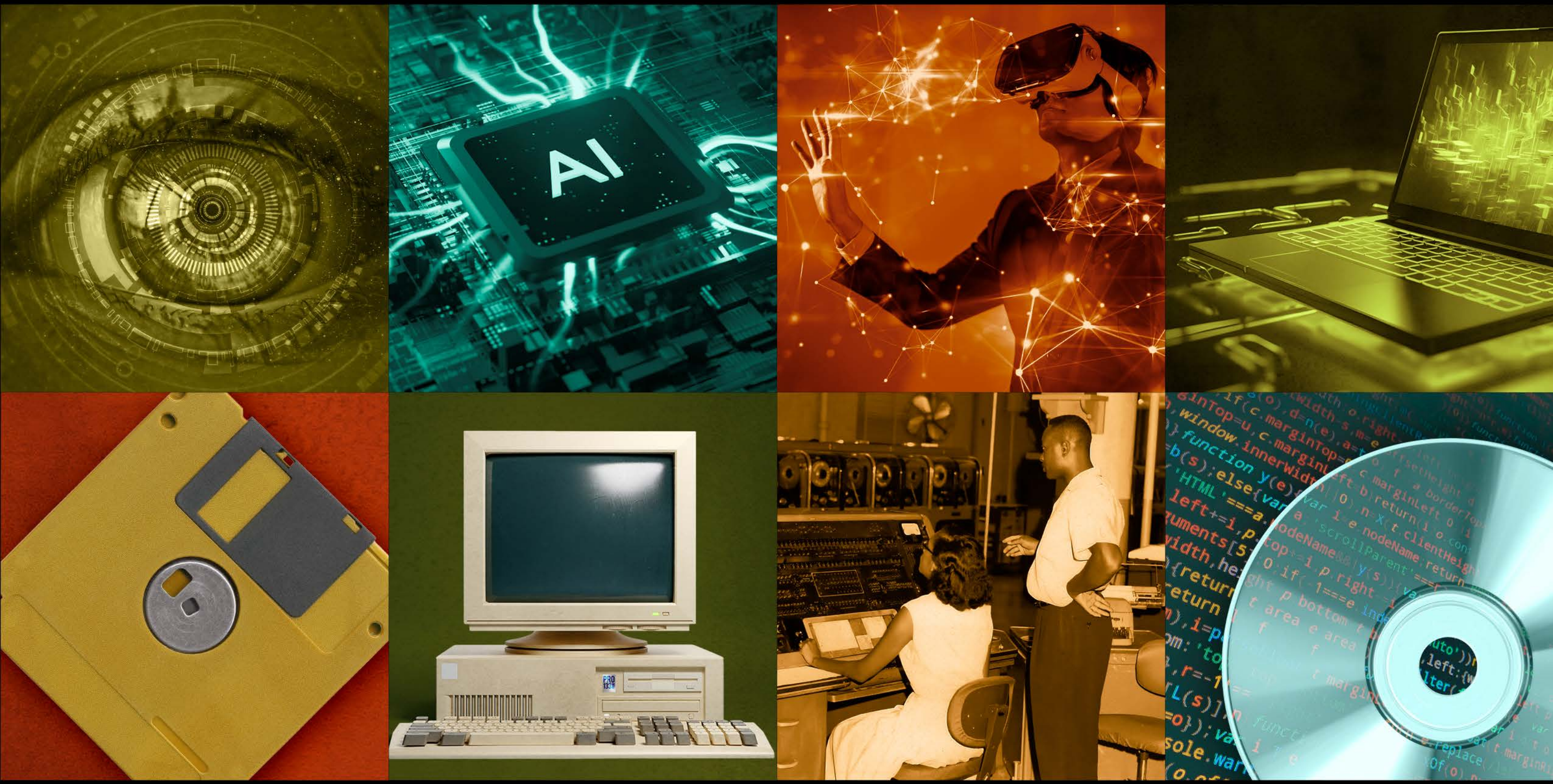
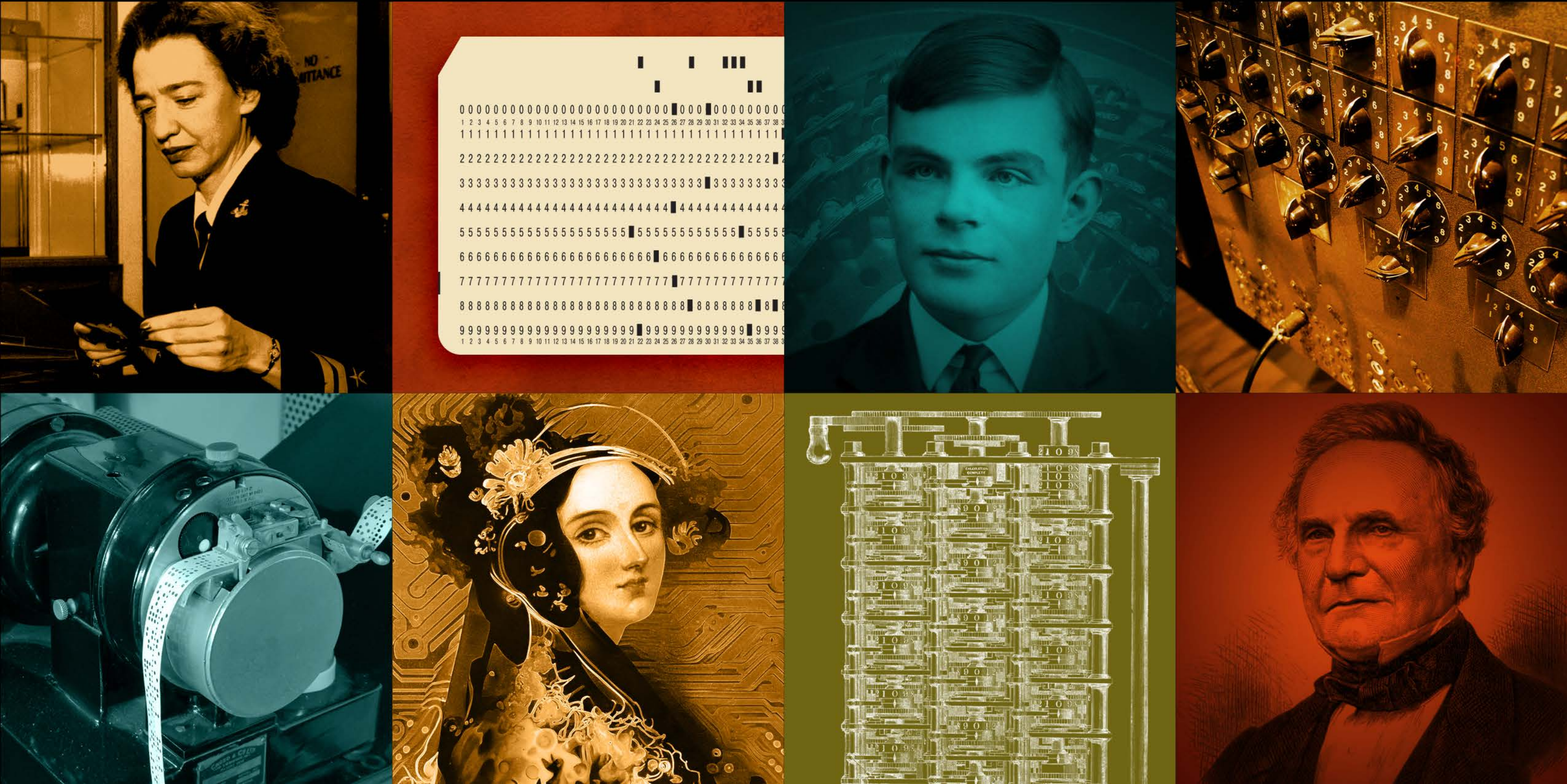
CrossTalk

The Journal of Defense Software Engineering February 2024



GENERATIONS IN SOFTWARE



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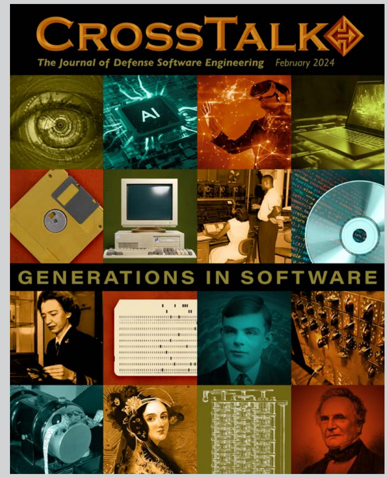

Cover Design by Kent Bingham

Generations in Software

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THE ONE CONSTANT IN SOFTWARE ENGINEERING: CHANGE

John N. Wood
Lead Systems Engineer, C2E2,
Naval Information Warfare Center Pacific

When I was in high school, my dad came to me with an unusual request. He wanted me to build him a case for his slide rule. The case would be wooden but have a glass front with the words “In Case of Power Failure – Break Glass” printed on it and a glass-breaking hammer hanging off the side. I eagerly agreed, not only because I needed a project for my woodshop class but also because I appreciated the humor behind it. My dad was an early adopter and grew to be a power user of computers but, before computers were commonplace, he used his trusty slide rule to get him through the electrical engineering courses at the university and design high-power transformers for the electric company.

I can envision my dad’s co-workers chuckling at the slide rule on the wall. Yet, as I think about it a little deeper, I see three distinct generations passing through his office with each generation having a different frame of reference. First would be those, like my dad, who used to rely on a slide rule for their daily tasks. Second would be those who remembered seeing slide rules as a kid but never needed to learn how to use one thanks to pocket calculators and personal computers. Third would be those passing through my dad’s office who did not even know what a slide rule was. To them, it would appear only as an obscure relic of the past.

Now, when people visit my office and see my dad’s slide rule on the wall, they almost universally think it is an obscure relic of the past. Yet, to me, it serves as a reminder. First, it is a reminder of my dad’s humor and his moxie to hang something with the words “In Case of Power Failure” in the very building that housed all the engineers responsible for avoiding power failures. Second, and most importantly, it is a reminder of how much things can and will change over the course of a career.

In the field of software engineering, I have seen countless changes. I have seen software teams

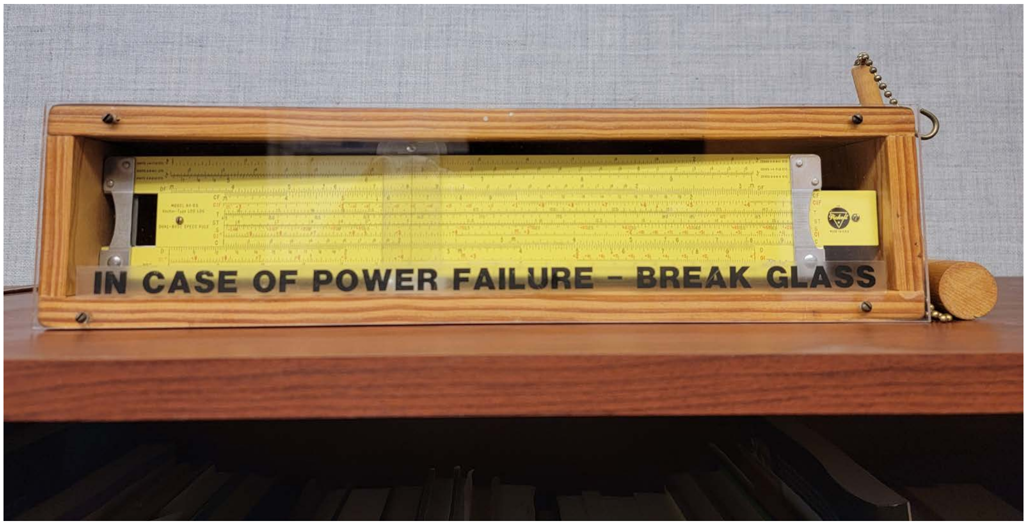

Figure 1. *Slide rule inside encasement with attached glass-breaking hammer.*

switch from waterfall to agile. Next, they performed agile at scale with scrum of scrums. Then, they launched into DevOps and DevSecOps. I have also observed changes in how they learned. At first it was degree programs with countless hours of in-person instruction and thick textbooks. Then, degree programs were accomplished via recorded sessions and distance learning. Next, came the shift to short courses and certificate programs. Now, most information needed can be found “on demand” and “just in time” with a few clicks directing engineers to an information-rich website or video. The target hardware has changed as well. First, it was servers and personal computers. Then, it was virtual machines. Next, it was cloud environments. Now, the target “hardware” is often a container that can be run on almost any device. The workplace has changed as well. First, it was co-located teams working together in an office building. Then, it was distributed teams in separate office buildings connecting via video teleconference. Then, as collaboration tools matured, remote work started becoming possible. Next, a global health scare forced more people to work from home and forced people to reexamine their work-life balance. Now, it is the norm to see fully distributed software teams, with team members operating around the world and around the clock, adapting to whatever workplace and worktimes are best for them.

In this issue of CrossTalk, several authors share their unique view of changes in software engineering from past to present to future. Capers Jones gives an insightful timeline of ancient to modern technology.

Anita Carleton, Dr. Doug Schmidt, Dr. Forrest Shull, John Roberts, and Dr. Ipek Ozkaya explore the fundamental research needed to support progress toward the goal of informing a community strategy for building and maintaining U.S. leadership in software engineering and Artificial Intelligence (AI) leadership.

Reagan Hoopes and Sullivan Udal explain the history and understanding of virtual reality and augmented reality systems.

Tawnya Coulter discusses the different core values, preferences, motivations, and communication styles of the five generations currently inhabiting the workplace.

If one was to view software engineers from 20 years ago, they would look very different than the software engineers of today. However, I would caution that looks can be deceiving. Yes, the tools, techniques, and teaming environments have all changed drastically. So, too, have the clothing and hairstyles. Yet, at the core, software engineers continue to have the same drive. Software engineers, both past and present, have an innate desire to leverage all available resources in order to build the best possible product for their end user. And that is something I hope never changes.

