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Shifting the Classical-quantum Boundary: Insights From Pilot-wave Hydrodynamics

By John W.M. Bush

In the legal proceedings of a criminal case, the prosecution must prove their point "beyond a shadow of a doubt." In civil litigation, the burden of proof is much less stringent: the prosecution need only prove that a stated claim is "more likely than not." Let us proceed by litigating the completeness of quantum theory at the level of a civil rather than criminal case; thus, we seek to show that it is *more likely than not* that quantum theory is incomplete.

To do so, we emphasize three points:

(i) A newly discovered hydrodynamic pilot-wave system has provided classical analogs for some of the most beguiling quantum systems.

(ii) This hydrodynamic system is a macroscopic realization of the double-solution pilot-wave theory proposed by French physicist Louis de Broglie in the 1920s.

(iii) New classical pilot-wave models—inspired by pilot-wave hydrodynamics—are providing fresh insights into longstanding conceptual difficulties with the standard quantum formalism.

For context, geophysicist Alfred Wegener's 1912 theory of continental drift won over some of his contemporaries but was not widely accepted by the scientific community until 1962. Wegener could thus be said to have won the civil case but not the criminal case. Let us try to do likewise.

The field of pilot-wave hydrodynamics was pioneered by French physicists Yves Couder and Emmanuel Fort in 2005 [5], advanced by my group[1] at the Massachusetts Institute of Technology, and is currently under investigation in several research groups worldwide [2]. The list of established hydrodynamic quantum analogs (HQAs) is steadily growing and now includes single-particle diffraction and interference, quantized orbits, probabilistic tunneling, statistical projection effects in corrals, interaction-free measurement, spin lattices, Kapitza-Dirac diffraction, superradiance, Anderson localization, and static Bell violations [3, 4]. The evolution of their reception has been noteworthy. The first HQAs were generally met with derision: "*Of course one cannot analogize quantum systems with classical mechanics; quantum mechanics is nonlocal!*" As we continue to expand the list of HQAs, new challenges are presented: "*Okay, you've done A-Q, but*

[1] https://thales.mit.edu/bush/index.php/4801-2

See **Pilot-wave Hydrodynamics** on page 4

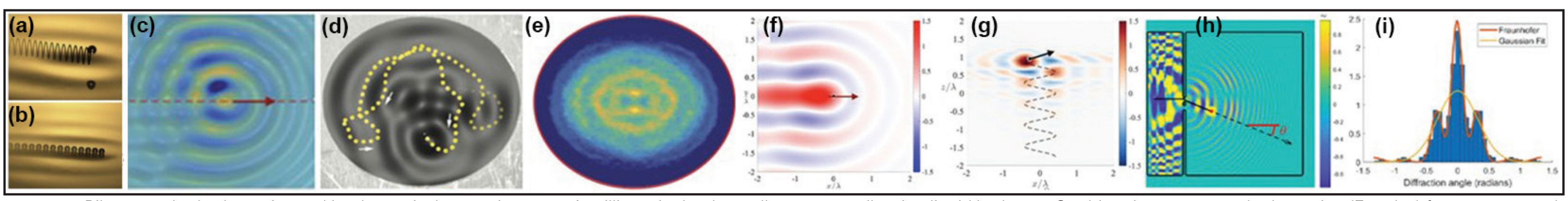

Figure 1. *Pilot-wave hydrodynamics and its theoretical extensions.* **1a.** *A millimetric droplet walks across a vibrating liquid bath.* **1b.** *Strobing the system at the bouncing (Faraday) frequency reveals the droplet gliding across the surface.* **1c.** *The pilot wave of the free walker (top is measured and bottom is computed).* **1d.** *A droplet explores an elliptical corral. Its trajectory (in yellow) is superposed on its instantaneous pilot-wave field.* **1e.** *The emergent statistical wave: the position histogram of the droplet.* **1f** *and* **1g.** *In our theoretical model of three-dimensional classical pilot-wave dynamics, a particle emits a spherically symmetric monochromatic wave field [12]. In response to its wave field, a stationary particle may destabilize into a dynamic state marked by rectilinear* **(f)** *or helical* **(g)** *motion. If the fast time scales associated with particle vibration and rotation are not resolved in the helical state, one would infer a particle with intrinsic angular momentum—i.e., classical "spin"—following the helix centerline.* **1h.** *A recent model of classical, relativistic pilot-wave dynamics captures a particle passing through a double-slit geometry [6].* **1i.** *The resulting Fraunhofer diffraction pattern is comparable to that arising in quantum mechanics. Figures 1a, 1b and 1c courtesy of [4], 1d and 1e courtesy of [3], 1f and 1g courtesy of [12], and 1h and 1i courtesy of [6].*

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Characterizations of Double Descent

By Manuchehr Aminian

Double descent is a machine learning (ML) phenomenon that pertains to an unexpected decline in test set errors during the creation of a sequence of increasingly overparameterized models. This behavior is vital to the success of modern generative models for image, video, and text because it allows them to generalize beyond their training data to seemingly new samples. Theorists are especially interested in double descent, as it seems to contradict conventional wisdom in applied mathematics and statistical learning. While the ML community often credits implicit regularization as the mechanism that enables overparameterized models, double descent can appear beyond this overparameterization in several ways.

