models of our designs. In fact, there are organizations such as the Utah Department of Transportation (UDOT) that are actively pursuing initiatives to transition away from 2D deliverables such as paper plan sets. See UDOT's Digital Delivery Website[4] or refer to UDOT's March 2017 Intelligent Design and Construction Guidance document.[5]

It is one thing to show clients or the public a realistic 3D rendering of your latest design in a video clip or simulation. However, sometimes it helps to sit around a table and point to a physical plan or model to collaborate effectively and communicate design intent or potential concerns. Relatively easily, we can now combine our 3D CAD designs with 3D printing to produce physical models.

From 3D CAD to 3D Print

Your CAD software handles the conversion from CAD format to a printer spool file that your inkjet or laser printer can print. However, most currently available 3D printers and 3D printing service providers require you to convert a 3D model to a specific type of file called a Stereolithography (STL) file. The STL file is currently the 3D printing industry standard for distributing 3D printable files. 3D Printers and printing service providers take the STL file and run the file through a "slicing" process where the model is broken down into the individual layers that will be printed and combined into the final 3D print.

Because every printer handles the actual slicing process slightly differently, we will limit our discussion to how to create an STL file from a 3D CAD model. Also, while several CAD software packages can generate 3D designs, we will focus on using Civil 3D. It is currently the most popular civil design CAD software on the market.

The image below is an STL file created from a concrete water tank design consisting of a finished grade surface, a 3D model of the tank, and the associated tank and storm drain pipe networks.

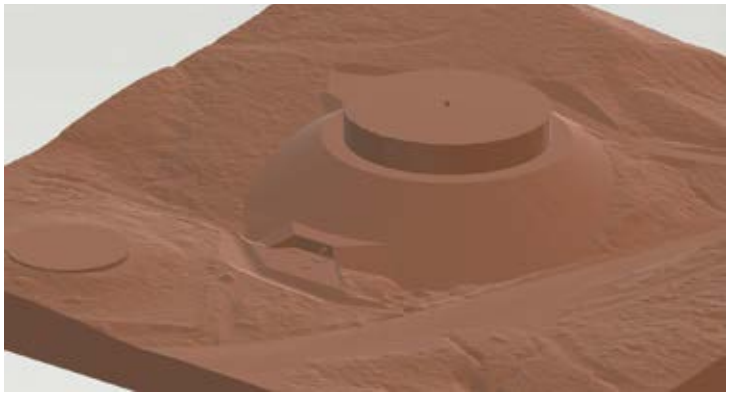

Figure 1. Image of an STL File Ready for 3D Printing

The creation of the Civil 3D objects that make up the design pictured above is beyond this article's scope. However, the commands described below can convert Civil 3D objects into a single, 3D printable STL file.

Export Surface to Solid.

Entering EXPORTSURFACETOSOLID in the command line will bring up the following dialog:

Figure 2. Civil 3D Export Surface to Solid Dialog Box

Select the TIN surface you want to export from the dropdown box. In the "Vertical definition" section, select "At a fixed elevation" and specify an elevation just below the minimum elevation of your selected surface. This selection will give your surface a thickness and a flat bottom at the elevation you specify, which is great for providing a solid first layer to your 3D print. Review the drawing output section, accept the default values or change as necessary for your needs. When you hit the Create Solid button, Civil 3D will create a solid model of your TIN surface. If your TIN surface is too dense (which is common when using LiDAR-derived terrain surfaces), you may need to use the SIMPLIFYSURFACE command to reduce the number of points in your TIN before you export the surface.

Convert Pipe Network Elements to Solids

In your design, you might have pipes or structures that are visible above ground that you want represented in your model, such as the maintenance holes, inlets and pipe and fitting shown in the image below:

Figure 3. Sample STL File Depicting Solid Pipes and Drainage Structures

Civil 3D pressure and gravity pipe networks contain all the information needed to create 3D models of pipes and structures by default, but you need to use the CONVERTO3DSOLIDS command to create solid objects that you can export for 3D printing. If you start the command from a plan view orientation, you will get a warning recommending that you switch to a 3D view. If you get this warning, cancel, use ORBIT to rotate your view slightly and start the CONVERTOT3DSOLIDS command again. Now select the pipes and structures you want to export and hit enter. Choose whether you want to delete your existing pipes and structures (probably not, as this would break the annotation labels, styles, and profiles associated with those pipes and structures) and hit enter again. The result of this command should be individual "3D solid" objects representing your pipes and structures.

Create Other 3D Solid Objects as Needed

Civil 3D includes all the advanced 3D CAD commands necessary to create primitive 3D solids such as cubes, spheres, cylinders, cones, etc. You can use these commands to create basic representations of tanks, buildings and other features you might need to be included in your 3D print. For more complex 3D objects, research the EXTRUDE, LOFT, SWEEP, REVOLVE, and PRESSPULL commands. The large tank in Figure 1 was created by tracing a structural section view outline and using the REVOLVE command.