- John N. Wood, Lead Systems Engineer, Command & Control and Enterprise Engineering Department (C2E2), Naval Information Warfare Center Pacific

Call For Articles

If your experience or research has produced information that could be useful to others, Crosstalk can get the word out. We are specifically looking for articles on software-related topics to supplement upcoming theme issues. Below is the submittal schedule for the areas of emphasis we are looking for.

Artificial Intelligence: transforming the digital Landscape Part 1

May 2024 Issue

Submission Deadline:
March 15, 2024

Artificial Intelligence Part 2

August 2024 Issue

Submission Deadline:
June 15, 2024

Big Data

Nov 2024 Issue

Submission Deadline:
September 15, 2023

Please follow the Author Guidelines for Crosstalk, available at the APAN or DTIC site.

We accept article submissions on software-related topics at any time, along with Letters to the Editor, Open Forum, and BackTalk. To learn more about the types of articles we're looking for, please visit the above sites or contact us by email or phone

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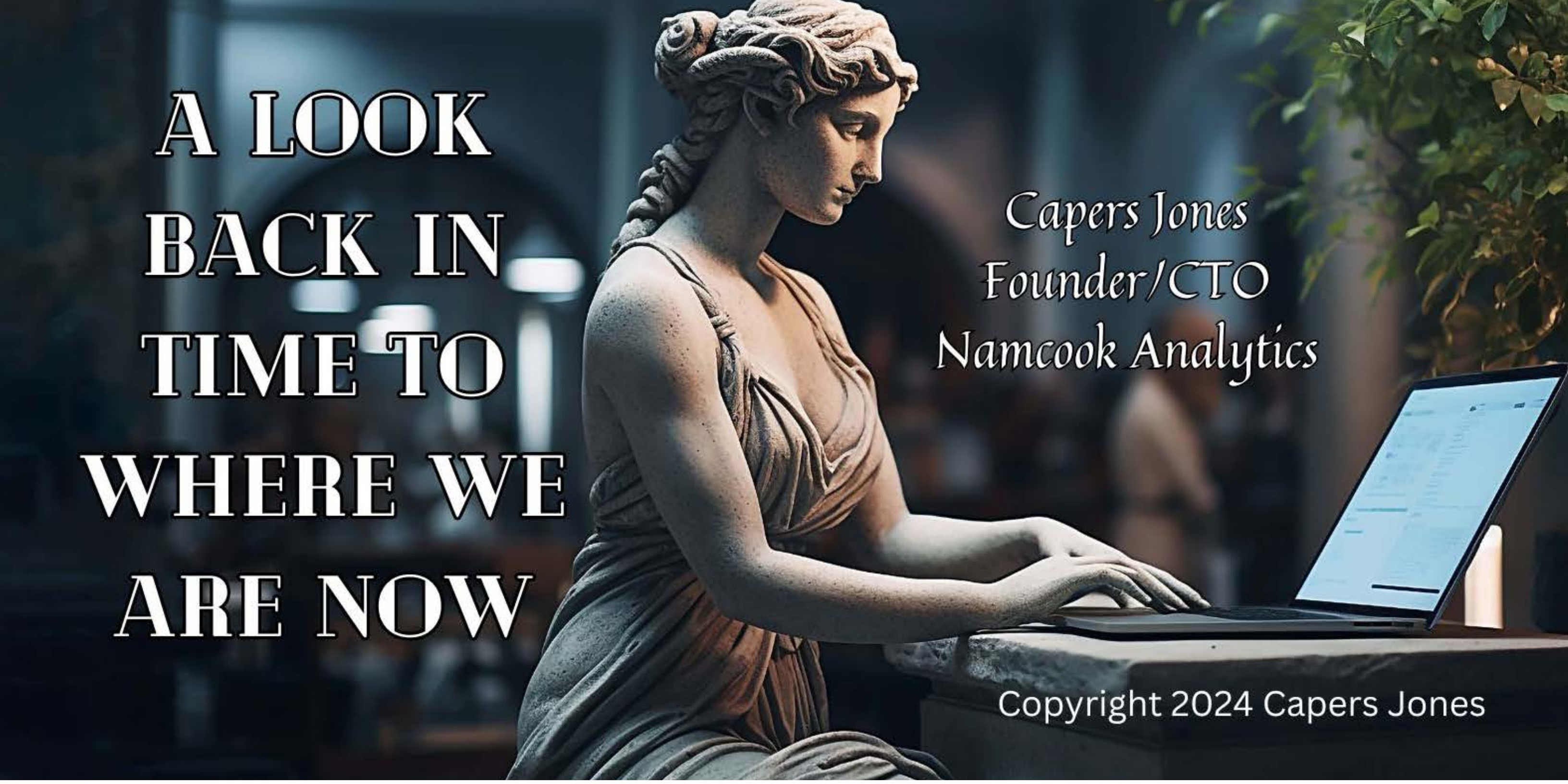


Introduction

In this day of continuous innovation, when software seems to evolve with every passing second and hardware allows anyone to complete a job with streamlined efficiency, it is easy to forget that the technology that permits all of this didn't always exist. The internet, for example, has only been widely available for barely more than 30 years. Cell phones, which practically every adult considers a necessity now, only began to grow in popularity in the 1990s. The pocket calculator has only existed since 1967.

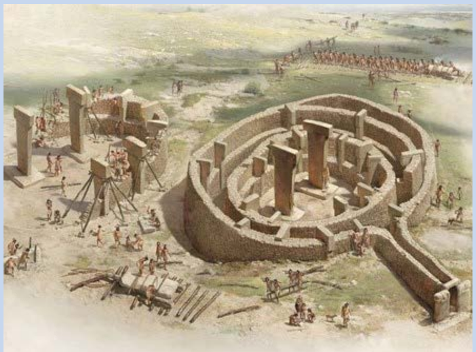
All of this begs the question: How did we get here? How, in only the last century, has the world of technology changed so much? The answer, however, is not so simple as studying that last century. If a person were to look back on history, they would find that the advancements that led to the world we live in today began further back than most might think, starting all the way back in 7000 BCE.

Distant Past

Before computers, there was the development of numbering systems and, in particular, the development and use of the number 0 and of negative numbers. The evolution of mathematical operations such as multiplication and division paved the way for mechanical computation. The practical use of numbers in fields such as architecture, astronomy, and navigation were the earliest predecessors of modern computation.

The report discusses interesting ancient numbering systems and calculation methods used by the Sumerians, Egyptians, Chinese, Greeks, Romans, Incans, and other ancient cultures. It also discusses mathematical curricula at early universities (such as Nalanda in India) and early libraries (such as Alexandria and Cordoba).

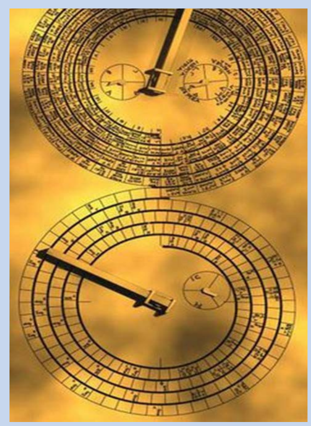
These innovations led to other advancements such as mechanical computing devices like the Antikythera mechanism, and, later, the abacus, the Peruvian Quipu, Napier's bones, the Pascal mechanical calculator, and Babbage's Calculating Machine.



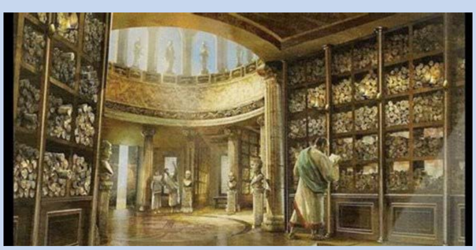
Gobekli Tepe in Turkey – First known astronomical observatory circa 7000 BCE. This strucuture was built before agriculture and before use of the wheel [A].

The early Chinese Suanpan Abacus Circa 4000 BCE is the first known mechancial computing device. It is still used today [B].

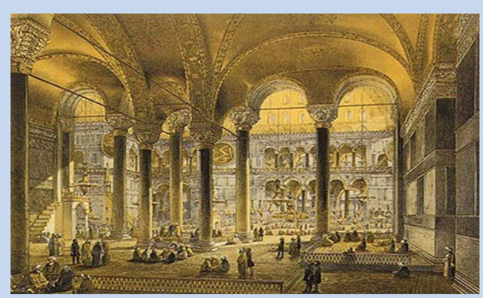
Greek Antikythera astronomical calculation mechanism circa 100 BCE [C].



Modern reconstruction of antikythera mechanism from circa 100 BCE [D].



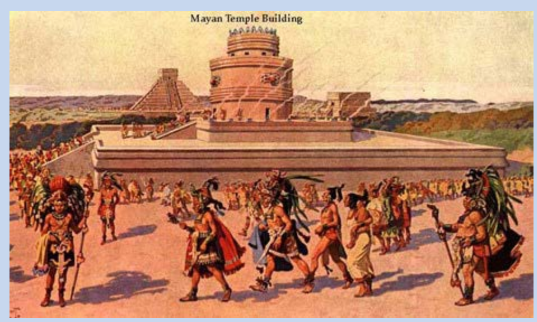
Library of Alexandria Circa 200 BCE. Large collection of mathematical scrolls [E].



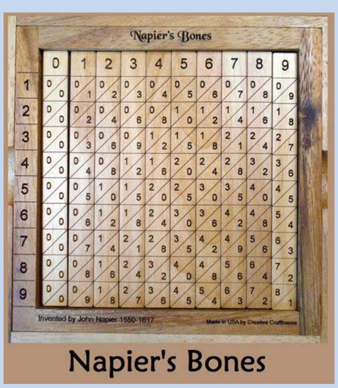
The Imperial Library of Constantinople circa 350 CE was the last major Roman library. It had a large collection of mathematical scrolls and texts [F].

University of Nalanda in North India taught sophisticated mathematical curriculum circa 400 CE. At its peak, the University had over 10,000 students from all over Asia. Curricula included astronomy, mathematics, medicine, and Buddhist studies. The University also had a large library. The University was destroyed during Moslem invasion circa 1200 CE [G].

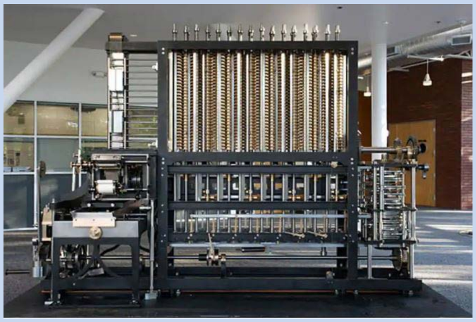
Peruvian Quipu knots for mathematical calculations circa 1000 CE [H].



The Mayans had sophisticated mathematics and also used math for architectural designs. Mayan buildings featured stone work that was so well done that a piece of paper cannot be put between adjacent carved stones. No one knows exactly how this precision was achieved using only stone tools [I].



The Napier's bones mechanical calculating device was developed by John Napier in 1617 [J].



Babbage calculating machine, circa 1850, developed by Charles Babbage. Babbage was friends with Countess Ada Lovelace who helped program the analytical engine [K].

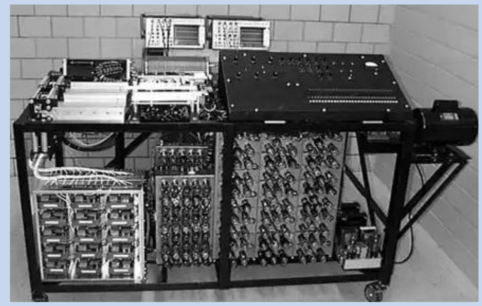
Countess Ada Lovelace was the first computer programmer circa 1850. Ada Lovelace was the daughter of Lord Byron the poet and a friend of Charles Babbage. The Ada programming language is named in her honor. She developed algorithms for Babbage's calculating engine [L].

Recent Past

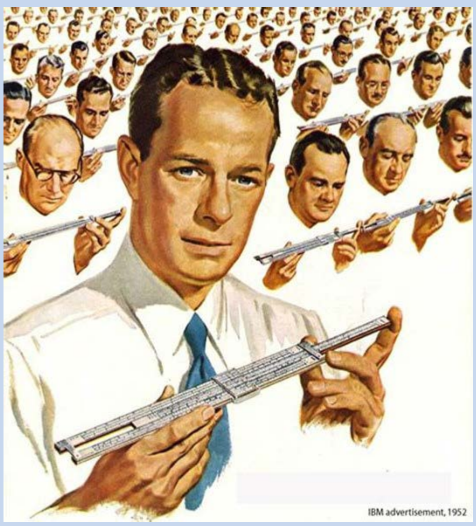
At the turn of the 20th century and beyond, the world of mathematics and technology changed by the widespread use of slide rules, mechanical calculators, pocket calculators, early digital computers, and the recent evolution of computers). The evolution of programming languages and software development methods came after.

Personal computers, in the forms of tablets and desktops, changed everyday life as the workhorses of modern business and government operations. Computers became imperative in business and government operations for both routine operations (such as payrolls and accounting) and for more advanced topics (such as competitive analysis and studies of market penetration).

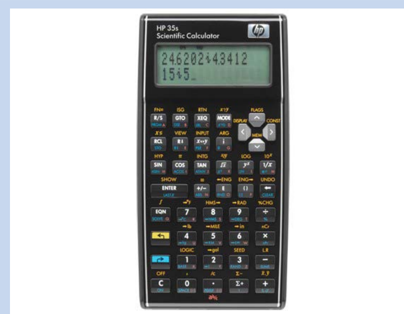
Henry Ford’s 1920 assembly line [M].



Atanasoff-Berry first digital computer in 1939 [N].