Because researchers can suppress or manipulate double descent in numerical studies, the technique continues to inspire mathematical analysis. The Third Joint SIAM/CAIMS Annual Meetings[1] (AN25), which took place this summer in Montréal, Québec, Canada, featured a two-part minisymposium titled "Double Descent and Related Phenomena in Modern Statistical Learning."[2] The session addressed theoretical frameworks and experiments with both synthetic and real problems, as well as broader perspectives on this theme.

A Minimal Working Example

The simplest demonstration of double descent relates to a common topic in numerical analysis. Let us describe an existing numerical experiment [3] with an associated minimal working example in MATLAB (see Figure 1b). Specifically, we seek a polynomial to fit a set of n points $(x_i, y_i) \in \mathbb{R}^2$ in the sense of ordinary least squares; an optimal polynomial minimizes $\sum_{i=1}^{n}(p_k(x_i)-y_i)^2$, where $p_k(x)$ is a polynomial of degree k. The problem reduces to a linear system $A\theta = y$, and the "backslash" operator in MATLAB stably implements the solution $\theta^* = A^\dagger y$ for any compatible matrix A. What degree k should we choose? A polynomial of degree $n-1$ is sufficient in exact arithmetic, but it is sensitive to data perturbations like floating-point roundoff or measurement error. Even if the "law" that underlies the data is a low-degree polynomial, this sensitivity yields fitted polynomials with wild oscillations in the interior of the domain. Such an outcome explains the conventional wisdom to prescribe a polynomial degree $k \ll n$ rather than $k = n-1$, and certainly not $k > n$. Larger degree polynomials do not behave well with extrapolation—or even with interpolation on unseen data—when oscillations begin to appear.

Ignoring this conventional wisdom reveals double descent, where increasing k well past the *underparameterized* regime ($k < n$) results in a model that *generalizes* by regressing unseen data — as evidenced when the test set error returns to values that are comparable to those in the underparameterized regime. In Figure 1a, the training set error approaches $\varepsilon_{\text{mach}}$ at a predictable pace; at the same time, the test set error

[1] https://www.siam.org/conferences-events/past-event-archive/an25

[2] https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=84982

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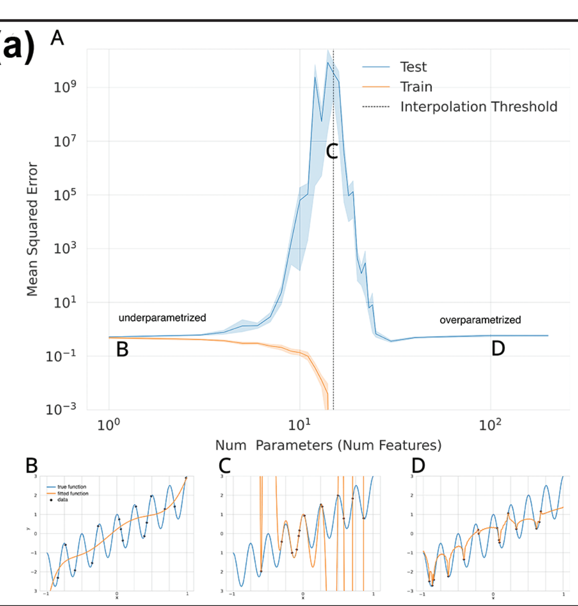
(a)



(b)

```
n=100; P=100;
x=linspace(-1,1,n)';
y=2*x + cos(25*x);

train=1:(n/2); test=(n/2+1):n;

% Build Legendre polynomial basis
L=ones(n,P); L(:,2)=x;
for k=3:P
    L(:,k)=(2*k-1)/k*x.*L(:,k-1) - (k-1)/k*L(:,k-2);
end

% Evaluate OLS solutions for increasing k
for k=1:P
    theta=L(train,1:k) \ y(train);
    residual=L(:,1:k)*theta - y;
    errors(k,:)=vecnorm(residual([test;train]), inf, 2);
end
loglog(errors)
```

Figure 1. *An example of the double descent phenomenon in polynomial regression.* **1a.** *As the polynomial degree and model size k increase, error on the training data (in orange) continues to decrease to $\varepsilon_{\text{mach}}$, while error on the test data (in blue) gets larger. The models pass the interpolation threshold and "generalize," and test error decreases to that of a low-degree polynomial.* **1b.** *A minimal implementation of this experiment in MATLAB. Figure 1a adapted from [4] and 1b courtesy of the author.*

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Obituary: Howard Elman

By Alison Ramage, David Silvester, and Andy Wathen

Howard Elman, a leading researcher in numerical linear algebra and trailblazer in computational mathematics, passed away on September 18, 2025, at the age of 71. He was an influential member of both SIAM and the applied math community at large, and his influence and wisdom will live on for years to come.

