The Optimality of Bayes’ Theorem

By Tan Bui-Thi~n

Inverse problems are pervasive in scientific discovery and decision-making for complex, natural, engineered, and social systems. They are perhaps the most popular mathematical approach for enabling predictive scientific simulations that integrate observational/experimental data, mathematical models, and prior knowledge. While indirect data provide valuable information about unknown parameters and the physical problem itself, such data are typically limited and therefore unable to sufficiently infer the parameters. Conversely, the prior encodes a priori knowledge about the parameters and its bias is thus unavoidable.

All the many frameworks that facilitate uncertainty quantification in inverse solutions, the Bayesian paradigm is perhaps the most popular.1 The Bayesian approach combines prior knowledge (via prior distribution of the parameters) with observational data (via the likelihood) to produce the posterior probability distribution as the inverse solution. The following two-part question hence arises: Is this method of using observed information from data the best way to update the prior distribution? If so, in what sense? Answering these queries yields insight into Bayes’ theorem and brings to light meaningful interpretations that are otherwise hidden.

Here we value three different perspectives—two from information theory and one from the duality of variational inference—to show that Bayes’ theorem is in fact an optimal way to blend prior and observational information. To that end, let us use a specific example to denote the unknown parameter of interest, $\pi_{\text{post}}(m)$ for the prior density (or distribution), $\pi_{\text{obs}}(d|m)$ for the likelihood of $m$ given observable data $d$, and $\pi_{\text{true}}(m)$ for the parameter space of all possible $m$. The Bayesian inference framework presumably knows that according to conditional probability (Bayes’ formula—the sole result of Bayes’ theorem)—reads

$$
\pi_{\text{post}}(m|d) = \frac{\pi_{\text{prior}}(m) \pi_{\text{obs}}(d|m)}{\pi_{\text{true}}(d)}.
$$

A Google search for “Bayes’ theorem” returns 7,510,000 results.

### Space Exploration and Data Science

By Simon Mak and C.F. Jeff Wu

In his famous 1962 address at Rice University about U.S. space efforts to reach the moon, President John F. Kennedy declared that “the exploration of space will go ahead...and it is one of the great adventures of all time.” This adventure has become even more of a reality in recent years, as modern breakthroughs in mathematical modeling, scientific computing, and data science have inspired numerous pioneering achievements that were only dreams in the past.

A crucial part of space exploration is the design and development of high-performance rocket propulsion systems, and a central component of such systems is the rocket injector. This device enables the intermixing of fuel and oxidizer prior to combustion; Figure 1 displays a schematic of a simple swirl injector [1, 2, 6, 10]. Liquid oxygen is injected into a gaseous fuel environment via the injector slots on the left, then swirled along the injector wall and propelled out for combustion. The design space consists of $p=5$ parameters: injector length $L$, injector radius $R_i$, slot width $\delta$, tangential inlet angle $\theta$, and the distance between the inlet and the headend $L_h$ (one can easily extend the methods that we propose for more complex design settings with additional parameters). The goal is to identify parameter designs that ensure good mixing of fuel and oxidizer, which translates to a fuel-efficient and robust combustion performance.

In order to explore potential injector designs, engineers must conduct experiments over the desired parameter space. Traditional physical experiments are prohibitively expensive due to high prototyping costs and the harsh requirements of operating conditions [4]. Because these experiments rely on optical diagnostics for measurements, they offer minimal insight into the underlying physicochemical mechanisms [9]. Due to recent advances in scientific modeling, numerical simulations are becoming a reliable alternative to physical tests. These so-called computer experiments can provide more salient features of the flow and combustion dynamics within the injector [7]. They also allow for significant savings in prototyping and experimental costs.

To reliably capture the rich physics within the turbulent flow, a sophisticated multiphysics computational fluid dynamics (CFD) model is necessary for simulation purposes. We begin with the well-known Navier-Stokes equations, which express the conservation of mass and momentum for Newtonian fluids. Then we model thermo-dynamic properties via the Soave-Redlich-Kwong equation of state, which correlates fluid pressure, temperature, and density under high-pressure conditions. The large eddy simulation (LES) framework achieves turbulence closure. Figure 2 depicts instantaneous snapshots of the simulated temperature and density flows of an injector design. Figure courtesy of [10].

### References

1. A Google search for “Bayes’ theorem” returns 7,510,000 results.

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**Figure 1.** Schematic of the considered simplex swirl injector. Figure courtesy of [10].

**Figure 2.** Instantaneous snapshots of the simulated temperature and density flows of an injector design. Figure courtesy of [10].

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**Society for Industrial and Applied Mathematics**

1. **Volume 54**/ Issue 6
2. **July/August 2021**
6 Celesteing the DOE’s Office of Advanced Scientific Computing Research The Advanced Scientific Computing Research (ASCR) program has helped to shape the entire discipline of computational science through its review of previous tangents, current issues, and potential future concerns for the field (see ASCR 40: Highlights and Impacts of ASCR’s Programs).

7 Incorporating Ethical Discussions in the Mathematics Classroom While the mathematics community is well versed in the ethics of scholarship, many scientists’ professional training does not include the ethical applications of their work. Joe Skufca shares some tested resources and encourages the incorporation of ethics-based questions and materials into existing classes or seminars.

9 A New IEEE 754 Standard for Floating-Point Arithmetic in an Ever-Changing World James Demmel and Jordan Reddy explore the 2019 version of the Institute of Electrical and Electronics Engineers (IEEE) 754 Standard for Floating-Point Arithmetic, which provides new capabilities for reliable scientific computing, fixes bugs, and clarifies exceptional cases in operations and predicates.

10 SIAM Advocates for Research Growth as Biden Administration Releases Funding Request At a time when both Congress and in Washington, D.C., mean new priorities for the federal government, this report applies math and computing science. Elinor Perlmutter discusses the role that the SIAM Committee on Science Policy and addresses the Biden administration’s fiscal 2022 budget request.

11 Panel Discussion at CSE21 Offers Advice to Mid-Career Mathematicians The mid-career point is an exciting time for applied mathematicians. During a panel discussion at the 2021 SIAM Conference on Computational Science and Engineering, Hans De Sterck, Katherine Evans, Sarah Knepper, Damian Rouson, and Miyaya Tomkin spoke candidly about their experiences in both academia and industry.