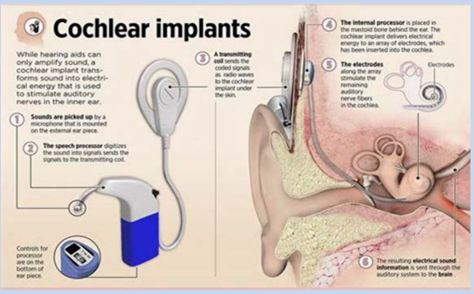
Slide rules were standard engineering tools for over 100 years. Photograph oringinally published as an is an IBM recruting ad in 1952 [O].



Calculators quickly replaced slide rules for engineering students. Example is a Hewlett Packard (HP) model 35 [P].

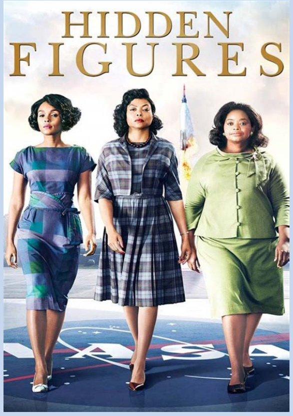
Cambridge University, England, offered the first degree in computer science in 1953. Purdue University in 1968 was the first American University with a computer science degree.

Cambridge is the University where Alan Turing studied. Turing developed some of the most important mathematical foundations for computing. He also applied mathematics to code breaking. The Turing machine is perhaps the first discussion of modern computer architecture [Q].



Cochler implants embedded computers to restore hearing to the profoundly deaf, first developed in 1957 [U].

Photograph of NASA women “computers” used to perform calculations for space topics before the use of digital computers. Work started about 1939 and continued through the 1950’s [R].

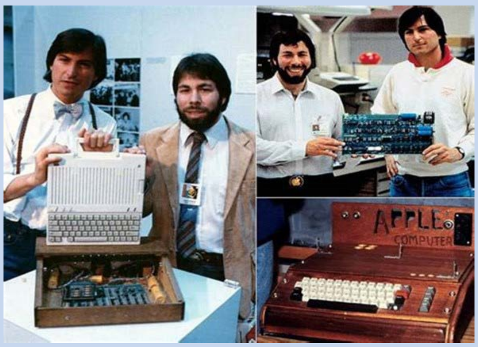


See the movie “Hidden Figures” for an interesting biography of these women mathematicians [S].

President Obama presenting Medal of Freedom to NASA mathematician Katherine Johnson [T].

IBM 1401 business computer circa 1959 [V].

IBM personal computer developed at IBM Boca Raton in 1981. IBM has been the dominant computer company since the industry began [W].



Steve Jobs and Steve Wozniak with Apple1 in 1983 during the growth of Silicon valley near San Jose, California. Some of the companies in Silicon valley include Adobe, Apple, Avaya, Broadcom, Cisco, eBay, Facebook, Google, Hewlett Packard, IBM, Intel, Oracle, PayPal, Tesla, VMware, and Western Digital. Total tech employment in Silicon valley tops 500,000. Without computers, none of these companies would exist [X].

Early TRS-80 Computer from Radio Shack from the 1980's [Y].

HP-100 handheld computer. One of the smallest portable computers ever built that actually had a useful screen and keyboard. This computer was marketed in 1981 [Z].

Present

Today, every major corporation and government agency depends upon computers for day-to-day operations and strategic planning for the future.

Computer usage in modern medical practice will be examined. Consider a future of human computing with wearable devices such as smart watches and surgically implanted computing devices. Without computers, many modern medical diagnostic tests such as CAT scans and MRIs would not be possible. Robotic surgery is becoming a standard for many surgical procedures.

The emergence of artificial intelligence (AI), autonomous robots, and the use of computers in space exploration may be the next turning points in technological evolution. The book also deals with modern peripheral devices such as 3D printers, pilotless vehicles, UV sterilization, and others. The advancement of quantum computing and what it may be capable of may lead to a complete overhaul in the day-to-day of every household, business, and government.

Today's typical computer for work and home use, opening many possibilites for the average person [Aa].

IBM Santa Teresa Laboratory in San Jose, California. One of the major companies in the famous Silicon Valley [Ab].

Computer-controlled robotic manufacturing assembly line in 2023. Notice the absence of human workers in comparison to Henry Ford's 1920 assembly lines (See page XXX) [Ac].

Computer failures and disasters: Shut down of Flight Information bulletin boards at Heathrow Airport in February of 2020 [Ad].

Computer-controlled, pilotless military aircraft and drones have added new capabilities to world military forces. They can fly dangerous missions without risking loss of pilots. Current use is mainly reconnaissance over hazardous terrain and at sea over enemy surface ships. They can also be used as cruise missiles with high-precision accuracy to minimize risks of collateral damages [Ae].

Computer controlled surface ships, tanks, and other military equipment are now being planned and some are under construction. The Air Force has already carried out an experimental dogfight between two computer-controlled aircraft [Ag].

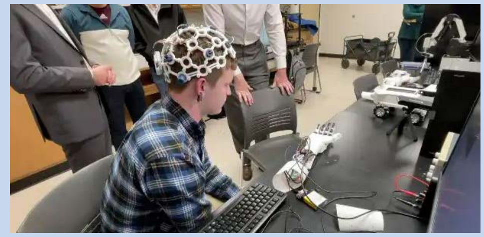
Experimental dogfight between computer-controlled, pilotless aircraft performed by the U.S. Air Force in 2020 [Af].

Computer controlled digital thermometer for covid-19 testing in 2023 [Ah].

3D printed houses are about to compete with conventional home construction since they are cheaper, faster, and use plastics instead of wood. Printed homes don’t need to be rectangular because 3D printers can handle curves as easily as straight lines [Ai].

Complex structures such as houses can be made using computer-guided 3D printers. The technology of 3D printing can print a 1500 square-foot house in 24 hours for a cost of about $4000. No doubt 3D printing will have a major impact on home construction and real-estate markets [Aj].

3D printed office buildings. These can be printed for about $15,000 and constructed in 48 hours once the land is prepared [Ak].

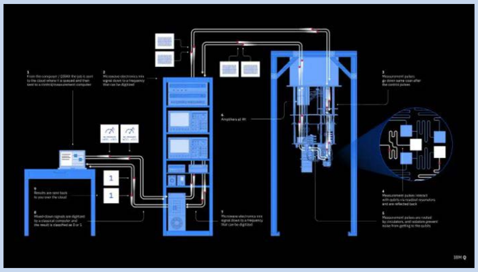


Computer-controlled prosthetic limbs made with 3D printers [Al].

University of Maine creates 3D printed boat [Am].

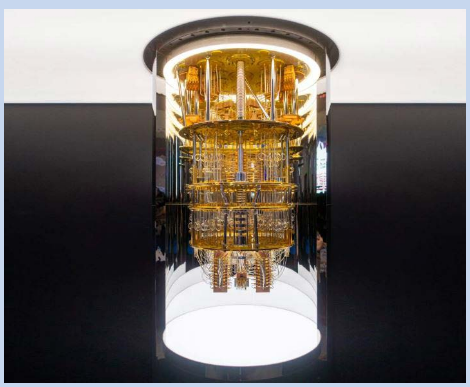
Future construction of automobiles from 3D printed components [An].

Computer-controlled, robotic, ultra-violet (UV) light sanitizers are now in the main-stream for eliminating the corona virus from hospital operating rooms, corridors, patient rooms, and public spaces. Smaller, portable UV sanitizers are available for home and personal use. The city of New York now uses UV sanitization on subway cars nightly [Ao].



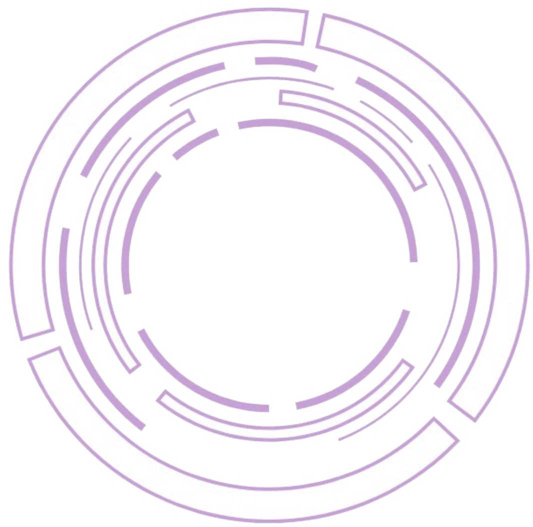
IBM has been building a 53-qubit quantum computer since before 2023 [Ap].

Today, in 2024, computers are playing an increasingly large part in all aspects of human life and commerce: construction, warfare, manufacturing, medicine, aviation, and science. It is interesting to look ahead and imagine the roles of computers in a hundred years in 2124 [Aq].



Conclusion

As I look back at one of my old pictures as author for CrossTalk, I think, “Wow, how times have changed.” The advancement in software, hardware, and technology in general has obliterated what anyone thought possible so many years ago. Taking a step back to look at how we started and how we got to where we are today is a humbling experience. Truly, the extent humans have evolved our understanding of mathematics, sciences, and technology is outstanding. And it does not stop here. New innovations and idea are coming to a head every day, including those such as quantum computing and artificial intelligence.



Acknowledgements

This article is dedicated to former IBM Chairman Thomas J. Watson, Jr. He was a great business and technical executive who guided IBM into the modern computer era. Thanks also to the faculty of the University of Florida in the Computer Science, English, and History Departments.

Picture Resources

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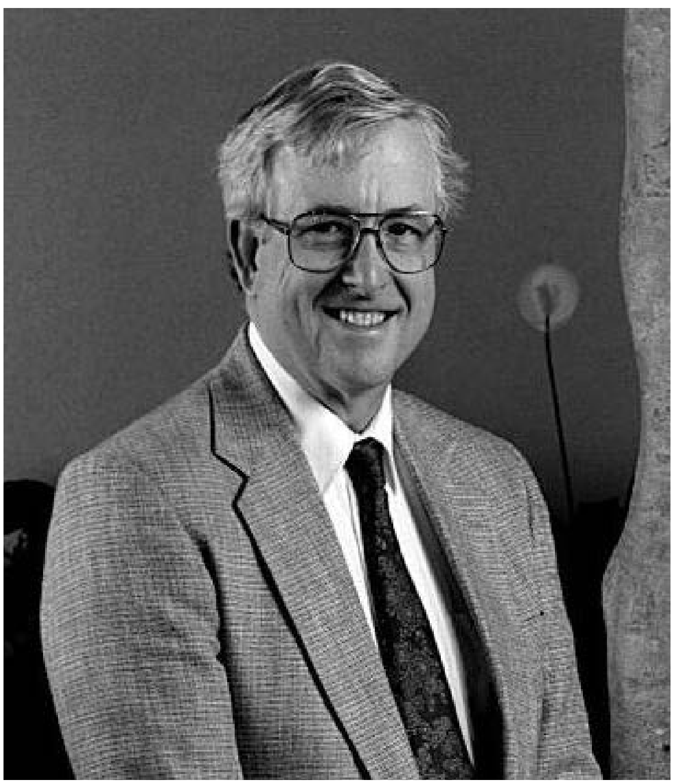

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Introduction

Advances in software engineering and artificial intelligence (AI) are providing critical and innovative capabilities across almost every domain, but the potential remains to do far more, particularly for applications that demand high levels of trustworthiness. To inform a community strategy for building and maintaining U.S. leadership in software engineering and AI engineering, the Software Engineering Institute (SEI) and the Networking and Information Technology Research and Development (NITRD) Program in the White House Office of Science and Technology Policy co-hosted a workshop at the National Science Foundation on June 20-21, 2023.

The event gathered thought leaders from federal research funding agencies, research laboratories, mission agencies, and commercial organizations to explore the fundamental research needed to support progress toward this goal. The workshop used the SEI's *Architecting the Future of Software Engineering: A National Agenda for Software Engineering Research and Development* (see further readings) as a starting point because the areas of focus identified in the study have been confirmed as even more critical and urgent, particularly due to the rapid advances of generative AI in the two years since its release. Specifically, three research areas from the study were identified by participants as having direct relevance: AI-augmented Software Development, Assuring Continuously Evolving Software Systems, and Engineering AI-Enabled Software Systems. Speakers and participants at the event worked to explore software-related challenges that are critical for multidisciplinary research across domains of importance to the nation, as well as the promising research that is needed to engineer the necessary systems reliably and well.

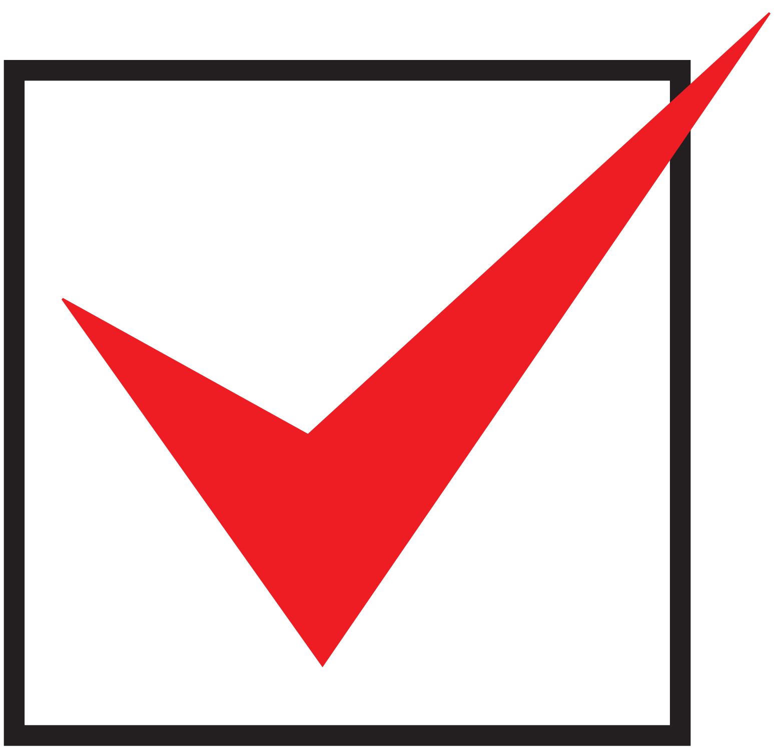
Workshop Goals and Motivation

The workshop organizers brought together participants to encourage new partnerships that will advance U.S. leadership and national interests through the disciplines of software and AI engineering, and positively impact progress across virtually all scientific domains. Specific objectives for the workshop included:

- Characterize how software engineering capabilities are having a direct impact on the future of our nation.
- Inform a community strategy for building and maintaining U.S. leadership in software engineering and AI engineering. Produce a report that summarizes challenges, opportunities, and strategic priorities.
- Identify research questions that energize the computing community and spark new collaborations.
- Identify updates to the CMU SEI National Agenda for Software Engineering National Study & Roadmap.