Howard was born in New York's Manhattan borough on February 21, 1954. He grew up in Queens, attended Stuyvesant High School, and remained in New York City for college, graduating from Columbia University with a B.A. in mathematics in 1975 and an M.A. in mathematics in 1977. Howard then went on to study computer science at Yale University, where he obtained an M.S. in 1979 and a Ph.D. in 1982 under the direction of Martin Schultz and Stanley Eisenstat. In his oft-cited thesis [1], Howard stated and proved the so-called "Elman bound" — a conception that guarantees the convergence of the generalized minimal residual method iteration for the solution of linear systems, as long as the numerical range of the coefficient matrix is contained in the right half of the complex plane.

Howard Elman, 1954-2025. Photo courtesy of the University of Maryland.

During his time at Yale, Howard was an integral part of a large and active research group that pioneered the development of fast iterative methods for the solution of sparse systems of linear equations. After he defended his thesis, he spent three additional years as a research associate at Yale before joining the faculty of the Department of Computer Science at the University of Maryland, College Park (UMD) in 1985. Howard remained at UMD for more than 40 years.

The U.S. National Science Foundation supported Howard's research of sparse matrix methods with a Presidential Young Investigator Award from 1989 to 1994. Since his professional interests straddled both computer science and mathematics, he also worked closely with colleagues in UMD's Department of Mathematics — notably Ivo Babuška and John Osborn. As a result of these collaborations, Howard's research focused increasingly on the design of efficient solvers for systems that arise from the finite element discretization of partial differential equations (PDEs).

A skilled administrator, Howard was particularly active in the University of Maryland Institute for Advanced Computer Studies.[1] In the later part of his career, he also served as director of UMD's Applied Mathematics Program. Howard was a particularly generous educator who willingly shared his time and knowledge with students and younger colleagues; throughout his tenure at UMD, he advised a plethora of graduate students with skill and patience. He likewise graciously extended this mentorship and assistance to many visiting scholars who were lucky enough to spend time with him in College Park.

Howard's research was very collaborative in nature, and he worked with many different people across the U.S. and internationally. Gene Golub was a longtime friend and supporter, and the two enjoyed a fruitful collaboration on parallel computing strategies and cyclic reduction techniques in the early 1990s. In fact, Howard spent part of his 1992-1993 sabbatical with Golub at Stanford University. He spent the remaining portion at the University of Manchester Institute of Science and Technology in the U.K. — a visit that kick-started another lasting partnership with David Silvester of Manchester and Andy Wathen of the University of Oxford that centered on solvers for PDE models of fluid flow. The trio's highly-cited monograph, *Finite Elements and Fast Iterative Solvers: With Applications in Incompressible Fluid Dynamics* [3], was first published in 2005; the widely-used Incompressible Flow and Iterative Solver Software package—with Silvester and Alison Ramage of the University of Strathclyde—followed soon after [2].

Other important relationships that built upon foundational perspectives from the aforementioned monograph include work with John Shadid and Ray Tuminaro of Sandia National Laboratories, which explored block multilevel preconditioners for large multiphysics simulations with fluids. Howard often joked that he "never got out of school;" indeed, he continued to expand his research interests in the new millennium to include topics like stochastic solvers and uncertainty quantification. His extensive background knowledge and experience with both linear algebra and PDEs put him in an ideal position to study these burgeoning areas of activity. Throughout all of his endeavors, Howard's perfectionism remained consistent; his papers are notable for their clarity of exposition and constructive strategies when developing technical results.

Beyond his own research projects, Howard played a significant leadership role within the wider applied mathematics community. His contributions to SIAM were invaluable and he was involved with many committees, including the Selection Committee for the James H. Wilkinson Prize in Numerical Analysis and Scientific Computing,[2] the Committee on Science Policy,[3] and the Financial Management Committee;[4] he served on this latter committee for 14 years, where his wise counsel and calm presence were much appreciated. In 2009, he became a SIAM Fellow.[5]

Howard's primary impact at SIAM, however, was through his editorial work and leadership in the area of publications. He sat on the Editorial Board of the *SIAM Journal on Scientific Computing*[6] for more than 25 years—including a six-year term as editor-in-chief—and served as Vice President for Publications from 2020 to 2025. In this latter position, Howard led SIAM's response to several key matters, helping to address the challenges of open-access publication and producing SIAM's first Editorial Policy on Artificial Intelligence[7] (where his wealth of experience as an editor was vital).

Outside the realm of publications, Howard's professional contributions extended to conferences. He spent over 30 years as a member of the Program Committee for the Copper Mountain Conference on Iterative Methods,[8] serving as chair for eight of those years. Howard's final major conference trip was to the 2024 SIAM Conference on Applied Linear Algebra,[9] which took place in Paris, France in May 2024. He very much enjoyed catching up with colleagues and friends at a three-part minisymposium on "New Directions in Iterative Methods and Applications,"[10] which we organized in honor of his 70th birthday.