Bayes’ Theorem

Continued from page 1

where \(\sum_{m}^{\cdot}\) denotes the expectation under the prior distribution. Bayes’ formula (1) provides a simple formula for the posterior as the product of the prior and likelihood. Indeed, so simple that deep insights are perhaps neither necessary nor possible. In fact, most researchers likely never wonder about this simple framework. This is so effective for many statistical inverse problems in engineering and the sciences. Calculating Bayes’ theorem tells us that if an optimizer for some objective function exists, it has to satisfy the first-order optimality condition (equation) that indicates that the first variation of the objective function at the optimal must vanish. The equation form of Bayes’ formula (1) triggers our curiosity and prompts us to wonder whether Bayes’s formula is the first-order optimality condition of some objective function. To approach this question, we note that the prior encodes our prior knowledge/belief before we see the data. By a view of information theory, we should elicit the prior so that it is consistent with the updated distribution \(p(m)\) to be found as small as possible. That is, if we believe that our prior is meaningful, the information that we gain from the data in \(p(m)\) should not be significant. The relative loss or gain between two probability densities is precisely captured by the relative entropy.–also known as the Kullback-Leibler (KL) divergence:[3] \(D_{KL}(p(m)||\rho\rhoπ)\). When the updated distribution \(p(m)\) is identical to the prior \(\rho\rhoπ\), the KL divergence is zero—the prior is perfect. But when \(p(m)\) deviates from the prior \(\rho\rhoπ\)—e.g., when the data provides additional information or strengthens information in the prior—the KL divergence is positive.

Since the observational data \(d\) is the other piece of information in the posterior’s construction, we wish to match the data as well as possible while avoiding overfitting. One way to do so is to look for \(p(m)\) that minimizes \(-\log(p(m)|d))\), which is a generalization of mean squared error (MSE) that comes from using the updated distribution to predict \(p(m)\).

At this point, we see that a competition exists between the prior knowledge and the information from the data in terms of constructing the updated distribution. On the one hand, the updated distribution should be close to the prior if we believe that the prior is the best within our subjective elicitation. On the other hand, the updated distribution should be constructed in such a way that the data is matched well under that distribution. We argue that the optimal updated distribution should compromise these two sources of information so that it captures as much of the limited information from the data as possible while also reemphasizing the prior. We can construct such a distribution by simultaneously minimizing the KL divergence and MSE (see Figure 1). The beauty here is that the optimization problem (2) is convex, its first-order optimality condition is precisely Bayes’ formula (1), and its unique updated distribution is exactly Bayes’ posterior \(p(m|d))\).

We can also achieve Bayes’ posterior by applying Bayes’ formula (1) from an information conservation principle [5]. In this approach, we divide the information—namely the updated distribution \(p(m|d))\)—into the input information \(\log(p(m))\) and \(\log(p(m)|d))\), and the output information \(\log(p(m))\) and \(\log(p(m)|d))\), that is provided by the updated distribution \(p(m|d))\). The optimal updated distribution is the one that minimizes the difference between the output and input information — it is exactly Bayes’ posterior \(p(m|d))\), at which the difference is zero. [5] In other words, Bayes’ posterior is the unique distribution that satisfies the information conservation principle (see Figure 2 for a demonstration).

We thus conclude that the positivity of Bayes’ formula (1) is also apparent from a duality formulation of variational inference [4]. Under mild conditions on \(p(m|d))\), the large class of functions \(\log(p(m))\), the following inequality holds true:

\[
-\log(p(m|d)) \leq \int_{\mathbb{R}} \log(p(m)) \, dm + \int_{\mathbb{R}} d\rho \log(p(m)).
\]

The equality occurs when the right-hand side of the formula attains its minimum and the data \(d\) (in the minimization of \(\log(p(m))\)). In this case, the right-hand side is exactly the objective functional (2). The objective functional’s minimum provides the evidence (the left-hand side of the formula); this is achieved only at Bayes’ posterior (see Figure 1).

Bayes’ posterior minimizes the sum of information gain and mean squared error (MSE), and is the only distribution that balances information gain + MSE with the evidence. Figure courtesy of Hai Nguyen.

References

Three-Part Panel Series at CSE21 Explores Equity, Diversity, and Inclusion in the Workforce

By Lina Sorg

The last several years have seen increased attention to issues of equity, diversity, and inclusion (EDI) in applied mathematics and computational science. Nevertheless, women, persons with disabilities, and African Americans, Hispanics and Latinos, and American Indians and Alaska Natives persons with disabilities are underrepresented in science and engineering fields across the U.S.1 In response, organizations are taking active steps to support these communities in the workforce, understand the unique challenges they face, and engage in direct conversation to invoive proactive change.

The 2021 SIAM Conference on Computational Science and Engineering (CSE21)2, which took place virtually earlier this year, featured a three-part panel that addressed EDI-related career challenges. The seven panelists—who have experience in academia, industry, and national laboratories—were divided into two groups. Members of the first group shared their personal experiences as minorities in CSE, while those in the second detailed the ways in which their respective institutions are working to foster a more diverse culture. A live discussion with all panelists followed both sessions. The second group included Mary Ann Lenski of the Sustainable Horizons Institute served as the moderator, and Ron Backstrom of Occidental College presented for EDI delivered the opening remarks.

Stories from Underrepresented Members of the CSE Community

Sally Ellingson of the University of Kentucky, Derek Jones of Lawrence Livermore National Laboratory (LLNL), and Bonita Saunders of the National Institute of Standards and Technology (NIST)—also a member of SIAM’s Vice President for Trustee—served on the first panel. Ellingson began with some background about herself. After earning dual undergraduate degrees in computer science and mathematics as a first-generation college student at the Florida Institute of Technology, Ellingson determined that she wanted to pursue further education. While working an office job after graduation, Ellingson learned about and completed a monetary offer for a fellowship. As a single mother, she decided to leave home with her daughter, move away from her support system, and attend graduate school. As she said, “I actually did not tell anyone in the program that I had a kid and was a single parent. I had nagged people that would find out and I would lose my fellowship. I felt like I had to go and prove myself a bit before I was comfortable talking about it, but of course I had lots of support once I did.”

Jones grew up in rural Kentucky and had limited access to science, technology, engineering, and mathematics (STEM) outreach during his youth. He was one of only a few Black students at his school, and recalls passing through textbooks and wondering why none of the computer scientists or mathematicians looked like him. But when he encountered people from other backgrounds while earning his undergraduate degree at the University of Kentucky—“I met Ellingson, when she was under her wing”—they exposed him to a number of inspiring research projects. Though the work is required for her PhD program, Ellingson received a competitive monetary offer to attend graduate school to study mathematics. It was not until she enrolled at the University of Kentucky for a master’s degree—and was automatically admitted to the Ph.D. program because she was a promising student—that Saunders began to feel recognized. “It would have been nice if someone had noticed me along the way and was encouraging.”