Executing and advancing the closely related disciplines of software engineering and AI engineering are indispensable to our ability to develop and deploy intelligent software systems effectively and rapidly. While the engineering of AI capabilities has unique and challenging requirements, these capabilities are implemented in software. To date, there has been significant research within software engineering on technologies and practices needed to build such AI-enabled systems with confidence. While comparatively more recent, the fundamental theories, practices, and knowledge base for AI engineering are receiving significant research attention to ensure that AI capabilities are incorporated into systems with expected trustworthiness and responsibility.

There has also been considerable excitement around the idea of using AI to help in the engineering of software systems at scale. Approaches exploiting large language models (LLMs) are already automating some tasks that were thought to require human creativity, including some aspects of software engineering. As the boundaries of software and AI engineering blend, the tools and techniques available to engineers to develop top priority capabilities are also changing. The rapidly changing technical environment creates further urgency to prioritize areas of most critical need and allocate multidisciplinary resources to the most challenging and essential areas of concern.



Critical Needs and Priorities: Five Primary Themes

In keynote speeches, breakout sessions, and lightning talks, participants almost unanimously remarked on the rapid acceleration of new technologies in the software development lifecycle and the role of AI in shaping the future of software systems. As the critical need for new approaches to navigate both the opportunities and the challenges was discussed, five main themes emerged.

AI is transforming the software engineering process and how we engineer software systems. The increasing symbiosis of humans and machines is transforming every phase of the software development lifecycle.

In software engineering, we are witnessing the emergence of a symbiotic workforce, where autonomous, intelligent assistants will work with software engineers to develop systems. This revolution in the way we approach software development will likely reshape the entire lifecycle, giving rise to approaches that promise to enhance productivity, quality, and efficiency. Software engineering should utilize AI tools and technology in the lifecycle, and software engineering principles should serve as a foundation for the development, evolution, and evaluation of AI-enabled software. The use of AI will likely make it possible to automate much harder programming and software quality problems. While we recognize that tasks, skills, and tools will inevitably undergo transformation in this new paradigm, the specifics are not yet fully evident.

Current technological advances, especially those related to AI and machine learning (ML) tools, will fundamentally alter the ways in which applications are built – from design-to-code platforms and tools, to ML models that automatically generate code, to models that automate elements of application testing. ML-generated code is already in commercial codebases, and the overall percentage is already rapidly growing.

In fact, the experimental application of LLMs shows promise across the entire lifecycle. Effective application of LLMs may enable the ultimate “shift left” approach, where tasks that are traditionally done at a later stage of the process, such as testing or performance evaluation, can be done early or incorporated effectively throughout software development. Design-to-code platforms and tools could make it easier for developers to bring their ideas to fruition as models automatically generate code and streamline repetitive coding tasks. Leveraging advanced automation techniques, including AI- and LLM-enabled capabilities for everything from coding and code review to deployment at scale, integration test, and debugging, could streamline workflows, improve code quality, and accelerate the development cycle. Research exploring how to apply LLMs is only in its early phases, however, and many potential issues must be addressed, including the following:

- A substantial number of solutions have been trained on a single proprietary data source or on proprietary algorithms, and as a result it is not clear how robust their inferences and conclusions are.
- Filtering issues can make conclusions hard to replicate, especially since it is not always clear what kind of filtering has been done. Some models are trained on data that specifically omits some knowledge, and in other instances, the companies that own the models decide to censor some results.
- More diversity in models, systems, and applications is needed, and the research community should not put too much trust in a single model. Public funding might help address this issue by generating models and software/hardware infrastructures that remove the proprietary or

black-box decision-making that influences results.

- Given the speed with which innovations can be developed in this space, the software research community has become increasingly focused on quick prototypes as opposed to long-term, systematic research.
- Most effective techniques will likely be based on hybrid solutions, that is, a combination of LLM, other AI, and data-driven automation approaches. Investigations of hybrid solutions should be accelerated.

While these new technologies promise to bring many benefits, they also have the potential to quickly multiply negative effects, such as security problems and AI debt (i.e., the cost of the complex mix of processes and procedures needed to discover, train, and deploy predictive models that are accurate and dependable). We need to develop sound and empirically based methods now for determining what approaches to consider successful and how to guide future software development lifecycle optimizations. Moreover, successful integration of AI in software development also relies on many non-technical factors, including the need for a "smart assistant" to understand team dynamics and roles and respond appropriately to human interactions and needs.

While generative AI has reached a level of sophistication that may seem to resemble human intelligence, it is considerably harder to determine the level of trust that should be placed in the outputs.

The assurance of mission- and safety-critical cyber-physical systems (CPS) has become increasingly challenging due to the growing complexity of these systems. The introduction of AI elements further compounds these difficulties because they can create large bodies of new code quickly, complicate the understanding of system behavior, and introduce new attack vectors, including the poisoning of training data and prompt injection, in which AI prompts can include code to generate pernicious behaviors.

As a result, while generative AI may make software developers more productive (in terms of producing code), there are well-founded worries about the quality and sustainability of the code produced. These new AI tools may already be producing a huge wave of technical debt that could overwhelm downstream software engineering efforts. In some studies, generative AI tools regurgitated old defects as often as they produced good fixes. Novice developers may lack the expertise to understand the limitations of the code being produced. AI-produced code will co-exist alongside human-built code for a long time. We have few options to help end users and developers decide whether or not to trust code generated by tools, and how this should compare to trust in human-written code. Do we trust an AI tool more or less than a human, even if humans may make more mistakes? Where do we address trust: in the ML models themselves, in the software engineering, in testing, in how users interact with the system, or all of the above?

Research has already begun on identifying the factors that can increase software developers' trust in AI tools. Key factors include source reputation; interaction (e.g., validation support and feedback loops provided); control (degree of ownership and autonomy); system features (e.g., ease of installation and performance measures); expectations (e.g., how good of a fit is the tool for style/goal of the developers). "Explainability" is not a proxy for "trustability." By their nature, many of our AI systems cannot explain cogently why they arrive at their conclusions.

One goal should be increasing our ability to build trustable systems out of untrusted components. A second goal to explore is adopting AI to generate evidence about a resulting system that can be independently verified (e.g., analogous to the development of proof-carrying code, or AI-generated code that comes with its own evidence). Another aspect of trust that requires research is whether AI tools leak intellectual property. It's possible a model might learn on a proprietary codebase and then recommend pieces of that codebase to inappropriate users. Today we don't trust AIs – but we don't always trust humans either. Rather than focusing on making AI trustworthy, we could use it to help us increase trust, using techniques such as generating evidence and incorporating AI into software testing and reviews.

Data assurance is another new frontier in the assurance of AI. In fact, it is one of the key components that makes assurance hard for AI, given the difficulty of understanding how data affects the final behavior of the system. The scalability of assurance for large AI models also poses a significant hurdle. Although some verification techniques have improved, the rapid increase in model size outpaces these approaches, which can render current verification methods inadequate from the outset.

Redefining the discipline of software engineering to encompass the use of new technologies (including but not limited to generative AI) is imperative, along with rethinking the associated curricula, tools, and technologies. This effort is key to designing and building, evolving, and evaluating trustworthy software systems in a responsible, ethical way.

Redefining the software engineering discipline with AI is leading toward a revolution that changes how engineering solutions are explored, systems are built, and AI-based tools in the operation of systems. Education is a crucial aspect of any transformation effort brought about by AI, with new degrees and curricula incorporating AI into various engineering disciplines.

To keep up with the rapid advancement of AI technologies, software engineering curricula must include instruction on both the application of AI in the software engineering lifecycle and on how tools can facilitate the design, development, training, testing, and authorization of AI-enabled software. This evolution of software engineering curricula, both at the undergraduate and graduate levels, requires a dynamic component to ensure that the workforce is well-equipped to effectively use these tools in supporting the development lifecycle.

Care must also be taken to make curricula equitable. Some initial observations as AI tools start to be used in software classes indicate that groups that are under-represented in technology disciplines are also less comfortable using these technologies. Factors such as this should be considered to avoid creating an environment where people with access to AI and other tools have clear advantages and other groups without equitable access get left behind. Retaining talent in academia is also a concern. PhD students and faculty often face financial challenges due to the demanding nature of research and the need to secure funding. Efforts to make PhD programs more attractive, reduce funding restrictions, and provide sustained funding can help address these issues. The cost of undergraduate education is also a significant concern. Government involvement in addressing the educational system's challenges can contribute to producing a workforce better equipped to address the nation's challenges effectively.

Enhancing fluidity between academia and other sectors can promote knowledge exchange. Incentivizing collaboration between universities and industry is crucial to address important research needs effectively. Key elements in fostering such collaboration include establishing public-modeled problems, data repositories, and testbeds to facilitate joint research efforts. Government agencies can also play a role by effectively utilizing commercial solutions and services where they prove beneficial, identifying bottlenecks that hinder progress.

New technologies, including generative AI, seem to hold the promise of making almost everyone a programmer. As a result, AI literacy and the development of new skills are needed throughout the workforce.

The landscape of programming is evolving dramatically. Instead of relying solely on those with traditional technical skills and expertise in software systems, and AI engineering, new tools promise to enable almost everyone to become a "programmer." For this approach to be successful, new skills and abilities must be cultivated across a much wider range of people. These new skills and abilities include problem solving and critical thinking and a general understanding of AI - in particular, appropriate uses of ML and LLM tools.

The skills needed by professionally trained software programmers and engineers will also shift. For example, research results from Microsoft about their Copilot tool that generates code via LLMs indicate that users need to spend less time writing code, but more time understanding and reasoning about code.

Software engineers will need a firm grasp of uncertainty and probabilistic reasoning, an increased capacity to detect problems and make informed design decisions, strong systems thinking skills, and a keen awareness of the ethics of AI. The discipline of prompt engineering is beginning to gain traction, which involves programming in natural language and has potential applications in various stages of software development. Different prompts given to code models result in the generation of different code, highlighting the challenge of obtaining trustworthy output from these models.

Moreover, the potential impact on society and the economy of using AI in software systems necessitates that decision-makers and leaders in all domains comprehend the fundamental principles of AI and be competent in asking the critical questions to enable their trustworthy development and responsible use. Initiatives can be launched to provide training, workshops, and resources to ensure that individuals in positions of influence and authority are equipped to make informed decisions regarding AI technologies and their applications. By empowering leaders with AI literacy, we can foster the responsible and beneficial integration of AI in our lives.

The use of AI tools such as LLMs can mask the tradeoffs being made between the functionality of software systems and their safety and security. Research is needed to identify and make explicit the key engineering tradeoffs being made during the design, development, training, testing, and authorization of systems that include AI components.

Trust, trustworthiness, and confidence in software systems that include or are developed using AI components are top priority considerations. To achieve trustworthiness, engineers must navigate key tradeoffs in system development, ensuring the system performs as intended without overstepping its boundaries. This trust should extend as the system inevitably changes over time, providing measurable confidence in the system's evolving performance. Research is essential to enable this outcome by providing mechanisms for identifying engineering tradeoffs throughout the specification, design, training, testing, and authorization of critical systems.

Explicit tradeoffs that set limits on AI systems are also needed to address concerns for both direct users and others potentially impacted by the system's actions or data. Although technologies like ChatGPT currently implement some features that prevent harm at the expense of performance, explicit engineering tradeoffs are needed during system development to clarify the relationship between functionality and safety/security. Research in AI-enabled systems must identify and analyze these tradeoffs explicitly to maintain safety and security throughout the software engineering lifecycle.

Additionally, AI-enabled tools should be designed to show explicitly the tradeoffs involved in developing a system instead of obfuscating or concealing them from key decision-makers. Transparency in engineering tradeoffs is especially critical when incorporating technologies like smart coding assistants to ensure the development of robust and trustworthy systems.

Research Needs

Software and AI capabilities are advancing rapidly around the world, and not just in high-resource nation-states. They will continue to advance in complexity and sophistication, without bound, for the foreseeable future. To bolster U.S. leadership in this incredibly competitive domain, participants at the workshop identified a need to focus on research breakthroughs and development in software engineering and AI engineering, system architectures, and defining trustable systems. Presentations and discussion from multiple federal agencies showed the extent to which their plans for executing their missions rely on advanced software and AI capabilities.