Although he lived in Washington, D.C., and Maryland for many years, Howard remained a proud New Yorker throughout his life. He eagerly shared his love of its sport teams (primarily the Jets and Mets), music (notably, Simon and Garfunkel) and food; in fact, he insisted that New York was the only place to get a decent sandwich. Howard was also a fan of the Beatles and regularly played tennis with friends and acquaintances.

Howard is survived by his wife, Barbara Schwartz, and their children, Meredith and Andrew. We will all miss him.

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[2] Elman, H.C., Ramage, A., & Silvester, D.J. (2014). IFISS: A computational laboratory for investigating incompressible flow problems. *SIAM Rev., 56*(2), 261-273.

See **Howard Elman** *on page 3*

1 https://www.umiacs.umd.edu

2 https://www.siam.org/programs-initiatives/prizes-awards/major-prizes-lectures/james-h-wilkinson-prize-in-numerical-analysis-and-scientific-computing

3 https://www.siam.org/get-involved/connect-with-a-community/committees/committee-on-science-policy-csp

4 https://www.siam.org/get-involved/connect-with-a-community/committees/financial-management-committee-fmc

5 https://www.siam.org/programs-initiatives/prizes-awards/fellows-program

6 https://www.siam.org/publications/siam-journals/siam-journal-on-scientific-computing

7 https://epubs.siam.org/artificial-intelligence

8 https://grandmaster.colorado.edu/copper

9 https://www.siam.org/conferences-events/past-event-archive/la24

10 https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=78687

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Double Descent

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first increases, then—for sufficiently large $k > n$—is comparable to when $k \ll n$. The overparameterized polynomial provides some insight about the activity within this regime (see Figure 1a, on page 1).

How does this phenomenon occur? Can we control or suppress it? The presentations in the AN25 minisymposium offered a variety of perspectives through which we can understand and control the appearance of such peaks in the loss of a model, and describe and connect related phenomena.

Tunable Double Descent in Large-data, Large-parameter Limits

Rishi Sonthalia of Boston College considered the question of double descent from a probabilistic perspective. He analyzed a similar linear regression task for learning θ in the relationship $y = \theta^T x + \xi$, where $x \in \mathbb{R}^d$ is sampled $N(0, I)$ and ξ represents independent, normally distributed noise. While linear regression is a far cry from neural networks, Sonthalia's framework utilizes tools from random matrix theory to analyze the data matrix X and fitted parameters $\hat{\theta}$ as a function of d and the number of data samples n. Curiously, the generalization risk $\mathcal{R} = E[((\theta^* - \hat{\theta})^T x)^2]$ in the joint large-data, large-parameter limit $c = d/n$ is actually a piecewise function of c with a simple pole at $c = 1$. This is a model of the phenomenon, but it cannot explain the variety of real-world behavior.

To add an element of control to the situation, Sonthalia proposed two approaches to regulate the peak in empirical risk relative to c [2]. The first approach involves data that was sampled from a mixture of two Gaussian distributions: (i) an isotropic Gaussian, sampled with probability π, and (ii) a one-dimensional Gaussian, sampled from rank-one subspace $\text{span}(z)$ with probability $1 - \pi$. By following this design, Sonthalia finds a generalization risk

$$\mathcal{R} = \begin{cases} \dfrac{\pi c}{\pi - c}, & c < \pi, \\ \pi\left(\dfrac{\pi}{c - \pi} + C(d, z)\left(1 - \dfrac{\pi}{c}\right)\right), & c > \pi. \end{cases}$$

The risk asymptotes at value $c = \pi \leq 1$, which means that it will contradict the classical interpolation threshold of $c = 1$. As such, it can be made to appear arbitrarily early in the underparameterized regime.

Sonthalia's second approach implements a more practically relevant *regularized* least squares method with regularization parameter μ and a sophisticated design for data distribution, with multiple additional parameters to n, d, and $c = d/n$. While the full risk expression is quite complicated, $\mathcal{R}$ peaks at $c = 1/(1 + \mu^2)$ in a simple setting. Risk peaks at the interpolation threshold $c = 1$ when $\mu = 0$; when $\mu > 0$, however, Sonthalia can push this peak towards $c = 0$ (the underparameterized regime).

Ultimately, Sonthalia's analysis reveals that double descent can occur even in the underparameterized regime—and with regularization in the loss—and is disconnected from other plausible explanations, such as the operator norm of the estimator for θ.