Ellingson echoed this sentiment and stressed the importance of engaged, encouraging mentors. When participating in an Integrative Graduate Education and Research Training (IGERT) program, she had a promising Ph.D. student who was especially dedicated to her mentees’ personal growth. He served as a role model, and Saunders noted that Ellingson received adequate support, stepped in to mitigate a diverse group project situation, and even helped her find a new babysitter. Jones then described the value of EDI programs, especially those that support funding and education. However, he noted that people of color often feel ashamed to receive money for school if it comes from a diversity scholarship or fellowship and is not purely merit based. “Everybody starts off at a different point in life, and we have plenty of data to say that people of color are definitely starting behind in that race,” he said. “It’s not mutually exclusive with academic abilities either. You can be diverse and also academically talented.”

Strategies for EDI at CSE-based Organizations

The second group of panelists included Scott Collins of Sandia National Laboratories, Lesia Cornwall, Young of Morgan State University (MSU), Bruce Hendrickson of LLNL, and Maria Klawe of Harvey Mudd College. Klawe has been a member of Harvey Mudd for 15 years, immediately began working to increase diversity within the student body upon her arrival. As a result, Harvey Mudd launched the President’s Scholars Program 3—a full-tuition scholarship for STEM students who come from backgrounds that are traditionally underrepresented at the college. Recipients are selected based on their leadership capabilities and ability to diversify the student body. Though the scholarship is not defined by race, most recipients are people of color. “It’s a huge impact and was relatively easy to do,” Klawe said. “We had to give up some tuition income, but the way we structured this as a leadership award means that those students who came had proportionately more impact.”

Ellingson repeated Saunders’ perspective is especially unique because she was born around the time of Brown v. Board of Education—“54 Supreme Court case where the justices unanimously ruled that racial segregation in U.S. public schools was unconstitutional—and even attended segregated schools until high school. She was keen to become the valedictorian of her integrated high school class and decided to focus on a common profession for Black women at the time. Though she completed the student teaching requirement, she was not able to graduate with her classmates. She was eager to attend graduate school to study mathematics. It was not until she enrolled at the University of Kentucky for a master’s degree—and was automatically admitted to the Ph.D. program because she was a promising student—that Saunders began to feel recognized. “It would have been nice if someone had noticed me along the way and was encouraging.”

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We employed the proper orthogonal decomposition (POD) to build this flow surrogate model [1, 2, 6, 10]. Researchers frequently employ the POD in experimental physics to decompose a turbulent flow into its component coherent structures. When $f_j(s)$ is the simulated flow at design setting $j$, where $s$ and $t$ are spatial and temporal variables—the POD yields the following decomposition:

$$f_j(s,t) = \sum_{k=1}^{n} \alpha_k(s) \varphi_k(s,t)$$

Here, $\varphi_k(s,t)$ is the time-averaged flow at design setting $k$, $\bar{\varphi}_k(s,t)$ is the set of coefficients, and $\alpha_k(s)$ is the set of time-varying coefficients. We can extract these spatiotemporal POD features via a singular value decomposition from the simulated flow snapshots.

To predict the flow $f_{\text{new}}(s,t)$ at a new design setting $\text{new}$, we first build two surrogate models: one for predicting the spatial modes $\bar{\varphi}_k(s,t)$ and one for predicting the time-varying coefficients $\alpha_k(s)$. We construct both models using Gaussian processes—a flexible Bayesian nonparametric predictive model—and train them with the extracted spatiotemporal POD features from simulated flows. We can utilize decision trees [10] and kernel smoothing methods [2] to further learn the changing physics over the parameter space, such as the boundary between jet and swirl injectors. Once we predict the spatial modes and time-varying coefficients, we can then reconstruct the corresponding flow prediction at the new design setting $\text{new}$ via the aforementioned decomposition.

Next, we examine the performance of this flow surrogate model on four test injector designs that were taken over a broad parameter space that contains the RD-1010 [8] and RD-170E [3] engines. We trained our model with both flow simulations at $n=30$ design settings from a sliced Latin hypercube design. Figure 3 presents the simulated flow snapshots from LES and predicted flow snapshots at different times. The predictions appear to successfully capture the large-scale features of the instantaneous flow, including the spray angle and the liquid film along the injector wall. The key advantage of this surrogate model is that it saves in simulation time. After simulating the initial $n=30$ training runs, we can train our model using 150 CPU hours. With the trained model, we can generate the flow prediction at a new design setting in approximately 30 CPU hours. This outcome provides significant computational savings in simulation time. The predictions appear to successfully capture the large-scale features of the instantaneous flow, including the spray angle and the liquid film along the injector wall. The key advantage of this surrogate model is that it saves in simulation time. After simulating the initial $n=30$ training runs, we can train our model using 150 CPU hours. With the trained model, we can generate the flow prediction at a new design setting in approximately 30 CPU hours. This outcome provides significant computational savings in simulation time.
High-Fidelity Simulation of Pathogen Propagation, Transmission, and Mitigation

By Rainald Löhner and Harbir Antil

The current COVID-19 pandemic has stimulated a renewed interest in pathogen propagation, transmission, and mitigation [1-3, 9]. In particular, the relative impact of transmission via "large droplets" versus "small droplets" or aerosols—combined with possible changes to existing heating, ventilation, and air conditioning (HVAC) systems, building footprints, pedestrian traffic management, and the installation of ultraviolet (UV) lights—has been the topic of thorough debate over the last year and a half. Natural and forced convection, the presence of moving pedestrians or objects, and accurate computation of droplets in airflow motion in the context of HVAC systems are all key requirements for the development of quantitative predictions of pathogen propagation, transmission, and mitigation in the built environment. Numerical techniques that satisfy these requirements have reached high degrees of sophistication and offer a built environment. Numerical techniques have received considerable attention in recent years, and researchers worldwide have carried out such work with both commercial and open-source software. Further cases with videos and descriptions are available online.1

Illustrative Examples

The following examples are by no means exhaustive or unique; the simulation of aerosol transmission via high-fidelity CFD techniques has received considerable attention in recent years, and researchers worldwide have carried out such work with both commercial and open-source software. Further cases with videos and descriptions are available online.1


1

Procedure

Measure

2m/4ft Distance

Large Droplets (splattering)

Small Droplets (cigarette smoke)

Person-Air

Person-Surface

Face Masks

Periodic Hand Cleaning

Plexiglass Shields

1-Way Person Traffic

2x Daily Cleaning

Nightly UV Cleaning

Maximize Fresh Air in HVAC

High UV Lamps in HVAC Ducts

HEPA Filters in HVAC Ducts

Upper Room UV Cleaning

Figure 1. Common procedures that mitigate the spread of pathogens. Green indicates effective measures, yellow designates somewhat effective measures, and red marks ineffective measures. Figure courtesy of the authors.