Workshop participants also discussed the importance of improving collaboration mechanisms among academia, industry, and the federal space, including suggestions to invest in operationally relevant datasets and testbeds to enhance collaboration. Likewise, participants highlighted the need for open access to resources, such as models and data sets, in software engineering and the importance of breaking down large models into smaller pieces for better understanding and progress. The significance of social factors, access, and soft skills in AI and the importance of taking a multi-disciplinary approach were also acknowledged. The high priority themes identified also revealed a significant need for intentional crosscutting progress in data, standards, and all tradeoffs and aspects of trust. Specific areas of needed research discussed included:

- *Software architectures for modern software needs. Architectures for AI-based systems should be developed so that they are resilient to attack and support federated data sources*. The development of modeling and analysis techniques is needed to guide early design decisions, facilitate downstream test and evaluation (T&E), and enable evidence creation.
- AI engineering practices for trustworthy use of ML and LLM capabilities. Research is needed to enable the development of trustworthy systems to mitigate weaknesses in ML and LLMs and support ongoing updates to ML- and LLM-based capabilities as algorithms and training improve.
- *Data-intensive software engineering*. Software repositories have a wealth of information regarding current and older projects. There is a need to support repository mining for defect repair, API compliance, refactoring, synthesis, transformation, and evidence-based T&E. Data federation, privacy protection, and multi-institutional data collaboration are important challenges in integrating various types of data, such as health and environmental data.
- *Diverse, advanced technical models and analyses to support development, evolution, and T&S*. The use of modeling and analysis is essential in modern practice. Modeling and analysis must be integrated into practice in a way that allows for a diversity of tools. More robust code models must be built by considering different code properties such as syntax, semantics, and evolution, and incorporating them into the model's design and loss functions.
- *Cybersecurity considerations for AI-reliant and software-reliant systems*. Systems are growing in interconnection and complexity, with larger external and internal attack surfaces, including AI attack surfaces. A focus on cyber risk is needed, including how to measure and manage attack surfaces since threats are growing in sophistication and scale. Architectures devised for security and resiliency are needed, as well as models and tools to enhance cybersecurity.
- *Clear standards and guidance*. There is a need for clarity in the development of standards for AI systems, as they are often asked to meet a large and varied number of requirements related to trustworthiness, security, privacy, and ethical considerations.

Conclusion and Next Steps

This workshop delved into various aspects of software and AI engineering, addressing challenges, opportunities, and ethical considerations. It highlighted the paradigm shift brought about by AI and LLMs, requiring alignment between models, researchers, and diverse user groups. Participants emphasized the need for transparency, trustworthiness, and collaboration across different sectors to effectively navigate the evolving landscape of AI technology.

The workshop also highlighted the impact of AI on various domains, including workforce, cybersecurity, and autonomous systems, and the importance of collaboration and engagement with stakeholders was emphasized. The growing influence of AI in society, along with the acceleration of technology in general, demands interdisciplinary collaboration, technical advocacy for broader use cases, and

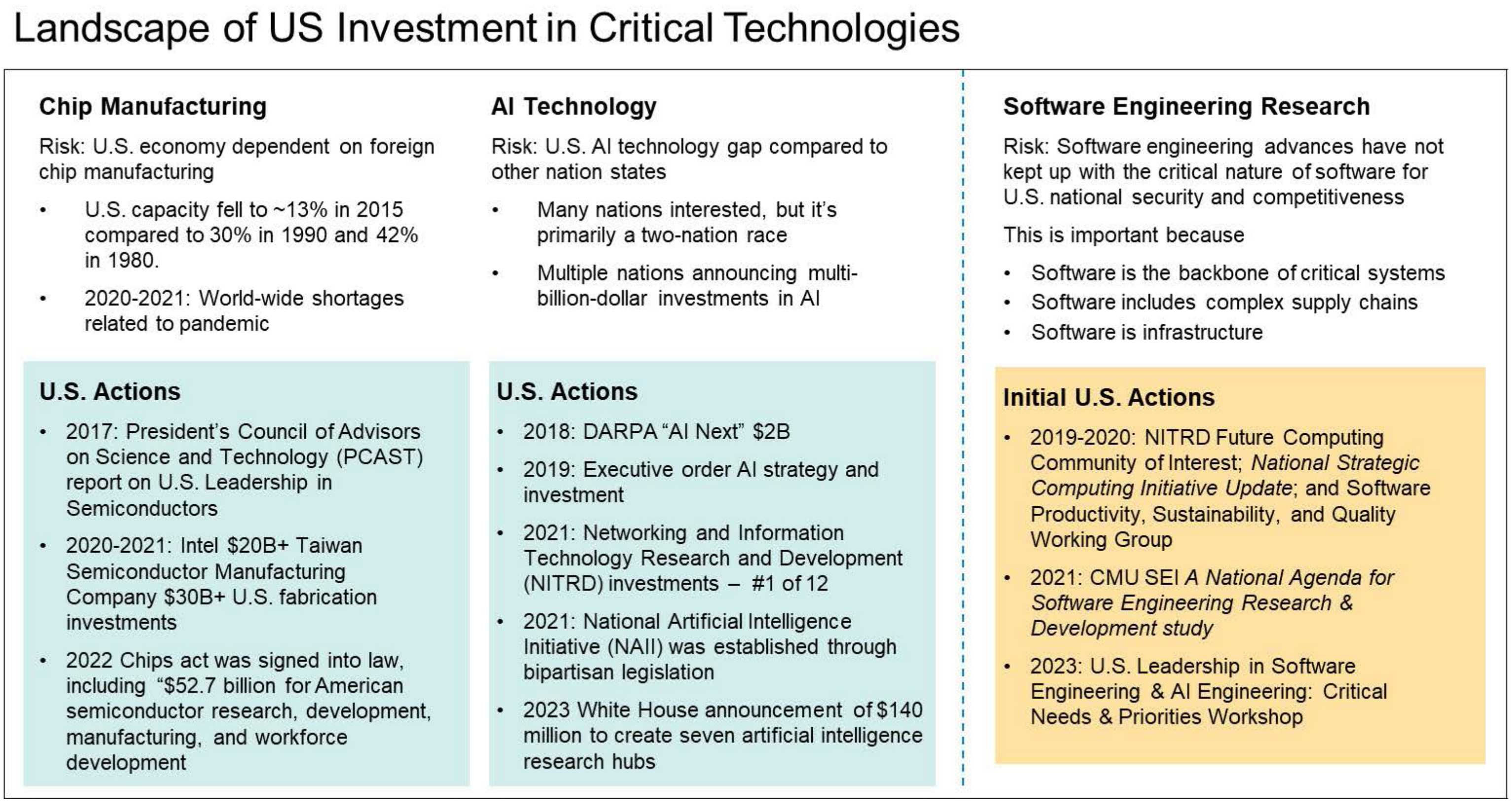


Figure 1. *Investment in U.S. Software Technology.*

policy development informed by the research community.

Making investment decisions in the right technical domains and fostering powerful partnerships is key to meeting the critical needs and priorities of the U.S. for software and AI engineering. For example, the figure above shows the actions taken to avoid the risks of a U.S. economy dependent on foreign chip manufacturing, which industry investments of around $50 billion and a proposed government investment of another $50 billion. AI technology investment followed a similar path, where a possible U.S. technology gap motivated major government and industry investment. The increasing awareness of the risks to national security and the U.S. economy motivated action in those cases, and such concerns also underscore the importance of making a similar strategic investment in software engineering research.

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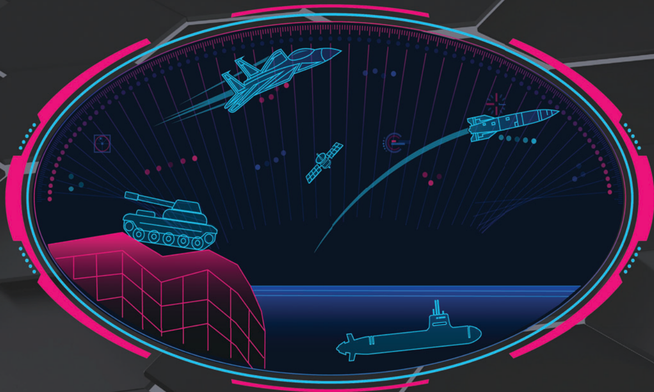

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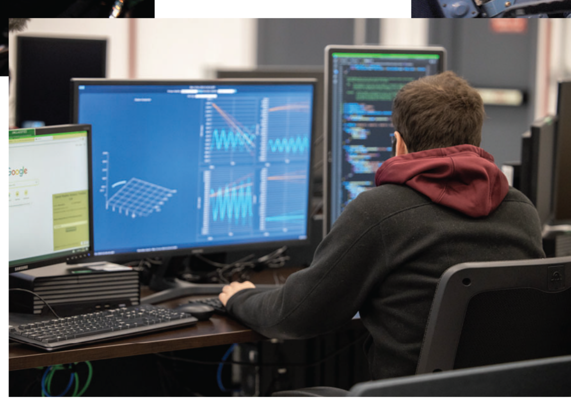

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AUGMENTED AND VIRTUAL REALITY: CEMENTING THEIR PLACE IN OUR REALITY

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Introduction

Augmented reality (AR) and virtual reality (VR) have increasingly attracted significant attention, not just within the tech sphere, but also in mainstream media. While virtual reality has gained familiarity with consumers due to its relatively long-standing availability on the market in the form of VR goggles, augmented reality (AR) headsets as well as headsets that are capable of providing both augmented and virtual reality experiences also known as mixed reality (MR) headsets remain less prevalent. Some people may have been introduced to the concept of AR devices following Google's unveiling of its futuristic smart glasses, Google Glass, over a decade ago. However, Google Glass never reached widespread use and Google ultimately ceased sales (for the second time) in March of last year [1]. Consequently, Apple's announcement of the Apple Vision Pro mixed reality headset in June of last year, is perhaps the most notable introduction of a device equipped with AR functionality that has prompted considerable anticipation and hope for a more successful integration of AR technology into mainstream user experiences.

Unlike virtual reality, which demands VR-specific equipment, augmented reality, despite being perhaps the less recognizable technology to the average consumer, is likely more accessible in culture than VR. Remember the breakout hit Pokémon GO? Dominating the mobile gaming industry immediately upon its release, Pokémon GO attracted a record breaking nearly 21 million daily active users in the United States in less than a week following its release [2]. It remains today one of the most recognizable AR applications, and augmented reality's ability to be implemented on devices such as smartphones and tablets make the technology more easily available to consumers.

With the much-anticipated release of the Meta Quest 3 mixed reality headset, along with the announcement of the Apple Vision pro, and discontinuation of Google Glass, 2023 marked significant activity in the AR, VR, and Mixed Reality (MR) device space, contributing to increased familiarity with this technology. However, the average consumer may still lack a comprehensive understanding of these technologies–what exactly they are, how they work, current applications, the latest advancements, as well as how they are being utilized for defense.

Understanding VR

What is VR?

Virtual reality comprises of computer-generated, three-dimensional environments or images that individuals can interact with and immerse themselves in, allowing them to transcend the limits of physical reality. Our understanding of reality is derived from sensory information processed by our brains, making our perception a blend of sensory information and our mind's interpretation. VR manipulates sensory information to offer an alternative experience that we perceive as real. Creating convincing VR involves precise synchronization of hardware and software that aims to make users feel present within the simulated environment through the use of equipment such as headsets, gloves, and hand controllers [3]. Prominent VR goggles such as those from brands like VIVE and Meta Quest (previously Oculus Quest) have transformed VR from a niche technology into a widely accessible experience available to consumers. While oftentimes associated with gaming, these devices boast capabilities that extend far beyond entertainment purposes, into the practical applications in manufacturing, healthcare, education, and defense.

Figure 1. *Google Glass [A].*

Figure 2. *Apple Vision Pro [B].*

Figure 3. *Meta Quest 3 [C].*

How Do VR Devices Work?

VR technology has the power to transform user experiences by placing users into interactive digital environments. Key elements that contribute to this immersion while using VR goggles are sensors, lenses, audio systems, and controllers. VR headsets use an assortment of sensors, including accelerometers and gyroscopes, to capture users' movements across six degrees of freedom, to ensure that every turn, tilt, and movement is precisely tracked. This dynamic tracking facilitates seamless adjustments in the user's view, to foster a life-like interaction between the user and the virtual world. Fundamental to the visual aspect of the goggles are the lenses and screen arrangement which are used to strategically distort the display between the screen and the user's eyes to create a realistic three-dimensional effect and simulate natural depth perception. Additionally, immersive audio technologies such as spatial or binaural audio heighten immersion by enhancing the perception of distance and space. Finally, controllers further the interaction element by allowing users to manipulate virtual elements using handheld devices and/or motion-sensing controllers. Precise fusion of carefully designed hardware and software components allows for the creation of realistic virtual environments, while creating a smooth and engaging user experience [4].

VR Applications

Beyond their association with gaming and entertainment, VR devices boast the ability to make an impact on almost any industry. Due to the simulated nature of its experiences, VR provides an invaluable training ground for maintenance and manufacturing personnel while mitigating the inherent risk of injury and potential damage to valuable equipment. With interactive training grounds accessible from anywhere you can take a headset, VR can also significantly reduce time and expenses by eliminating the necessity for on-site training and experimentation with potentially costly materials. Another field taking advantage of this technology is the real-estate industry, where agents can now save time by leveraging VR to conduct seamless and immersive remote property tours to offer prospective buyers the chance to experience an estate of interest, without the constraints of physical visits. Similarly, automotive designers have leveraged VR environments to develop iterations of vehicle designs, allowing them to fine-tune details before building expensive prototypes. Finally, within the medical sphere, VR serves as a groundbreaking tool for surgeons and other medical professionals to develop their skills and gain familiarity with equipment without the need for direct patient involvement [5]. These are just a few of many examples of various sectors that are using VR to modernize and enhance the way that they do things.

Figure 4. *Medical Student Training with VR [D].*

Figure 5. *VR Real-Estate Tour [E].*

Recent and Future Advancements in VR

Recent developments in VR signify a rapid and impactful evolution in performance, quality, and accessibility. Initially, VR headsets were expensive, difficult to use, and offered only basic features. However, today's market offers affordable, standalone units that aren't limited by a need to be connected to a computer. Additional features continue to be introduced and improved as Artificial Intelligence's (AI) pervasive integration touches VR, enhancing object recognition and Natural Language Processing to refine eye and body tracking as well as voice command recognition. Embraced by diverse industries, VR continues to demonstrate its ability to be a valuable tool as it continues to reach further adoption across sectors.