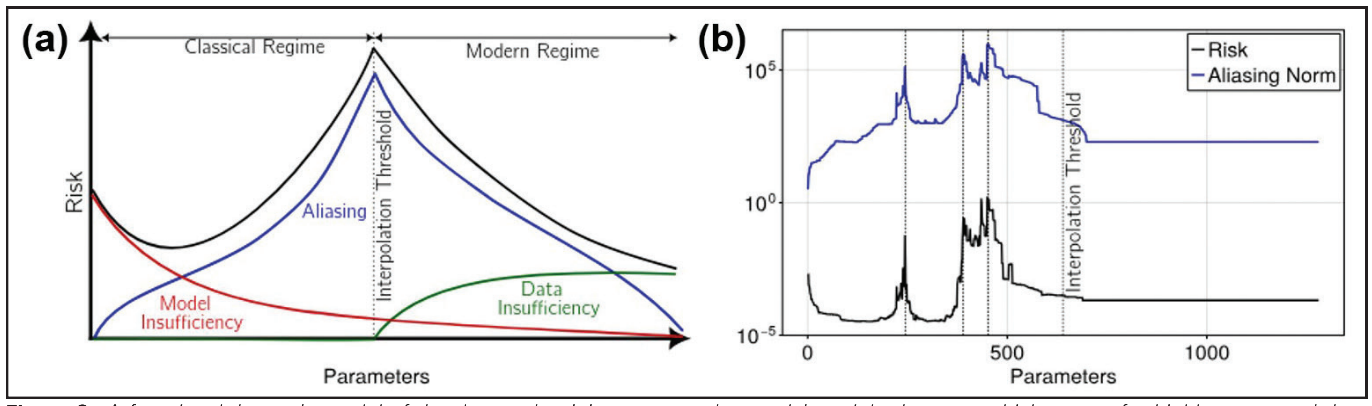

Figure 3. *A functional-theoretic model of the data and training process that explains triple descent, which occurs for highly structured data.* **3a.** *The decomposition of risk as a sum of three terms characterizes components of a classical double descent curve.* **3b.** *Numerical computations for the decomposition exhibit a triple descent (in black) during the training of a specialized model to predict the enthalpy when forming an alloy as a function of elemental composition and configuration. Calculations of the aliasing norm (in blue) associate with peaks in risk. Figure 3a courtesy of Mark Transtrum and 3b courtesy of Gus Hart.*

Double Descent in Training and Scale-time Equivalence

During his presentation, Akhilan Boopathy of Kuai identified specific scenarios wherein a "double descent in time" transpires during training and can be explained based on the concept of *scale-time equivalence*. A key observation pertains to the ability to observe and control double descent throughout the training process. Consider a binary classifier: a function $f : \mathbb{R}^n \to \{0,1\}$. For most binary classification tasks with "big" and "small" data, minor perturbations to the data do not significantly affect the resulting decision boundary — a concept that is key to the formulation of support vector machines.

However, Boopathy argues that the interpolation regime is sensitive to small perturbations with respect to directions of low variance in the data. Using this perspective, he broadens the sense of an interpolation threshold to include the moment when a model that is being trained first "discovers" all directions of variance in the data. This incidence may arise at the classical threshold $n = d$, but it can also occur elsewhere depending on the nature of the data and model.

Boopathy and his collaborator, Ila Fiete of the Massachusetts Institute of Technology, harness projectors to bridge the gaps between model size, trainable space, and directly controllable parameters [1]. They implement these ingredients in a toy model that is based on random subspaces. First, they train a model with n parameters whose outputs depend on subspace dimension r; here, p of the model parameters are controllable, with $r < p < n$. A linear projector K sends the original parameters $\beta \in \mathbb{R}^n$ to parameters $\alpha \in \mathbb{R}^r$, and the model is fit to discover β by trainable parameters $\theta \in \mathbb{R}^p$.

Boothpathy and Fiete demonstrated the formation of the following *projected gradient flow* problem for a smooth loss function L on α:

$$\frac{dA_t}{dt} = -\eta K K^T \nabla L(A_t),$$

$$A_0 = K\beta_0.$$

Here, the norm $\|\alpha_t - A_{pt}\|$—which depends on the joint quantity pt, among other terms—can be bounded. Researchers can thus relate the practically trainable α_T with r parameters to models A_T with r parameters, but also to A_{2T} with $r/2$ parameters or $A_{T/2}$ with $2r$ parameters.

Moving beyond nested linear-affine models, Boopathy and Fiete also used a family of convolutional neural networks to test scale-time equivalence on an image classification task and found an empirical scaling law that showed good agreement with their hypothesis (see Figure 2). The implications of scale-time equivalence are striking, suggesting that larger models require fewer epochs to generalize than smaller models. This equivalence also cleanly connects parameter-wise and epoch-wise double descent theory.

Double Descent as a Manifestation of the Generalized Aliasing Decomposition

Tyler Jarvis—in collaboration with Mark Transtrum, Gus Hart, and Jared Whitehead, all of Brigham Young University—presented a third view of double descent and took a functional-theoretic approach with their *generalized aliasing decomposition* [5]. This technique is inspired by the classical signal processing phenomenon of mistaking an undersampled, high-frequency sinusoid for one with a lower frequency. The team motivated their work with an application in materials science that exhibits *multiple* peaks prior to the classical interpolation threshold (see Figure 3b).