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Figure 2. Illustrative Examples

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1

1
Celebrating the DOE’s Office of Advanced Scientific Computing Research

A s part of its website, the mission of the Advanced Scientific Computing Research (ASCR) program is “to discover, develop, and deploy computational and networking technologies that support and model, simulate, and predict complex phenomena [that are] important to the Department of Energy [DOE].” ASCR’s primary dates back to John von Neumann’s advocacy for increased mathematics and computing activities during the Manhattan Project in the 1940s. Since its inception, ASCR and its predecessor organizations have played a pivotal role in shaping the entire discipline of computational science through investments in basic research, leadership-class facilities and computers, and workforce development. The program’s full history is available to support SIAM conferences, funding with SIAM in many ways throughout initiatives. ASCR has also intersected investments in basic research, leadership-predecessor organizations have played a 1940s. Since its inception, ASCR and its activity after the Manhattan Project in the networking capabilities to analyze, model, and science concepts, the creation and support capabilities, an array of innovative computer investments, including the development commitment drove nearly all of ASCR’s commitments to invest in the research and development (R&D) that is necessary to build and deploy energy-efficient systems with increased scientific capabilities. To do so, ASCR should keep investing in training and finding R&D—such as the PathForward program—and non-recurring engineering efforts that are associated with the acquisition of specific systems. through scientific computing centers at universities and national laboratories have tried to finance medium- to large-scale systems by charging users for access, this business model does not work for large-scale leadership systems. To advance the science of the art in HPC, the funds to purchase computers must be appropriated and system access should be free for users.

Lesson 1: A Compelling and Consistent Vision Can Drive Scientific Revolutions

ASCR and its predecessor organizations have established a consistent vision that is driven by the needs of the scientific community. This vision has been central to ASCR’s success and growth. It is important for the community to have a clear and consistent vision to guide its efforts. ASCR has embodied this vision in its strategic plan, which sets the direction for the department’s research and development efforts.

Lesson 2: Diverse Funding Models Are Required for Diverse and Impactful Outcomes

ASCR has enjoyed a wide variety of different funding models over the years. Short-term versus long-term, open-ended versus narrowly targeted, large collaborations versus single investigator, and so forth. These different funding models are important to the Department of Energy and are thus highly recommended for scientists, students, and science historians. The following text is an excerpt from chapter six of ASCR.pdf, entitled “Lesson Learned and Challenges of the Future.” It has been lightly edited for brevity and provides readers with a thorough overview of previous takeaways, current issues, and potential concerns regarding the future of applied mathematics and computational science.

Lesson 3: Workforce Investments Have Been Critical

When working on methodologies that universities that had not yet embraced, ASCR invested in workforce development initiatives. The Computational Science Graduate Fellowship is one example. ASCR has invested in research and software as well. Networking, high-performance computing (HPC) facilities, and HPC platform requests are under another funding model. This broad ecosystem of funding modalities has facilitated ASCR’s greatest successes.

Lesson 4: Partnerships Are Essential

Complex challenges require interdisciplinary teams that can work together to solve problems. This is especially true in the field of computational science. ASCR has collaborated with many partners, including universities, national laboratories, and industry. These partnerships have been crucial to the success of ASCR’s programs.

Lesson 5: Testbeds and Platform Access Funding Models Are Important

At points of architectural uncertainty, investing in small testbed systems is critical for understanding the strengths and weaknesses of different designs and making informed decisions about future directions. Larger “early access systems,” within users can try full-scale applications and adapt them for the next generation of machines, are particularly beneficial. These steps build confidence in the architecture and allow vendors to learn from early adopters. ASCR has also helped drive this approach by funding co-design centers on the path to exascale systems.

Lesson 6: New Roles for Computing to Advance Science

For many years, ASCR’s primary goal was to enable more rapid, detailed, and accurate simulations. But in recent decades, it has broadened its activities to support collaborative technologies and data-centric workflows that work together to generate novel insights. Moving forward, ASCR intends to nurture scientific ML with both fundamental research and investment. These new workflows will likely drive innovative thinking about the design and usage models for scientific computing.

Challenge 1: Technology Disruptions

The vast majority of supercomputer performance improvements have been in single- versus multi-core processors. These new workflows will likely drive innovative thinking about the design and usage models for scientific computing.

Challenge 2: Funding Balance

The rapid emergence of data science and machine learning (ML) in scientific workflows comprises another dramatic shift in the ASCR landscape. As we continue to push the limits of what supercomputers can do, researchers must find new ways to squeeze additional performance gains out of our machines. As AI and machine learning are increasingly utilized in scientific workflows, ASCR is partnering closely with ML researchers to explore new ways to integrate these technologies.

Challenge 3: Software Stewardship

An important issue that ASCR has been working to address is the need for a clear, consistent approach to software development. ASCR has developed a series of guidelines and best practices to help ensure that software developed under ASCR funding is of high quality and meets the needs of the scientific community.

Challenge 4: Broader Partnerships

The ASCR program is rightly regarded as a visionary success in building transformative, interdisciplinary partnerships across departments and agencies. These partnerships have enabled a clear vision and are thus highly recommended for scientists, students, and science historians.

Challenge 5: A Sought-after Workforce

Many of the challenges facing ASCR are related to the need for a skilled workforce in computational science. ASCR has emphasized the importance of attracting and retaining top talent, including graduate students, postdoctoral researchers, and computational scientists.

Challenge 6: New Roles for Computing to Advance Science

For many years, ASCR’s primary goal was to enable more rapid, detailed, and accurate simulations. But in recent decades, it has broadened its activities to support collaborative technologies and data-centric workflows that work together to generate novel insights. Moving forward, ASCR intends to nurture scientific ML with both fundamental research and investment. These new workflows will likely drive innovative thinking about the design and usage models for scientific computing.