VR experts expect haptics to become a standard addition to VR in the near future. Haptics is the technology that simulates the sense of touch, meaning that VR would achieve a realistic sense of touch and grasp to help increase the perception of immersion. Additionally, biometric sensors could be integrated into VR headsets and accessories to measure physiological data such as heart rate, brain activity, and respiration which could help analyze user's stress levels and emotional responses, which could be especially useful in therapy and clinical uses [6].

Understanding AR

What is AR?

Augmented reality is an interactive, enhanced version of your true surrounding environment that is achieved by incorporating visual elements, immersive sounds, and other sensory components into your real-world space. Microsoft, the creator of the HoloLens 2 AR headset, defines AR as incorporating three fundamental elements: a combination of physical and digital worlds, interactions made in real time, and accurate identification of three-dimensional virtual and real objects [7]. In essence, AR serves as an innovative technology that enhances actual surroundings by seamlessly integrating virtual two-dimensional and three-dimensional images, often referred to as holograms, into the user's physical space. AR is just starting to breach the surface in redefining how users interact with and perceive their immediate environment, hinting at its vast potential and promising future in reshaping our everyday experiences.

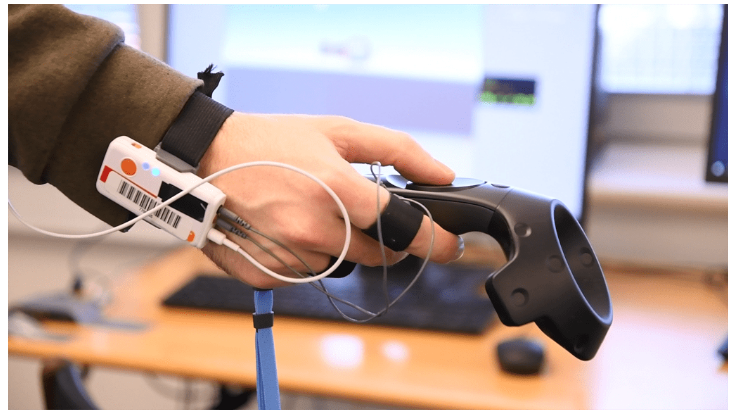


Figure 6. *VR with Biosensors [G].*

Figure 7. *VR with Haptic Gloves [F].*

How Do AR Devices Work?

AR technology operates at the intersection of reality and the digital world. AR devices work to seamlessly merge both worlds to deliver users an enriched experience of their current environment. AR software on headsets, smartphones, and tablets leverage computer vision technology to discern and interpret elements from the live video stream of the devices' camera. The device then responds by overlaying and superimposing lifelike three and two-dimensional objects onto the real-world view. Users are then able to interact with and control these virtual components via touchscreen, voice commands, and intuitive gestures. Additionally, as users navigate through their environment, AR intelligently adapts to their movements and dynamically adjusts the size and orientation of the displayed graphics. The responsive nature of the display allows digital elements to smoothly enter and exit the frame according to the user's movement. The ability for AR to seamlessly integrate virtual components into the user's real-time surroundings not only enhances their experiences, but also showcases the technology's potential to redefine how our daily interactions are carried out.

AR Applications

As previously mentioned, one of the most widely used examples of AR is Pokémon GO, a mobile game that allows users to embark on adventures in their real world and catch virtual creatures that are integrated into their surroundings. Perhaps the most exciting and impactful applications of augmented reality, however, lie outside of the realm of gaming. Retailers have leveraged AR to revolutionize the customer experience by providing customers the opportunity to envision furnishings, decor, and paint in their home by tapping into the latest smartphone sensory technology such as LiDAR sensors, so that they can better grasp the impact of products before purchasing. The same has been done by fashion and makeup brands by allowing potential customers the chance to virtually try on products through smartphone apps [8]. By harnessing the power of existing smartphone technology, many AR applications ensure accessibility for the average user.

AR headsets, on the other hand, can be leveraged to allow users to have their hands free, while still having access to text and images that they need for reference when carrying out tasks. The AR software on headsets can walk maintenance personnel through steps for repairing equipment quickly, efficiently, and safely [9]. Additionally, intuitive dotted lines and arrows can guide personnel to tool locations or work areas. As mobile and AR-specific device technology continues to improve, the potential for further integration of AR into everyday tasks can continue to expand.

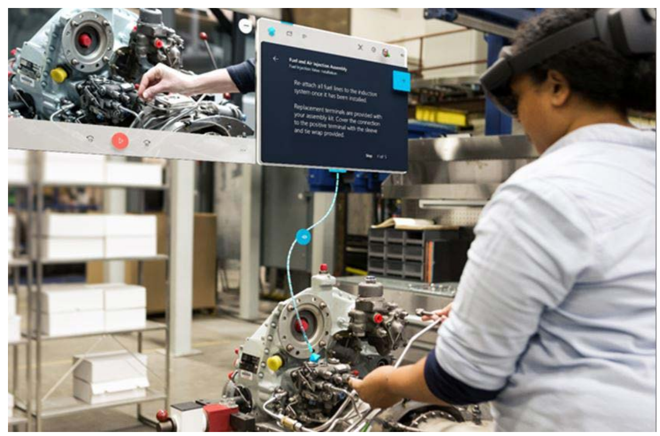


Figure 8. *Left: Pokémon GO [H]. Right: AR For Maintenance Training [I].*

Advancements in AR

Advances in AR technology showcase its evolution from mobile-focused applications to devices dedicated to AR and MR use cases, such as the Microsoft HoloLens 2, Apple Vision Pro, and Meta Quest 3. Having AR and MR devices become available to the general public has been a large step in the right direction alone, however, invested consumers now hope to see products geared towards the average person. The market is starting to see this embraced by companies through marketing and price adjustments. For example, the Microsoft HoloLens 2, released in 2019, was primarily targeted for business and manufacturing use with a price tag of approximately $3,500 [10]. Despite a similar price tag, the Apple Vision Pro's marketing is much more targeted for personal use, as opposed to use in a warehouse or maintenance area setting [11]. The Meta Quest 3, however, starts at a retail price of approximately $500 and is accompanied by similarly aimed marketing as the Apple Vision Pro [12]. Along with greater accessibility, improvements in functionalities such as eye and body tracking as well as voice command recognition, have accompanied a reduction in device bulkiness, to foster improved user experiences and increase adoption across various sectors.

AR and VR Throughout the Department of Defense

Figure 9. *Staff Sgt. Renee Scherf Demonstrating VR Training System at Sheppard AFB [K].*

At various United States Air Force bases, VR technologies have sparked transformative changes in training and operations. For example, at Sheppard Air Force Base, the foundational Crew Chief Fundamentals Course has been reengineered into an immersive VR experience [13]. VR goggles and body-worn sensors at the Inter-American Air Forces Academy (IAAFA) in Joint Base San Antonio-Lackland aid military and law enforcement students in countering transnational criminal organization's narcotic efforts through simulated scenarios [14]. Barksdale Air Force Base has employed VR technology to enhance pilot training by integrating instructors with VR goggles for teaching and assessing student pilots [15]. Additionally, Dyess Air Force Base has embraced VR to modernize C-130 maintenance training, offering a more dynamic and effective learning environment [16]. Lastly, Hill Air Force Base's 75th Security Forces Squadron utilizes VR for comprehensive training in real-life scenarios, covering responses to domestic violence, traffic stops, and active shooter situations [17]. In the realm of AR, the United States Army's substantial invest-

Figure 10. *Airman 1st Class Alex Muralles, 75th Security Forces Squadron Hill AFB, during a Use-of-Force Response Scenario with the Street Smarts VR System [J].*

ment in custom Microsoft Integrated Visual Augmented System (IVAS) headsets, with a contract valued at up to $21.88 billion over a decade, signifies a robust commitment to leveraging AR technology for defense purposes. Using HoloLens technology, some of the capabilities that the IVAS system will allow soldiers to have include the ability for the aim of a weapon to be projected onto their field of view along with maps and a compass to reveal the location of people in the dark using thermal imaging. This move aims to acquire over 120,000 devices for comprehensive training and operational use [18]. Additionally, research engineers at Wright-Patterson Air Force Base's Air Force Research Lab have developed an AR capability designed to aid technicians in detecting fatigue cracks between metal aircraft layers [19]. Joint Base Langley-Eustis has an AR project that uses the HoloLens 2 to offer interactive menus and provide detailed insights into aircraft engines by displaying information about individual parts and their complex configurations [20]. These initiatives are just a few of many defense-related projects that illustrate the ways in which AR and VR are being adopted across the Department of Defense.

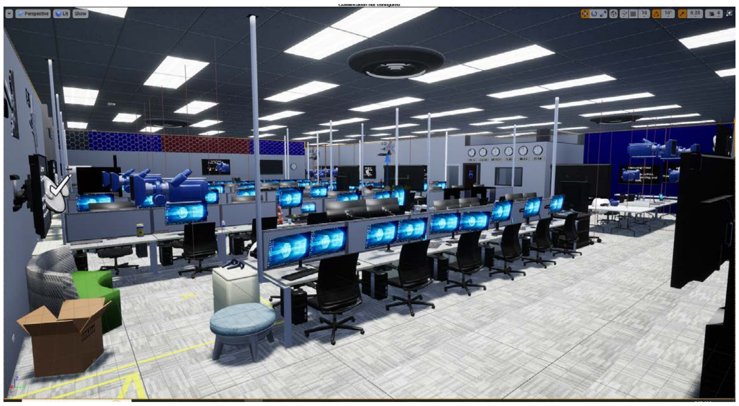
Figure 11. *IVAS Prototype [L].*

Figure 12. *U.S. Air Force Senior Airman Logan Belknap wears a HoloLens Headset That is Being Used to Train Airmen on Advanced Avionic and Propulsion Maintenance Techniques [M].*

AR and VR in the 309th Software Engineering Group's Launchpad

Introducing ARDVRK

The 309th Software Engineering Group (SWEG) at Hill Air Force Base includes the Launchpad which is the training location for SWEG interns and new employees. Due to its unclassified nature, the Launchpad also serves as an ideal space for research and development efforts that aren't limited by the constraints associated with classified spaces. In the Launchpad, the Augmented Reality Devices Virtual Reality Knowledge (ARDVRK) team works to explore potential applications of AR and VR within the United States Air Force. A primary objective of the Launchpad is to offer training and projects that are beneficial for everyone. Currently the Launchpad hosts high school volunteers with limited exposure to computer science and engineering, college interns with a firm grasp of the basic fundamentals, all the way up to new employees who are waiting for their security clearances and may have decades of experience. The Launchpad strives to find a way for all individuals to learn something new and work on a meaningful project during their time spent there. However, it is difficult to anticipate when security clearances will be granted, and some students are only in the office a few times a week when they have time away from school. Having to integrate individuals from a wide range of backgrounds into a project that they will be working on for alimited period of time, can prove to be challenging. ARDVRK stands out as an exceptionally inclusive project, requiring no previous experience or background, facilitating a smooth onboarding for all team members.



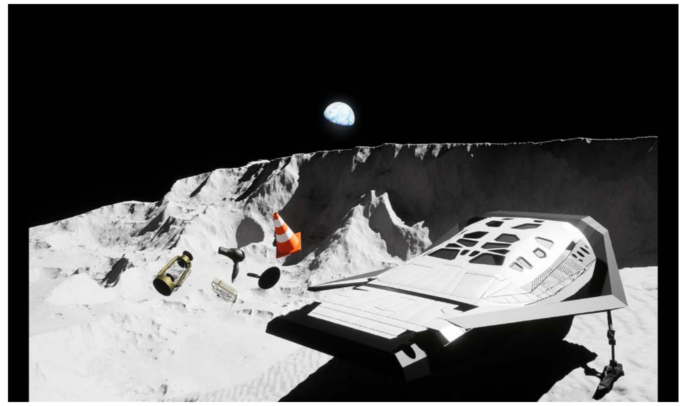


Figure 13. *Left: Building Simulation [N]. Right: Unreal Engine Moon Scene with the Progression of Models Made Throughout the Training Process [O].*

ARDVRK Training Program

New ARDVRK team members undergo a structured training regimen that starts with learning 3D modeling through the Blender software. Comfortability with Blender prompts further training tasks focused on leveraging their 3D models within Unreal Engine. As a culminating assignment, team members have a chance to learn or practice using Git and GitLab to integrate their work into a sample ARDVRK team project. Within the span of a few brief weeks, individuals who, in many cases, started as novices, smoothly transition into proficient and confident 3D modelers and can begin contributing to the team's workload.

Current VR Workload

Curious about the connection between the team's training and AR/VR technologies? Upon completion of their training, team members help add to the team's VR simulation of the Launchpad building. The simulation, developed in Unreal Engine, serves as a replica of the inside of the building that can be toured on the team's HTC Vive Pro 2 headset. This VR experience continually evolves as ARDVRK team members consistently add new 3D models of different items such as desks, chairs, monitors, and more. This simulation is then able to be taken to career fairs and STEM events to give potential future interns and full-time employees the chance to see one of the spaces that they would spend time working in and get them excited about the opportunities that Hill Air Force Base has to offer. The team also aims to broaden its scope by modeling additional spaces at Hill Air Force Base, such as aircraft hangars, to offer new employees in those spaces a chance to acquaint themselves with the layouts prior to physically entering the space. Additionally, ARDVRK extends its support by creating models for other teams on base to use in their simulations. The team currently works to model aircraft for the Visual Threat Recognition and Avoidance Trainer (VTRAT) team.

VTRAT approached the ARDVRK team because they currently have no access to any 3D modeling software and thus are limited to only the models available in the Unreal Marketplace.