From the lens of function approximation, Jarvis and his colleagues assumed a complete set of model functions $\Phi_j : \Omega \to \mathbb{R}$ so that convergent series $y(t) = \sum_j \Phi_j(t)\theta_j$ describes the true function $y(t)$ for approximation. Then, $\mathbf{y} = \mathbf{M}\theta$ for a bounded linear operator $\mathbf{M}$, which maps parameter space Θ to data space $\mathcal{D}$. In this setting, the researchers decomposed model space Θ into modeled and unmodeled components $\mathcal{M} \oplus \mathcal{U}$, and data space $\mathcal{D}$ into training and prediction $\mathcal{T} \oplus \mathcal{P}$. They analyzed this block operator and identified three contributions to model risk: model insufficiency, data insufficiency, and aliasing.

This aliasing—which is expressible as $A = \mathbf{M}^+_{\mathcal{T}\mathcal{M}}\mathbf{M}_{\mathcal{T}\mathcal{U}}$ and related to a block decomposition with modeled and unmodeled components of the operator $\mathbf{M}$—has operator norm $\|A\|$, whose value explains the classical interpolation threshold peak in synthetic experiments (similar to Figure 3a), the multiple peaks in their original application (see Figure 3b), and other standard nonlinear ML problems.

Reflections

Ultimately, the AN25 minisymposium captured myriad ways to describe, analyze, and control the unique phenomenon of double descent. Several other viewpoints—including the information-theoretic perspective of Vapnik-Chervonenkis theory, the use of sharpness-aware minimization to improve generalizability, and a philosophical and scientific take on double descent—offered important critiques and comments on the ML community and scientific process at large. Given the many subtleties and bridges between theory and application, it is naive to think of double descent as a phenomenon in which a single framework dominates. Rather, we should view it as distinct perspectives that provide guidance under different settings. I look forward to the field's continued evolution and the ultimate transformation of theory into action.

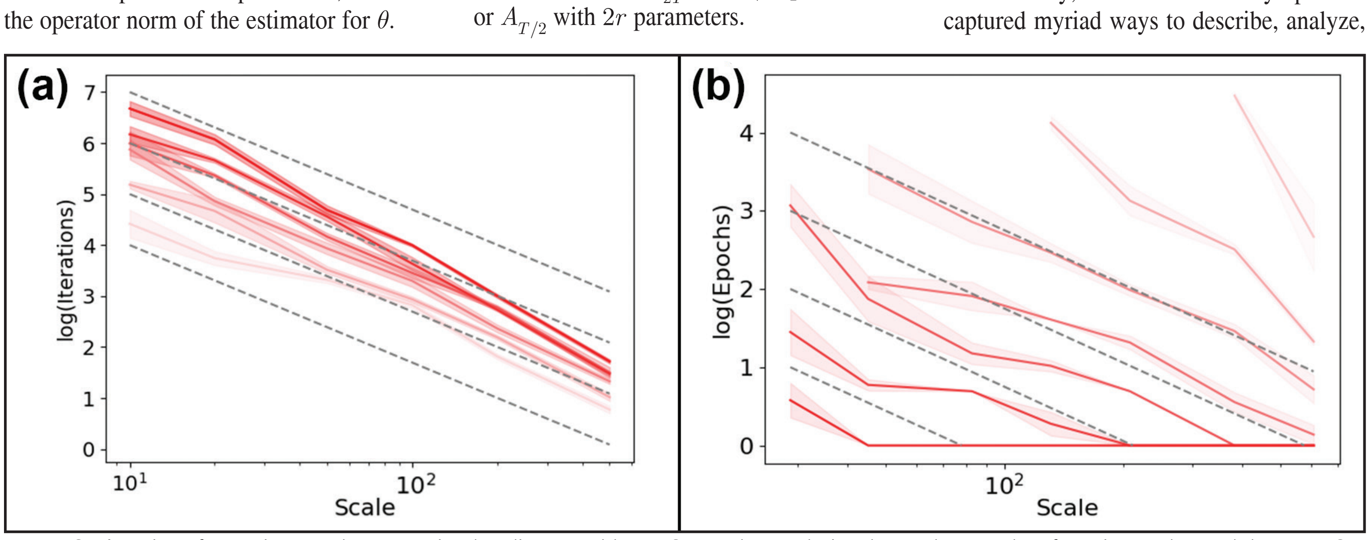

Figure 2. *A series of experiments that are trained on linear problems* **(2a)** *and convolutional neural networks of varying scales and datasets* **(2b)** *to reach a specified loss. Each red curve represents repeated iterations over pairs of parameters on an image classification task. Dashed lines indicate a linear approximate power law $p \propto t^{-1}$ that relates training epochs to model scale. While numerical results do not reflect perfect scaling, they lend evidence towards a scale-time equivalence. Figure adapted from [1].*

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Howard Elman

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Pilot-wave Hydrodynamics

Continued from page 1

you'll never do R." And so it goes as we march through the alphabet.