Challenge 7: A Visionary Success

The ASCD program is rightly regarded as a visionary success in building transformative, interdisciplinary partnerships across departments and agencies. These partnerships have enabled a clear vision and are thus highly recommended for scientists, students, and science historians.
Incorporating Ethical Discussion in the Mathematics Classroom

By Joe Skufca

As mathematics, computational science, and data science fields become increasingly involved in situations with large societal impact, researchers in these areas are beginning to consider the role that sound ethical reasoning plays in their professions. Maurice Chiodo and Dennis Müller’s recent SIAM News article [1] about ethical questions in the context of COVID-19 modeling serves as an example. Our community is well versed in the ethics of scholarship, but our professional training likely did not address the ethical applications of our work. Here, I provide some tested resources to guide the incorporation of ethics-based questions and materials into existing classes or seminars.

Why Ethics Now?

Some fields (law or medicine, for example) have a formalized understanding of ethical standards, but mathematics does not. However, a number of professional organizations in the mathematical sciences have developed efforts for such standards. Efforts like the Cambridge University Ethics in Mathematics (EiM) Project[2]—and the two corresponding conferences in 2018 and 2019—serve as flagships standards and guidelines for ethical applications in a community-wide format. Of course, a simple “code of ethics” is not sufficient; ethical guidelines need to be tied into professional preparation. Many higher educational institutions recognize this necessity and are making ethics an explicit component of their curricula. Chiodo has been a continuing leader in this space for the last several years (2020).[3] His webpages at Cambridge contain a wealth of resources, and several of the

2 https://www.ethics.maths.cam.ac.uk
3 https://www.ethics.maths.cam.ac.uk/conference
4 https://www.demm.soton.ac.uk/~sx656

Pathogen Propagation

Continued from page 5

Sneezing in Subway Car

An obvious vector for pathogen transmission and spread is mass transport, as passengers are in extremely close proximity and airflow might result in considerable mixing. We therefore chose to analyze a sneeze in a subway car. The flow enters through two parallel slits in the ceiling and exits through the ceiling at both ends of the car. A detailed STL triangulation yielded the geometry [3], and the mesh had approximately 10^6 elements. As one might expect, the flow field is highly turbulent. Figure 2 (on page 5) illustrates the distribution of particles after a sneeze in the middle of the car by someone who is facing one end. The large red particles follow a ballistic path and fall to the ground. The air quickly stops the green particles of size d = 0.1 mm, which then sink slowly towards the floor in close proximity to the sneezing person and start to sneeze. The blue particles, which are even smaller, rise with the cloud of warmer air that is exhaled by the sneezing person and disperse much further at later times.

Sneezing in an Airplane Cabin

The air flow in airplane cabins has been a media focal point throughout the COVID-19 pandemic. Given that the air in planes is renewed much more often than in air-conditioned buildings—one exchange every two minutes versus one exchange 12-15 times per hour—people would likely assume that the risk of particles on the subway? The New York Times. Retrieved from https://www.nytimes.com/interactive/2020/08/10/new-york-times/new-york-times-pens-to-viral-particles-on-the-subway.html

References


Background Materials

For the Instructor: Bonnie Shulman’s “Is There Enough Poison Gas to Kill the City?” The Teaching of Ethics in Mathematics Classes [6] is a great starting point to help instructors design a frame- work that addresses ethical issues within mathematics curricula. This article is espe- cially valuable for faculty members who are still exploring whether they want to include ethics in their teaching.

Background Definitions: The Internet Encyclopedia of Philosophy’s article about ethics[7] provides an excellent summary of key terms in the field. I recommend equipp- ing your students with this standard terminology to inform their reading, ease discussions, and facilitate their consideration of multiple viewpoints (i.e., “That is the utilitarian argument, but how might your argument change if you take a deontic ethics perspective?”).

See Ethical Discussion on page 8


Raulino Löhner is head of the Center for Computational Fluid Dynamics at George Mason University. His areas of interest include numerical methods, solv- ers, grid generation, parallel computing, visualization, pre-processing, fluid-structure interactions, shape and process optimization, and computational crowd dynamics. He is also a member of the Center for Mathematics and Artificial Intelligence and a professor of mathematics at George Mason University. His areas of interest include optimization, calculus of variations, partial differential equations, numerical analysis, and scientific computing with applications in optimal control, shape optimization, free boundary problems, multi-scale reduction, inverse problems, and deep learning.

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Figure 4. Countercflow movement in a corridor of size 10.00 m × 2.00 m × 2.50 m. Solutions are at t = 1.000 sec. As before, the particles are colored according to the logarithm of the size of the particle. The very strong mixing effect is due to the large-scale turbulence that is generated by the moving pedestrians and their wake; this leads to a much higher transmission and transmis- sion of pathogens in such environments. Figure courtesy of the authors.


Image 404x520 to 738x772
Math in the World, from Mosquitoes to Gerrymanders

Ronald Ross’ analysis of mosquitoes and malaria led to a revolution in public health. Karl Pearson, Poincaré, Albert Einstein, and Andrey Markov, and concludes with Claude Shannon’s use of Markov chains to generate English text. Three chapters focus on AI, game playing, and the need for engineers to be programmed into an excursion into cryptography. A chapter on metric spaces ends up mostly examining the vector representation of words that are used in AI programs. Two chapters detail prediction and include a long discussion of the attempts to predict the course of COVID-19 in the United States. One chapter describes nearly geometric properties, such as centroids, while another delves into graph connectivity. Next comes a true masterpiece: Ellenberg’s chapter on “The Good Stuff.”

In the 1970s, a data scientist who engaged with mathematics—such as Ronald Ross or William Rowan Hamilton—might have been viewed as a ‘savant.’ Yet another chapter addresses symmetry, in the context of Poincaré and Emmy Noether. The final chapter explores embeddings into a calculoid of the Pythagorean theorem. There are 100 pages on AI—all mostly applied to language—but barely a reference to computational complexity, or solid modeling. As I mentioned, the text contains a lot of poetry, but the only work of art mentioned is Salvador Dalí’s Crucifixion: Corpus Hypercubus. The subtitle promises “the story of numbers and their power,” but the book spans over 400 pages. These are the only two reviews in the entire book that mention numbers and their power, as well as the importance of mathematics and its applications.