Therefore, the Launchpad is the perfect playground for ARDVRK to produce the assets that VTRAT requires. Working with VTRAT consists mostly of modeling the exterior and interior of aircraft that pilots use in the training simulation. The VTRAT team uses the latest version of Unreal Engine 5 for its development. Again, due to its classified nature, VTRAT has limited access to online documentation, tutorials, and videos to teach all the aspects of Unreal Engine. This puts ARDVRK in another position to support the VTRAT team with understanding Unreal Engine by leveraging an unclassified space to experiment with and learn from all available resources on the internet. The collaboration with VTRAT has exposed many advantages of utilizing a hybrid of unclassified and classified spaces to achieve the mission at hand.

Current AR Workload

The ARDVRK team recently acquired a Microsoft HoloLens 2 headset, to support further exploration into the augmented reality space. As the 309th SWEG transitions into its Directorate membership, the Launchpad seeks to bolster its training initiative for new employees. ARDVRK is exploring augmented reality's potential to enhance traditional presentations with interactive simulation components such as exploring models related to aircraft that the 309th SWEG supports. The team is also working to forge partnerships, notably with the 309th Aircraft Maintenance Group (AMXG) to leverage the HoloLens' capabilities for modernized maintenance training. AMXG's implementation of VR training for aircraft painting demonstrates significant cost savings by reducing paint wastage. ARDVRK plans to pursue involvement by creating AR-based workspace tours and providing step-by-step guidance for aircraft painting processes, to aid personnel in understanding intricate painting requirements. The HoloLens 2 headset has also been a beneficial tool for recruiting and allows the Software Organization Development Office team, who also operate out of the Launchpad, to show students what

Figure 14. *C-17 Model [P].*

Figure 15. *C-17 Cockpit Model [Q].*

Figure 16. *View of VR Headset and Controllers model through AR Headset [R].*

Figure 17. *View of Building Model through AR Headset [S].*

current interns and employees are working on in the Launchpad. Looking ahead, ARDVRK aims to showcase AR's potential to other base groups, advocating for the integration of AR-based training and facility tours.

Final Thoughts

AR and VR technology has undergone an impressive evolution, leaving a lasting impact on many industries. VR with its expansion beyond entertainment, has become a widely used tool in fields like healthcare and design. And AR, with its ability to enhance real-world experiences, has reached wide-spread utilization in sectors such as manufacturing and education. As these technologies progress, their increased adoption throughout systems promises an exciting future where training and daily processes are revolutionized. The ARDVRK team at Hill Air Force Base will continue to explore new applications for AR and VR within the Air Force and is excited to see how the technology is further embraced throughout the entire Department of Defense.

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[P] Udall, Sully. C-17 Model.

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[R] Udall, Sully. View of VR headset and controllers model through AR headset.

[S] Johnson, Jared. View of Building 1208 model through AR headset.

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The Power of Unity: Bridging the Gap Between Generational Differences

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Introduction

"If everyone just thought the way I did, the world would be a better place." Almost all of us have said this out loud or thought this internally. More waking hours are spent with coworkers then with family and one of the challenges faced is understanding and communicating effectively with a variety of people. Considering different backgrounds, beliefs, cultures, views, and values, and things can seem "sticky" at times. Now, with the addition of generational differences, that's a whole other animal.

We have all worked with someone whose mentality was, "but we've always done it that way." Where did that thinking come from? Exploring the 5 Generations in today's workforce, can assist in understanding where statements like this originate. It helps to understand that we all have differences, but the similarities outweigh them. It's easier to focus on the negatives than the positives. If everyone is willing to work past the differences and find commonalities, communication and productivity can be increased in the workplace.

To fully understand this concept, let's explore the different generations currently in the workforce. What shaped them? How did the generation before them play a role in molding the behaviors and values of the next generation? We'll also look at how each generation functions in the workforce and how one can overcome generational challenges.

What Defines a Generation

A "generation" is defined as a group of people born in the same time period, and generation names exemplify our human tendency to categorize ourselves. Over time, sociologists and generation researchers usually deem titles for the different age groups based on historic social trends [1]. In order to understand the dynamic of each generation, it is imperative to look at key elements such as: major events during the time period, typical core values, preferred work environment, motivational factors, and work assets. Compiling information from each generation will paint a bigger picture on how to understand what assisted in shaping their viewpoint: why they believe what they do, why they think the way they do, and how to better engage with different generational perspectives. Understanding the history of a generation is the beginning of understanding differences, expanding perception, and bridging communication gaps.

Traditionalists: Born between 1928 – 1945

Major events that influenced this generation: World War II, The Great Depression, The Rise of Corporations, and The Space Age.

Raised by parents that survived the Great Depression, Traditionalists experienced hard times while growing up, which were followed by times of prosperity. They were taught to save everything and be frugal. Everything that could be reused was reused [2][3].

Core values:

- Adherence to rules
- Duty before pleasure
- Loyalty
- Frugality
- Patriotism
- Trust in government
- Family-focused

They believe that rank was earned by time and effort put into the workplace and typically stayed with one company, being more loyal to the company than to people [2].

Preferred work environment:

Traditionalists account for less than 1% in the workforce. They are prudent and appreciate recognition and respect for their experience. Value is placed on history/traditions, job security, and stability. Traditionalists want clearly defined rules/policies [2].

Motivated by:

Respect and job security [2][3]

Work Assets:

Traditionalists bring value to the workplace with their experience, knowledge, loyalty, discipline, consistency, and use their institutional wisdom to face changes in the workplace [2].

Bably Boomers: Born between 1946 – 1964

Major events that influenced this generation: The Vietnam War, The Civil Rights Movement, The Cold War, tensions with Russia, and Space Travel [2][3].

World War II led to the high birth rate which greatly influenced the name Baby Boomer. Divorce rates were beginning to rise. The radical and “yuppie” movement became popular during this era [2].

Core Values:

- Anti-war
- Equal rights
- Personal gratification
- Personal growth
- Question everything

The mentality of buy now, pay letter became popular during this era [2].

Preferred work environment:

Baby Boomers account for around 25% of the workforce and are retiring rapidly. They prefer managers who seek consensus and treat them as equals. They are service-oriented, goal-oriented, and competitive [2].

Motivated by:

Being valued and money [2][3]

Work Assets:

Baby Boomers challenge the status quo, are mission-oriented hard workers who will go the extra mile. They excel at seeing the big picture and creatively breaking it down into assignments [2].

Generation X: Born between 1965 – 1980

Major events that influenced this generation: Watergate, Dual-income families, single parents, first generation of Latchkey kids (children who returned to an empty home at the end of a school day), The Energy Crisis, and an increase in mothers joining the workforce.

Gen X grew up having to take care of themselves. Divorce rates rapidly increased during this era [2][3].

Core Values:

- Balance
- Self-reliance
- Informality
- Entrepreneurship
- Independence
- Skepticism/cynicism
- High job expectations

Gen X were increasingly suspicious of Baby Boomer values, leading them to “go their own way” [2].

Preferred work environment:

Gen X account for around 30% of the workforce. They prefer managers who are straightforward, genuine, and “hands off.” Their results-oriented nature and desire for flexibility shows in how their work gets done [2].

Motivated by:

Freedom, fewer restrictions, and time off [2][3]

Work Assets:

Gen X adapts well to change, are eager to learn, determined, excellent multitaskers, and are not intimidated by authority. They do not mind direction but resent intrusive supervision and are good task managers [2].

Millennials (Gen Y): Born between 1981 – 1995

Major events that influenced this generation: Increase in school shootings, digital media (such as Facebook, Twitter, and YouTube), Rise in Terrorist attacks (9/11), and a child-focused world.

Millennials typically grew up as children of divorce and were more sheltered than any other generation. This was the first generation of children with strict schedules and "helicopter" parents. They are the most educated generation [2][3].

Core Values:

- Personal attention
- Self-confident
- Educated [2]
- Tech savvy
- Achievement driven

Preferred work environment:

By 2025, Millennials will represent around 75% of the global workforce. They crave meaningful work where they feel part of the organization's mission, and value helping others more than a large paycheck. Work-life balance is a fundamental expectation, and they expect to work when and where they want [2].

Motivated by:

Working with other bright people and time off [2][3]

Work Assets:

Millennials are goal-oriented, tenacious, highly educated, collaborative, have a positive attitude, and are technically savvy [2].

Generation Z: Born between 1996 – 2009

Major events that influenced this generation: The Great Recession, the rising costs of higher education, Instagram, Snapchat, and selfie culture.

Most of their lives have been spent using personal technology, such as smartphones, with many of their waking hours being online [2][3].

Core Values:

- Self-directed
- Independent
- Societal Change
- Entrepreneurship

Around 72% want to start their own business one day – and around 3% already have [2].

Preferred work environment:

Gen Z account for around 25% of the workforce. They seek challenge, growth, and development. An enjoyable work life and work-life balance are craved. Gen Z is likely to leave an organization if the organization resists change [2].

Motivated by:

Diversity, inclusion, and a sense of purpose in the workplace [2][3]

Work assets:

Gen Z are technologically proficient, open-minded, diverse, inclusive, adaptable to change, and innovative [2].

The Value of Each Generation

It's important to know that each generation brings value to the mission/team. If asked, "Would you want a team only made of Boomers?" or "How about a team of only Millennials?" most people would answer no. Some reasons are because of the need for different perspectives, viewpoints, and experience that each generation brings to the team. Regardless of generation, everyone brings a certain level of expertise and knowledge that fosters growth and teamwork.

Generational Influence

So, how has each generation shaped the one that precedes them? Although there are very few Traditionalists still in the workforce, it's still a benefit to be educated on how they played a role in shaping future generations. We need to study history in order to understand the present. The Traditionalists were dealing with WWII and The Great Depression. Because of these events, families were taught to save, save, and save some more.

Baby Boomers grew up with this mentality, and in turn wanted to not only have more for themselves, but also for their children. Baby Boomers watched their Traditionalist parents "blindly" trust the world around them and were motivated by a sense of duty. They began to question the loyalty of their parents, resulting in more human rights movements and questioning authoritative decisions. The birth rate during the Baby Boomer era dropped significantly. This is partly due to more emphasis on career vs. family. Baby Boomers have a hard time retiring because their worth is tied to their careers. They need to feel needed and, therefore, many are putting their retirements off more and more. However, as they retire, they will be taking a wealth of knowledge with them, so it's important to harness their experience before they leave the workforce.

Gen X are best known as "latchkey" kids. With both of their Baby Boomer parents in the workforce, they were often left to take care of themselves. Many of them awakened to empty houses and returned home with no supervision. Because Baby Boomers were more focused on work, many Gen X children were left unsupported in school events, sports, and discipline. This led to Gen X becoming "helicopter parents" and scheduling their Millennial children down to every minute of their day, wanting to give them parental guidance and opportunities they felt they had missed out on. Gen X is often referred to as "rude, ruthless, and uncaring." The phrase, "I'm Gen X, you can't hurt my feelings" is often heard when working with this generation. This is due to their independent nature of having to "raise themselves."

The rise of the Millennials in the workforce brought new challenges for Baby Boomers and Gen X. The question "why?" became a sticking point for frustration until the older generations learned that Millennials asked "Why?" not to go against authority, but to truly understand the meaning of why something was being done the way it was. They have a need to create efficiency when making a process or product. We saw a shift in communication style with Millennials. Many preferring texting as their primary way of communicating vs. face-to-face. The greatest Millennial frustration lies in the older generations use of the phrase, "It's always been this way. If it isn't broken, don't fix it." What a lot of younger generations are unaware of is that it is not that Baby Boomers and Gen X are against change. Change leads to them feeling as if they can't compete or keep up with the younger generations and rapidly changing technology. On the other side of that coin, Millennials and Gen Z experience "Tech Shame" and Imposter Syndrome when compared to the experience of a Baby Boomer or Gen X professional.

With the influx of Gen Z flooding into the workforce, we are seeing many similarities to the Traditionalists viewpoint. Gen Z watched the Millennials go into student debt in order to obtain an education because it was ingrained in them by their Gen X parents. Gen Z is realizing how trade schools are more cost beneficial; less money, less time in school, and higher pay up front. Gen Z is also shaped by watching Millennials struggle to buy homes with the rising costs of housing. With that, Gen Z is more interested in saving for their future and being more involved in financial investing and understanding financial benefits. They are looking at companies to provide stability instead of moving from job to job. While Millennials look up to celebrities, athletes, and politicians, Gen Z admire active participants in their lives such as their parents or mentors.

This is just a small snippet of how each generation effects the next one. We often blame the younger generations for their way of thinking, work values, communication, etc. but what many do not realize is that they are a product of how their generation was shaped by their upbringing. When we say things like, "what is wrong with kids today?" we should look at our own reflections. But not all is lost. We can fix this and learn to bridge the gap between each generation.

Bridging the Gaps

I was once told a story by a supervisor who had a Baby Boomer and Millennial working for him. No matter how hard he tried, he couldn't get them to work together. Until one day, the problem seemed to solve itself. He asked them what happened to bring them together. Their simple answer was "fishing." He was confused as to how fishing had helped their working relationship. One day, the Millennial overheard the Boomer talking about his love of fishing. It turns out, the Millennial also loved fishing. In no time, they were talking. But it didn't stop there. They began fishing together after hours. That led to a better working relationship and open communication. It can be something as simple as fishing. With one small commonality, a person stops being a stranger and becomes an ally. It is all about developing relationships.

More time is spent with coworkers than with families. When we focus on building a foundation with our coworkers, we understand that we are not so different from one another after all. We all have values, beliefs, work ethics, hopes, dreams, and common goals. If one can understand that everyone has a different perspective, that person can begin to realize it does not make one perspective superior. We all view the world through a different lens. Just because we listen to different music while working does not mean that one generation has worse work ethic than another. Our expectations shouldn't be placed on others just because it's the way we "see" things. Taking the time to understand why someone sees something the way they do can really bridge the gap in teamwork and communication. One does not need to change themselves to understand a different perspective. There are people who will not budge and to that I say this: you can only control yourself. You cannot control others. You cannot control how they react or see things, but you can control your reaction to the challenges faced by differences of values.