Combine all 3D Solids and Export STL File

Once you have all individual design elements converted to "3D solid" object types, use the UNION command

Continued on the following page

Continued from the previous page

to combine the separate entities into a single object. When complete, use the STLOUT command and select your single 3D solid object. You will be asked if you want to create a binary STL file. You can enter yes or no; both will result in a 3D printable STL file.

I have one note of caution with the STLOUT command. There is a software bug that sometimes affects models that are exported from their true world coordinates. If the resulting STL file appears to have lost a significant amount of resolution and appears "blocky" as in Figure 4 below, try moving the solid object in Civil 3D to the drawing file's global origin (i.e., coordinates 0,0,0) and executing the STLOUT command again.

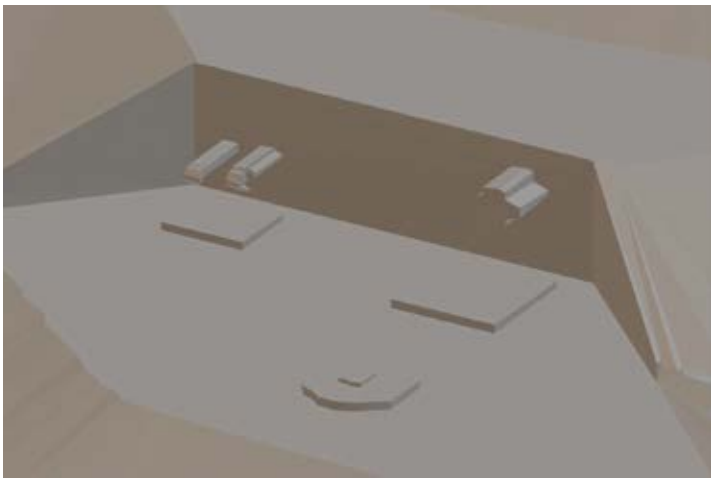

Figure 4. Example of a "blocky" or low resolution STL file created from Civil 3D.

Print the STL file

You can now take the STL file you created and print it!

Figure 4. Completed 3D print, printed on an FDM 3D printer.

There are dozens of good 3D printers on the market now, ranging in price from a couple of hundred dollars to thousands of dollars. Below are a few examples. These are all plastic extrusion (FDM) printers:

- Creality Ender 3 (about $200)[6]
- Prusa i3 MK3S (about $1,000)[7]
- Ultimachine Ultimaker S5 (about $6,000)[8]

If you don't have a 3D printer, try your local library, university or "makerspace." These organizations often have 3D printers available to the public for reasonable fees. Alternatively, you can upload your STL file to an online 3D print service provider. They will print your model and ship it directly to you. A couple of providers include:

- 3D Hubs[9]
- Shapeways[10]
- Sculpteo [11]

References

1. *From https://www.3dhubs.com/guides/3d-printing.*
2. *3D printed Eiffel tower time lapse: https://www.youtube.com/watch?v=FqQAjkZOBeY*
3. *Baby Groot: https://www.youtube.com/watch?v=m_QhY1aABsE*
4. *UDOT Digital Delivery Website: https://digitaldelivery.udot.utah.gov/*
5. *UDOT March 2017: https://drive.google.com/file/d/1wvmo_0lAY6yeWyLcYsFmKCFEpYPah3Ar/view*
6. *Creality Ender 3: https://www.creality3dofficial.com/products/official-creality-ender-3-3d-printer*
7. *Prusa i3 MK3S: https://shop.prusa3d.com/en/3d-printers/181-original-prusa-i3-mk3s-3d-printer.html*
8. *Ultimachine Ultimaker S5: https://www.matterhackers.com/store/l/ultimaker-s5/sk/MH6DVDNK*
9. *3D Hubs: https://www.3dhubs.com/*
10. *Shapeways: https://www.shapeways.com/*
11. *Sculpteo: https://www.sculpteo.com/en/*
12. *Visit www.3dhubs.com/guides/3d-printing/.*

Further Reading

For additional details about 3D printing and associated best practices, I highly recommend reading the 3D printing guide on the 3D Hubs website.[12]

Feel free to contact me with additional questions at cmerrell@bowencollins.com.

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Clint attended Brigham Young University and graduated with a Master of Science in Civil and Environmental Engineering, emphasizing water resources, in 2009. Since then, he has worked throughout Utah, Colorado, and California on a variety of heavy civil projects, including roadways, railroads, storm drain systems, water distribution systems, and large flood control structures. Clint is currently a project manager and associate at Bowen Collins and Associates. He lives in St. George, Utah, with his wife, Jessica, and their three children.

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