Ellenberg is an enviable, skillful writer. His explanations of technical material are simultaneously crystal clear, patient, complete, and entertaining. He is also an exceptional raconteur. Ellenberg’s many biographical and historical passages are skillfully integrated with the mathematical content, and he recounts them in a way that seems leisurely—as if he had all the time in the world. He makes even the most serious, the most curious story or fun anecdote—but never drags. His incursions of himself in the commentary are unfailingly tasteful — enough to make the narrative “enthralling, personal but never so much as to appear egotistical.”

Ellenberg is witty yet balanced. His account of the history of mathematics is clear-eyed but sympathetic. His descriptions of contentious topics—such as artifical intelligence and machine learning—are scrupulously fair. Ellenberg loves math but is fully aware of the limitations of the human mind and the role of creative intuition in the development of mathematics. He writes that “Mathematicians are prone to an imper-
A New IEEE 754 Standard for Floating-Point Arithmetic in an Ever-Changing World

By James Demmel and Jason Riedy

Since 1985, most computational scientists or anyone who uses floating-point (FP) arithmetic—have assumed that their computing platforms implement arithmetic operations according to the Institute of Electrical and Electronics Engineers (IEEE) 754 Standard for Floating-Point Arithmetic. This standard has made it much easier for researchers to write correct and portable code, since computers no longer round results or handle exceptions with the level of variability that existed among companies such as Digital Equipment Corporation, IBM, Cray, and Intel in 1985. Almost all differences become user-controlled under the standard, which also defined interchange formats to ease data porting between platforms and debugging efforts. The 2019 version of the IEEE standard provides new capabilities for reliable scientific computing, fixes bugs, and clarifies exceptional cases in operations and predicates.

The ever-changing world of technology motivates IEEE to periodically update all of its standards. One can only imagine an arithmetic standard that was (literally) set in stone and still uses base 60 instead of binary [6], as we do for keeping time. Beyond the few inevitable bug fixes, what changes in the world motivated updates in the most recent version of the IEEE 754 standard [4]? And what changes are still underway, unpredictable, and left to future versions of IEEE 754 or other arithmetic standards?

At a high level, one significant change is the burgeoning demand for reliability. Increasingly more groups now depend on computing to make important decisions.

One corresponding change in IEEE 754 is the addition of several new recommended operations: augmented addition, subtraction, and multiplication. Augmented addition takes two arguments—x and y—and returns two results: $h = x + y$ rounded in a new way, and $t = (x + y) - h$ exactly. Here, h stands for head and t stands for tail, since (barren exceptions) $h = x + y$ exactly; $h$ represents the leading bits of the sum (the head) and $t$ represents the trailing bits (the tail). The new rounding mode for this specific instruction rounds to the nearest FP number, breaking ties toward zero (as opposed to the nearest even number, which is the standard approach). This new instruction accelerates two high-level operations that both support reliability.

Augmented addition is also known as two sums, which programmers have long used to simulate double precision via single or quad precision via double [5]. When done appropriately, performing some operations in higher precision can significantly improve the error bounds and increase a calculation’s reliability. For example, Donald Knuth’s original algorithm for computing $h$ and $t$ costs six FP operations. A “fast” version requires three operations, assuming that $|x| \geq |y|$. Neither algorithm handles exceptional cases uniformly. But if one implements augmented addition in hardware, it requires only one or two instructions and provides both significant speedups and uniform exception definitions.

The new definition of augmented addition employs a novel (the binary) rounding mode—rounding halfway cases to the nearest result that is smaller in magnitude (i.e., towards zero)—to support a new use case: bitwise reproducible FP summation [1]. Parallel and vector processing is now ubiquitous, and codes can no longer assume a fixed summation order. Because FP addition is not associative, the final results can differ substantially between runs. A prior SIAM News article [1] discusses reproducibility and the recent international effort to achieve reproducible BFLOPS [2].

Another requirement for reliability is “consistent exception handling.” This concept’s definition may depend on context, but everyone agrees that computing the maximum or minimum of an array of numbers should yield the same result regardless of the argument order. Due to an oversight in the interaction of two sections in IEEE 754-2019, the definition of max and min did not have this property when one argument is a “signaling NaN.” These old definitions are deprecated in the 2019 standard, and new suggested operations guarantee that min and max are associative.

Ensuring that higher-level software behaves consistently and portably with exceptional values requires work that falls outside of standard IEEE 754 arithmetic. For example, the reference implementation of the Basic Linear Algebra Subprograms (BLAS) routine NRM2—which computes the 2-norm of vector v—may return NaN if two or more entries of v equal infinity and no NaN; some releases, like Intel’s Math Kernel Library, have repaired this issue. The reference implementation of the BLAS routine ISAMAX, which returns the index of the largest entry in terms of absolute value of input array x, returns ISAMAX([0, NaN, 2]) = 3 and ISAMAX([NaN, 0, 2]) = 1. Even more examples of this phenomenon exist in BLAS and other widely used software. Carefully defining “consistency”—and automating the identification and repair of such cases—is a work in progress.

An interesting challenge when defining consistency is that not all high-level languages agree on the definitions of basic operations. For example, multiplying two complex numbers $z_1 = |z_1| e^{i \alpha}$ and $z_2 = |z_2| e^{i \beta}$ yields $z_1 z_2 = |z_1 z_2| e^{i (\alpha + \beta)}$ in C, but Fortran and other languages with a complex data type use the alternate formula $z_1 z_2 = |z_1| |z_2| e^{i (\alpha - \beta)}$.

Nevertheless, this continues to be an objection to the title. Shape is a wonderful book; it is supereffortively well written and full of history, mathematics, and much else. Readers that range from professional mathematicians to people who disliked geometry in high school can enjoy and learn from the material.

References
2. Ernest Davis is a professor of computer science at New York University’s Courant Institute of Mathematical Sciences.
The Biden administration proposes major increases across NSF in both administration and research priority areas, as well as core programs. Overall, Research and Related Activities would grow by 18 percent from the FY 2021 estimated level, while Education and Human Resources would grow by 16 percent. The budget request recommends an increase of $110 million—or seven percent—for the Mathematical Sciences Directorate and an increase of 16 million—or 6.5 percent—for the Division of Mathematical Sciences. II. Enacted by Congress, the Office of Advanced Cyberinfrastructure in the Computer & Information Science & Engineering Directorate would see an increase of $22 million, or 9.4 percent. Across both the new Directorate for TIP and existing NSF directorates, NSF would continue to prioritize critical technologies like AI, QIS, wireless research, advanced manufacturing, and biotechnology while simultaneously adding additional priorities in climate change and clean energy research.