What else can we do?

- **Acknowledge differences when they arise.** It's important to talk about generational differences. Problems can't be solved if they go unacknowledged.
- **Identify "sticking points."** Sticking points are where generational differences tend to emerge, particularly around the use of technology, communication, feedback, time manage-

ment, work ethic, expectations, work-life balance, and how people prefer to be managed.

- **Appreciate commonalities among the team.** It's easier to focus on what is different than what is common. Take time to understand the common ground and the positives that each team member brings to the table in order to create mutual purpose.
- **Collaborate.** As a team, it is important to collaborate and agree on what the "end" result will be.
- **Maximize the strengths that each generation carries.** Learn your team so as to best know where to put them to excel. It's not a one-size-fits-all in the workplace. Knowing where best to place team members according to their strengths can help alleviate some frustrations and increase productivity. A team member who feels valued for what they bring to the table will naturally step up and contribute, feeling proud and accomplished, and all because they were "seen" for who they are and not how they're "expected" to be [4][5].

In the case of conflict, here are some questions to consider:

> "Is my reaction going to foster teamwork, understanding, and communication?"
>
> "Is it going to create division, drama, and miscommunication with my coworker and possibly the team?"
>
> "Is being right in the moment worth damaging the working relationship that I've worked hard to build with this person?"

The answers to these questions are up to you. We all have a part to play in creating a cohesive work environment. Consider:

> "What steps are you going to make in understanding that generational differences are all about perspective?"
>
> "How will you be part of the solution and not the problem? "
>
> And lastly, "what will you contribute to assisting in bridging the gap between generations?"

Further Readings

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About the Author

Tawnya Coulter is a civilian Instructor, Coach, and Scheduler for the 309th Software Engineering Group in the United States Air Force. Tawnya received her Master of Science degree through Lubbock Christian University, Lubbock Texas, majoring in Human Services. She received her Bachelor of Science degree through American Inter-Continental University, online, majoring in Criminal Justice. Tawnya facilitates emotional intelligence workshops such as 4-Generations, Myers-Briggs, 4-Lenses, and many other topics. She enjoys being an instructor and helping others develop and reach their goals.

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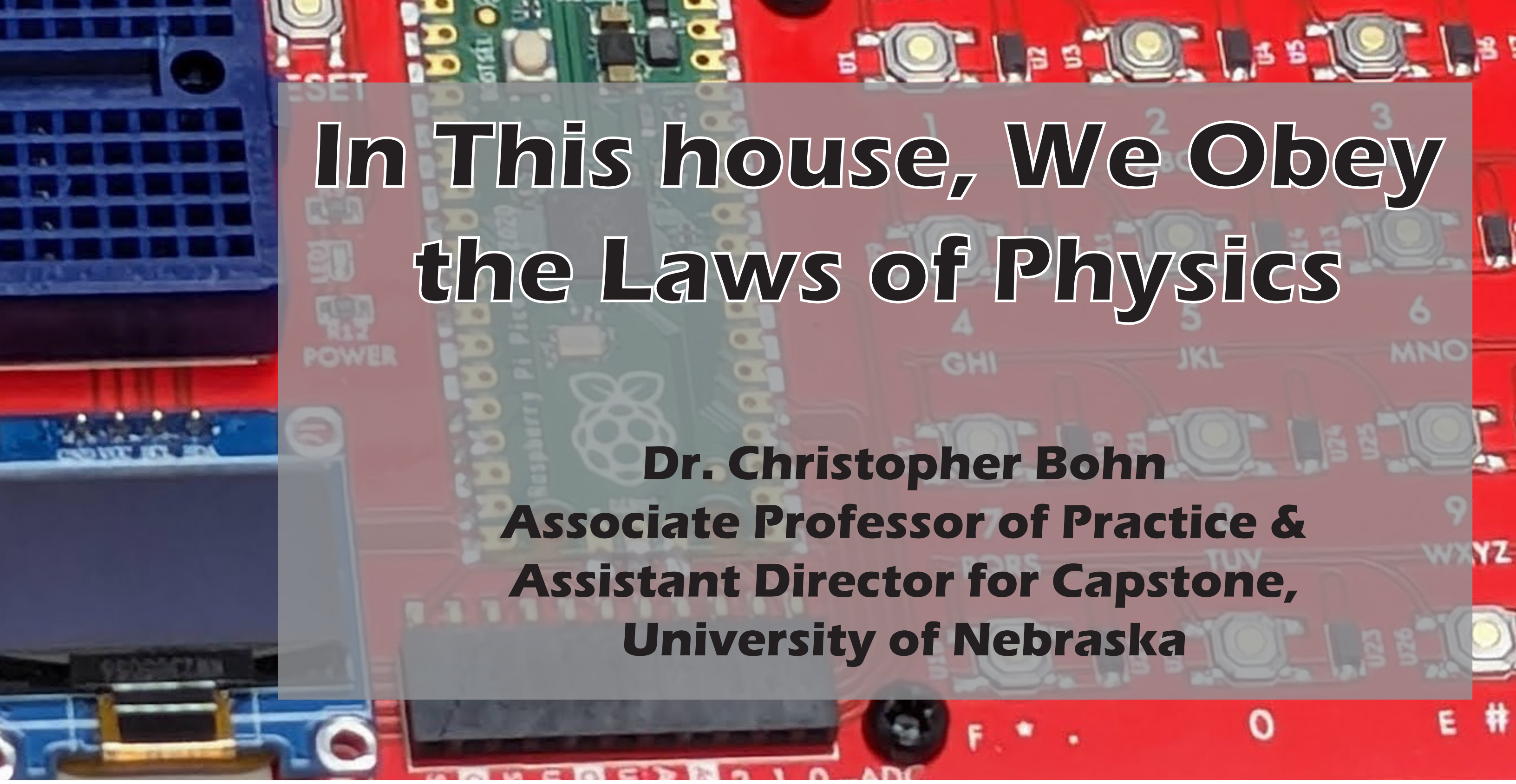
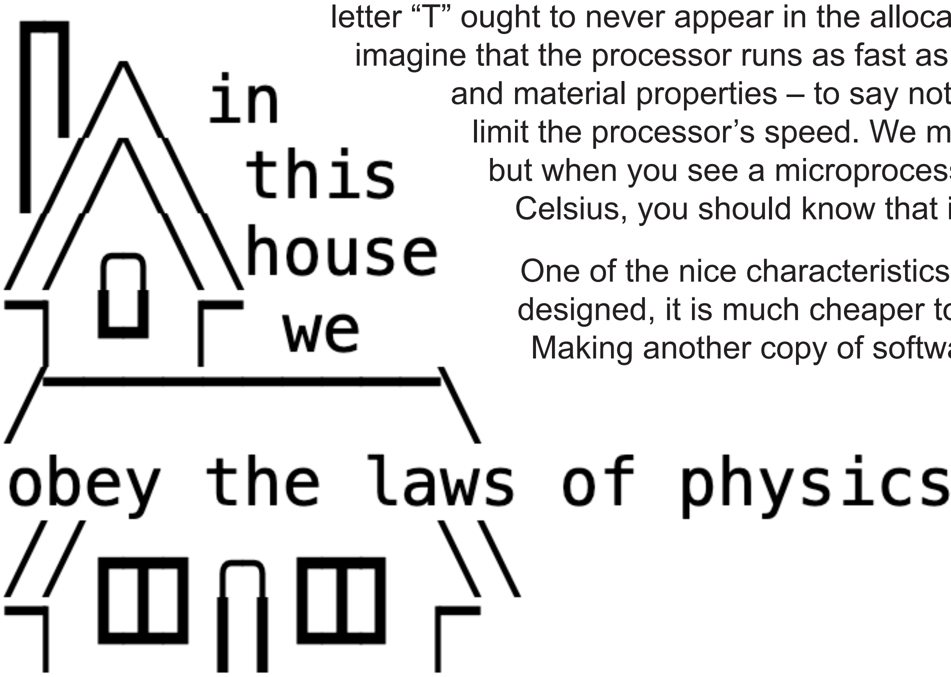


In This house, We Obey the Laws of Physics

Dr. Christopher Bohn
Associate Professor of Practice & Assistant Director for Capstone, University of Nebraska

When I teach a software engineering course, I'll often note that we are not bound by the laws of physics <insert maniacal laughter>, that our creations are limited only by our imagination <insert wild maniacal laughter>, that we can design software of unimaginable complexity – and that is why it is important to engineer our software. When I teach a computer organization course, my students discover that while a software design in the abstract might be unconstrained by real-world considerations, the laws of physics and other practical issues tend to assert themselves on actual computers.

Edsger Dijkstra famously said that computer science is no more about computers than astronomy is about telescopes. Yet, the practice of astronomy relies heavily upon telescopes, and practical computing depends just as heavily upon computers. A great deal of design has gone into providing a simple programming model, but the abstractions only carry you so far. It's nice to assume unlimited memory that can be accessed instantaneously, but as our system administrator noted after he rescued the server from a runaway student program, when looking at a list of running processes, the letter "T" ought to never appear in the allocated memory column. It's pleasing to imagine that the processor runs as fast as we need it to, but electromagnetics and material properties – to say nothing of more fundamental physics – limit the processor's speed. We might assume that ints are integers, but when you see a microprocessor reporting its temperature as -125° Celsius, you should know that it is very hot indeed.



One of the nice characteristics of software is that after it has been designed, it is much cheaper to manufacture than hardware. Making another copy of software costs only time, electricity, and the storage medium, whereas making another copy of hardware incurs not only the cost of the components but also the costs associated with the complexity of assembling the hardware. Combined with the perceived malleability of software, and we find ourselves solving hardware problems with software. Do you have a problem with switch bounce? You could introduce a simple RC low-pass filter, or you could filter-out the bounces in software. Do you want to control the temperature in a room? You could manufacture a thermostat using a bimetallic strip, or you could attach a thermistor to a microcontroller. Does your telescope's mirror have an aberration? You could grind a new mirror, or you could use software to post-process the images.

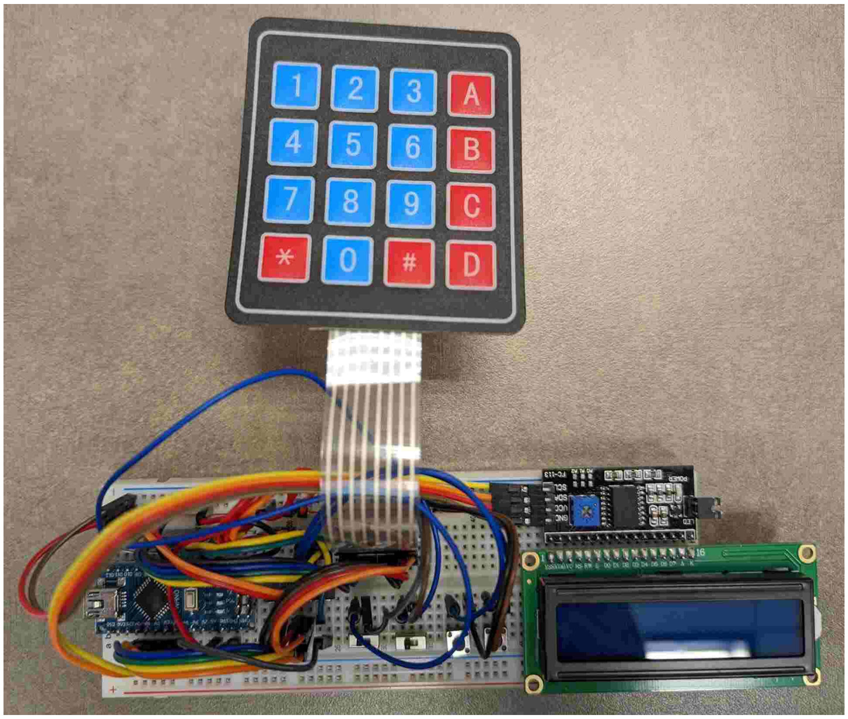


Figure 1. *A microcontroller circuit kit for student use.*

For as much as this issue is about the software/hardware gap, designing hardware and designing software require many of the same skillsets and differ only in the particulars. Even the pitfalls are similar. In my computer organization course, students need to assemble a small microcontroller circuit to use in a few of the lab assignments. The library that supports these assignments also has test routines to help students check their progress when assembling the kit. Inevitably, when students start on these assignments, a small handful discover that the outputs from a logic gate integrated circuit aren't what they should be. Sometimes the problem is miswiring; sometimes the problem is that the IC was inserted backwards; sometimes the problem is that the student inadvertently folded some of the pins when inserting the IC. In each of these cases, the output from the test routines showed that the IC wasn't providing the expected output, but the students didn't notice. This tendency to not pay attention to the details of the test routines' output is essentially the same tendency not to pay attention to the details of error messages or to ignore compiler warnings.

One semester, a student who was having difficulty assembling the kit noted, "If I wanted to worry about hardware, I wouldn't have majored in software engineering." But a software engineer who understands the hardware – and a computer engineer who understands the software – is very well equipped to design the best system for the job.

By the way, in case you're curious, I recently removed the logic gate IC from the assignments' microcontroller circuit by moving its functionality into the supporting library – I solved the hardware problem with software.

About the Author

A 24-year Air Force veteran, Christopher Bohn is an Associate Professor of Practice and the Assistant Director for Capstone of the University of Nebraska's School of Computing. He holds a bachelor's degree in electrical engineering from Purdue University, a master's degree in computer engineering from AFIT, and a doctorate from The Ohio State University. Dr. Bohn is the author of Programming at the Hardware/Software Interface, published by Great River Learning.

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