The analogs can be either quantitative or qualitative, but they collectively suggest that there need be no conceptual distinction between microscopic and macroscopic physics; when a particle serves as a resonant excitation of a field, it may exhibit quantum features at either micro- or macroscopic scales. Of course, it is a logical possibility that the similarities between the two systems are mere coincidence. But as the compendium of HQAs grows, this possibility becomes progressively less likely, and it becomes more likely that the similarities arise because the two systems have comparable underlying dynamics.

In pilot-wave hydrodynamics, a millimetric droplet self-propels along the surface of a vibrating liquid bath (see Figures 1a-1c, on page 1) [5]. The droplet interacts with a wave field of its own making, its self-potential. A key feature of the system is that the droplet bounces at or near the Faraday frequency, in resonance with its pilot wave. At each impact, it thus generates a quasi-monochromatic standing waveform with the Faraday wavelength whose longevity is prescribed by the bath's vibrational acceleration. The resulting physical picture is of a vibrating particle acting as a moving source of monochromatic waves in a medium that serves as the system's memory. The droplet dynamics are non-Markovian because the self-potential that pilots the droplet depends on the droplet's history. In an ever-growing number of settings, these non-Markovian dynamics give rise to features previously thought to be peculiar to the quantum realm, where they are often regarded as evidence of quantum nonlocality [3, 4].

The walking-droplet system has three distinct timescales — those of particle vibration, particle self-propulsion, and statistical convergence [2]. Strobing the system at the Faraday frequency reveals a droplet that surfs on a monochromatic pilot-wave envelope with the Faraday wavelength, but eliminates from consideration the timescale of wave generation (see Figure 1b, on page 1). Resolving all three timescales has proven to be critical when rationalizing the emergent quantum-like features. For example, variability in the bouncing dynamics—associated with the disruption of resonance between droplet and wave—directly affects the emergent statistical behavior in the analogs of both Kapitza-Dirac diffraction and the quantum corral (see Figures 1d and 1e, on page 1). While standard quantum theory correctly predicts the statistical behavior of quantum systems, it offers no description of the underlying dynamics. HQAs thus suggest that quantum theory is incomplete in the sense that it only resolves one of the three timescales that would be required for a rational, local quantum theory.

An important signpost along the HQA path was the realization that the physical picture suggested by pilot-wave hydrodynamics has a historical precedent. Specifically, it corresponds to that proposed by de Broglie in the 1920s in his double-solution pilot-wave theory [7]. As in pilot-wave hydrodynamics (see Figures 1d and 1e, on page 1), de Broglie's theory has two waves: the instantaneous pilot wave and the emergent statistical wave. Also as in pilot-wave hydrodynamics, there are three characteristic timescales — enabling a mapping between the two systems [2].

In de Broglie's theory, particle vibration at the Compton frequency $(\omega_c = mc^2\hbar)$ generates a pilot wave that conforms to the Klein-Gordon equation. If the particle is dressed in a monochromatic pilot wave, then the particle speed and group velocity of its wave must be equal, yielding the de Broglie relation $p = \hbar k$. In all HQAs, the Faraday wavelength plays the role of the de Broglie wavelength $\lambda = 2\pi/k$ in their quantum counterparts. Strobing the quantum system at the Compton frequency would reveal a pilot-wave envelope that satisfies the linear Schrödinger equation, but eliminate from consideration the timescale of wave generation. De Broglie proposed—but never proved—that this type of pilot-wave dynamics could yield emergent statistics of the form predicted by standard quantum theory. A century later, pilot-wave hydrodynamics has provided evidence in support of his proposal.

The notion of nonlocality, or action at a distance, should be anathema to any rational scientist. Nevertheless, most physicists have made peace with it; they either remain agnostic on the subject or believe it to be an essential, inescapable feature of quantum physics. Because standard quantum theory describes probabilities but not particle dynamics, nonlocality is perceived to be everywhere — in wavefunction collapse, single-particle interference, the quantum mirage, and interaction-free measurement. Correlation at a distance is taken as evidence of action at a distance. HQAs have demonstrated that if we adopt de Broglie's physical picture of quantum dynamics, we need not invoke nonlocality for any such effects. In short, HQAs suggest that quantum nonlocality is a misinference that is rooted in the incompleteness of quantum theory. While nonlocality is a feature of quantum theory, it need not be a feature of quantum physics.