The Biden administration’s FY 2022 budget request would provide the DOE’s ASCR program office with $1.04 billion, a $25 million—or 2.5 percent—increase over the FY 2021 enacted level. As the demands of the Exascale Computing Project (ECP) continue to grow, the request for ASCR re-emphasizes foundational research to advance AI, QIS, and strategic computing initiatives that can continue to increase the competitive advantage of U.S. industry. It also includes a new focus to address climate change and develop a clean energy future. Within ASCR, the proposal would provide the Mathematical, Computational, and Computer Science Research account with a $33 million—or 12.7 percent—increase above the FY 2021 enacted level. This account includes $51 million—a five percent increase—for Applied Mathematics Research activities that conduct basic research in scalable algorithms and libraries; multiscale and multi-physics modeling, and integration of scientific modeling, data, and AI/machine learning with advanced computing to promote efficient data analysis. The request also recommends $86 million—or 12.9 percent—for Computational Partnerships, which primarily support the Scientific Discovery through Computational Science Graduate Fellowship program to fund additional fellows and expand participation from members of underrepresented groups. The budget request suggests funding basic research (6.1) at DOE at $2.5 billion, which is a 13 percent decrease from the FY 2021 enacted level. Overall, the DOE accounts (6.1-6.3) would see an increase of $110 million—or seven percent—for the Division of Materials Science and Engineering (6.1) at DOE at $2.3 billion, and $2.1 billion—or 6.5 percent—for the Division of Advanced Energy Systems (6.2) at DOE at $3.2 billion, which is a 13 percent increase from the FY 2021 enacted level. These increases are consistent with existing legislation to invest in research and development for national competitiveness.

The basic research proposal would increase funding for fundamental research at key science agencies across the federal government in support of emerging technology areas, such as quantum information science (QIS), artificial intelligence (AI), microelectronics, and advanced computing. The request includes $51 million—a five percent increase—for Applied Mathematics Research activities that conduct basic research in scalable algorithms and libraries; multiscale and multi-physics modeling, and integration of scientific modeling, data, and AI/machine learning with advanced computing to promote efficient data analysis. The request also recommends $86 million—or 12.9 percent—for Computational Partnerships, which primarily support the Scientific Discovery through Computational Science Graduate Fellowship program to fund additional fellows and expand participation from members of underrepresented groups. The budget request suggests funding basic research (6.1) at DOE at $2.5 billion, which is a 13 percent decrease from the FY 2021 enacted level. Overall, the DOE accounts (6.1-6.3) would see an increase of $110 million—or seven percent—for the Division of Materials Science and Engineering (6.1) at DOE at $2.3 billion, and $2.1 billion—or 6.5 percent—for the Division of Advanced Energy Systems (6.2) at DOE at $3.2 billion, which is a 13 percent increase from the FY 2021 enacted level. These increases are consistent with existing legislation to invest in research and development for national competitiveness.
Panel Discussion at CSE21 Offers Advice to Mid-Career Mathematicians

By Lina Sorg

The mid-career point is an exciting time for applied mathematicians, engineering, and mathematics (STEM). As experienced scientists settle into their professional roles, they face myriad challenges—ranging from driving essential research and education projects to driving changes at institutions such as the mid-career stage. Many mid-career scientists need to consider the ramifications of major workplace changes (including changing institutions at the mid-career stage). Tomman admitted that it is often quite difficult to keep up-to-date on STEM and advised participants to do so before reaching tenure. Academics should ideally start thinking about this type of transition in their early-career stage. Yet as researchers contemplate the opportunities and challenges that the mid-career point brings, they typically have less time to devote to each individual. Tokman initially had limited time to advise a graduate student, which was a challenging adjustment. Some institutions, which was a challenging adjustment. Some disasters have changed the history of mathematics. Some disasters have changed the history of mathematics. Some disasters have changed the history of mathematics. Some disasters have changed the history of mathematics. Some disasters have changed the history of mathematics.

IEEE 754 Standard

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machine learning (ML) applications. IEEE 754-2008 formalized binary16 (which has 10-bit precision plus one implicit bit, five bits of exponent, and one sign bit) with input from graphics hardware manufacturers. ML applications bring a wide exponent range to represent smaller probabilities, thus leading to formats like Google’s 10-bit16 (with 7±1 bits of precision, eight bits of exponent, and one sign bit). Other ML architectures implement different partitions of the 16 bits, and researchers are investigating the data movement patterns to accelerate both ML training and inference. IEEE 754 offers multiple options to increase the accuracy of calculations, but the options are limited in some cases.

The Euclidean distances between floating-point numbers are always greater than the Euclidean distances between floating-point numbers. The Euclidean distances between floating-point numbers are always greater than the Euclidean distances between floating-point numbers. The Euclidean distances between floating-point numbers are always greater than the Euclidean distances between floating-point numbers. The Euclidean distances between floating-point numbers are always greater than the Euclidean distances between floating-point numbers.

Our research does not necessarily have to be a bad thing if it helps individuals slow down and reevaluate their priorities. Knepper warned that stakes can feel higher at the mid-career point. Tokman acknowledged that this type of stagnation is more common in academia, who have particularly strongly early careers and are exhausted from work- ing towards tenure. Achieving tenure, mental health, and support vary widely within universities are typically less strong than in early-career settings. These factors— when combined with the temptation to take a bit—a can collectively cause burnout. To combat a prospective slump, Tomman advises team-building and brainstorming to best exercise the newfound flexibility of tenure.“Think about the opportunities that are there, it might be a bit more risky,” she said. “Being able to say no [is important] as well, because the amount of service requests is going to grow quite significantly.”

Evans reminded participants to take risks and that failure is always a part of the deal. “When you fail at something, it’s not the end of the world. It’s a way to learn and grow, and that’s part of the deal.” Coming to terms with the reality that failure is always a part of the deal, it’s good to be aware of what you’re going to have to do. “It’s not the end of the world. It’s a way to learn and grow, and that’s part of the deal.” Coming to terms with the reality that failure is always a part of the deal, it’s good to be aware of what you’re going to have to do. “It’s not the end of the world. It’s a way to learn and grow, and that’s part of the deal.” Coming to terms with the reality that failure is always a part of the deal, it’s good to be aware of what you’re going to have to do.

REFERENCES


James Dennel is a professor of mathematics and electrical engineering and the director of the scientific computing program at the University of California, Berkeley. He is the former chair of the Department of EECS at Stanford University and the founder and chief executive officer of the technical staff at Lucada Corporation, where he applies novel memory-centric architectures to data analysis problems. Both Dennel and Riedy are part of the 2019 IEEE Standard Committee.
Growing, Inspiring, and Diversifying Computational Science and Engineering through Broader Engagement

By Mary Ann Leung and Jasmine Pineda

The COVID-19 pandemic forced most of the world to reinvent collaborations due to circumstances that limited possibility for scientific discovery. Here, in this virtual format, we work together, the possibilities for scientific discovery are limitless. The Sustainable Horizons Institute1 of Broader Engagement (BE) program2 endeavors to widen these possibilities.

In 2015, Mary Ann Leung—president and founder of SHI—initiated BE@CSE to encourage student participation while she was serving on the CSE15 Organizing Committee.3 Since then, SHI has continued the program at each subsequent CSE meeting. BE offers financial support to members of underrepresented and disadvantaged groups, affording them full access to the rich technical material at CSE conferences. It also fosters a sense of community and belonging through mentorship, networking, and other activities that connect participants with each other. In addition, the program promotes inclusion by providing opportunities for scientists to volunteer, recruit, and learn.

The budget request would fund NIH at $46.5 billion of this proposed $6.5 billion—or 21 percent—above the FY 2021 enacted level. Much of this increase would help establish ARPA-H, the aforementioned entity within NIH that would use nontraditional research and development approaches to invest in highly innovative science that has the potential for transformative breakthroughs. It established ARPA-H could reshape the nation’s biomedical research enterprise. The Biden administration would also invest in new research priorities that are related to climate change’s impacts on human health, in addition to research that aims to eliminate health disparities—such as an emphasis on community and house voting margins. Congress will likely struggle to add appropriations to make up for diminished fiscal year 2022 (FY22). The Biden budget request would fund NIH at $52 billion in FY22, an increase of $9 billion—or 21 percent—above the FY 2021 enacted level. Much of this proposed increase would help establish ARPA-H, the aforementioned entity within NIH that would use nontraditional research and development approaches to invest in highly innovative science that has the potential for transformative breakthroughs. It established ARPA-H could reshape the nation’s biomedical research enterprise. The Biden administration would also invest in new research priorities that are related to climate change’s impacts on human health, in addition to research that aims to eliminate health disparities—such as an emphasis on community and house voting margins. Congress will likely struggle to add appropriations to make up for diminished

Over the last six years, BE participation has increased from just a handful of students in 2015 to more than 100 in 2021. In 2017, BE began organizing Guided Affinity Groups4 to strengthen participants’ connections with CSE, enhance conference experience, and provide psychosocial support. Volunteers with expertise in one or more of the conference’s technical themes lead daily group meetings to discuss sessions of interest, answer questions, and discuss recent talks. At the end of the week, each group presents its findings. BE@CSE continues to evolve and improve with each meeting.

The Army, Navy, and Air Force budget request would fund NIH at $46.5 billion of this proposed $6.5 billion—or 21 percent—above the FY 2021 enacted level. Much of this increase would help establish ARPA-H, the aforementioned entity within NIH that would use nontraditional research and development approaches to invest in highly innovative science that has the potential for transformative breakthroughs. It established ARPA-H could reshape the nation’s biomedical research enterprise. The Biden administration would also invest in new research priorities that are related to climate change’s impacts on human health, in addition to research that aims to eliminate health disparities—such as an emphasis on community and house voting margins. Congress will likely struggle to add appropriations to make up for diminished

Although technical topics were the primary focus of most conversations, leaders also extended their advice and professional networks to their groups. “My group had a wonderful leader who helped connect us with her network, gave us amazing advice and suggestions, and instilled so much confidence in us,” Vaid said. “She was incredible and has already made lasting impacts in our scientific lives.”

All BE groups presented their takeaways during the BE wrap-up session (see Figure 2). This year’s presentations included creative displays and heartfelt messages about the program’s positive impacts. Andy Salinger’s (Sandia National Laboratories) “Impacting Science for Impact on Society” group featured a show-and-tell presentation of ongoing simulations for many agencies that are related to climate, energy, and resilience—including the aforementioned entity within NIH that would use nontraditional research and development approaches to invest in highly innovative science that has the potential for transformative breakthroughs. It established ARPA-H could reshape the nation’s biomedical research enterprise. The Biden administration would also invest in new research priorities that are related to climate change’s impacts on human health, in addition to research that aims to eliminate health disparities—such as an emphasis on community and house voting margins. Congress will likely struggle to add appropriations to make up for diminished

Figure 2. Broader Engagement (BE) participants, members of the Organizing Committee, and staff from the Sustainable Horizons Institute celebrate during the BE wrap-up session at the 2021 SIAM Conference on Computational Science and Engineering, which took place in March. The BE program thanks everyone who participated in this year’s activities at CSE21 and looks forward to continued engagement with the SIAM community at future conferences. Mary Ann Leung is founder and president of the Sustainable Horizons Institute. Jasmine Pineda is a program assistant at the Sustainable Horizons Institute.

The FY 2022 budget request formally initiates the Congress’s consideration of appropriations for the FY 2022 appropriations process. However, the timing of passing final FY 2022 appropriations remains uncertain. The administration’s request for new funding for federal agencies beyond September 30—the end of FY 2021—will stay abreast of the FY 2022 appropriations cycle and its impact, advocate for strong funding for applied mathematics and computational science, and request extensions of expiring legislation, and keep members informed.

Eliana Prenn has been a government relations associate at Lewis-Burke Associates LLC.

1 https://shinstitute.org/conferences/cm-conference/cse21
2 https://shinstitute.org
3 https://shinstitute.org/siam-cse21-broader-engagement-program
4 https://shinstitute.org/guided-affinity-groups-for-be-cse
5 https://shinstitute.org/guided-affinity-groups-for-be-cse

Funding Request

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decrease; the administration instead prioritized scientific discovery and prototyping. This reflects DOD’s overall FY 2022 goal to deliver fieldable capabilities with diverse, quick access, and efficiency. The Army, Navy, and Air Force basic research accounts would respectively decrease by $79 million, $43 million, and $45 million from FY21, with the Navy’s cuts to near the enacted levels. Given these and other DOD cuts, the administration’s flat topline for defense research and development was a hedge against late start. Congress will likely struggle to add appropriations to make up for diminished