What about Bell's theorem? The experimental violation of Bell's theorem is widely accepted as proof that any hidden variable theory for quantum mechanics must be nonlocal. Of course, one is more inclined to believe a proof that something exists if one perceives it to be everywhere. I have been puzzling over Bell's theorem (its lacunas, loopholes, and implications) for more than 40 years and have come to the conclusion that the matter is not yet settled. For example, it is not entirely clear that the assumptions made in its derivation apply to non-Markovian, pilot-wave systems. Moreover, Bell's theorem was first derived a century earlier by George Boole and numbered among his "conditions of possible experience," from which one might reasonably infer that Bell violations hint at a deep misunderstanding [11]. While mathematical proofs are nonnegotiable, one should be deeply suspicious of impossibility proofs as they pertain to the physical world. Indeed, the history of impossibility proofs in quantum mechanics should fuel one's skepticism [1]. In my view, such impossibility proofs smack of the best laid plans. *"Our holiday will be perfect and here's the proof: I have booked our flights, the finest hotels and restaurants. What could possibly go wrong?"*

De Broglie did not specify the nature of the quantum pilot wave. Stochastic electrodynamics is a modern extension of de Broglie's theory, in which the pilot wave is sought in the electromagnetic quantum vacuum [8]. Others have suggested the appealing prospect of pilot waves being gravitational in origin, in which case de Broglie's pilot waves would exist in the fabric of spacetime. By redefining the boundary between classical and quantum, HQAs are prompting a revisitation of quantum foundations [11]. Most importantly, they have furnished a physical picture that allows one to develop physical insight into quantum systems. When we adopt this physical picture, many conceptual problems in the standard formalism simply vanish. For instance, wave function collapse and the superposition of states are simply attributable to the incompleteness of quantum theory. Beyond the many quantum features that HQAs capture directly, recent theoretical explorations of generalized pilot-wave dynamics have suggested viable, classical rationales for Bohr-Sommerfeld orbital quantization, spin (see Figures 1f and 1g, on page 1), and single-particle Fraunhofer diffraction (see Figures 1h and 1i). Recent static Bell violations—achieved with classical pilot-wave models—raise the following question: *Might wave-mediated chaotic synchronization account for entanglement?*

Bohmian mechanics have provided another valuable touchstone for HQAs. In his monograph on the subject, theoretical physicist Peter Holland enumerates the central conceptual difficulties of quantum physics [10], which I paraphrase here. First, individual events are unpredictable, but coherent statistics emerge when one considers a large number of such events. Central puzzling quantum phenomena include self-interference of particles and the tunneling of particles across a barrier that would be forbidden to classical particles. Atoms and molecules exist only in certain discrete energy states and do not collapse, as would their classical counterparts. Quantum particles may possess spin — a form of intrinsic, nonclassical angular momentum. Finally, quantum particles might be entangled: the properties of one particle can depend on those of an arbitrarily distant particle with which it has interacted in the past. Pilot-wave hydrodynamics suggests a physical picture that would provide classical rationale for all such features while averting the need to invoke nonlocality.

I rest my case in the civil prosecution of the completeness of quantum theory and invite the applied mathematics, dynamical systems, physics, philosophy, and engineering communities to join in its criminal prosecution.

A senior colleague of mine liked to cast applied mathematicians as the sherpas of physics. He evoked an image of sherpas waiting patiently at the summit, smoking cheroots, their cargo strewn willy-nilly, wondering when their glorious expedition leader might be joining them. In the case of HQAs, a more appropriate metaphor would be that of explorers surveying new terrain with a view to pushing back the border between the classical and quantum realms, transforming terra incognita into terra firma. While the landscape is vast—and Mount Bell casts a long shadow—we now have a well-established base camp from which to launch our expeditions and ascents. Come join the adventure, enjoy the spectacular views — and pass the cheroot.

Acknowledgments: I gratefully acknowledge the financial support of the U.S. National Science Foundation through grant CMMI-2154151 and the Office of Naval Research through grant N000014-24-1-2232.

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Your Support at Work in 2025

By Abby Addy

As we approach the end of another year of incredible support from the SIAM community, I'm excited to share some updates and recent accomplishments from the Development and Corporate Relations team. I'm continually grateful for the wonderful people that surround me at this impactful organization, and for the myriad ways that their philanthropy and encouragement make a lasting difference.

In 2025, SIAM received many notable gifts from new and returning donors. Marty Golubitsky and Barbara Keyfitz marked their fourth consecutive year of philanthropy for the SIAM Postdoctoral Support Program,[1] which brings together postdoctoral researchers and mentors from different institutions to collaborate on a project that relates to their mutual research interests. The Life Sciences and Dynamical Systems Travel Fund,[2] which was established in 2023, also received increased funding from founding donor Simone Bianco, who will now provide full support for six students and early-career SIAM members to attend the SIAM Conference on the Life Sciences and SIAM Conference on Applications of Dynamical Systems.

SIAM members Fariba Fahroo, Lisa Fauci, Suzanne Lenhart, Deborah Lockhart, and Rosemary Renaut came together to lead a fundraising effort in memory of SIAM member Mary Ann Horn, who passed away in February 2024.[3] Thanks to both their work and the generosity of Mary Ann's friends and family, the Mary Ann Horn Memorial Fund will help two student and early-career SIAM members travel to the SIAM Conference on the Life Sciences in perpetuity.

SIAM also established the Nicholas J. Higham Prize for Research Impacting Scientific Software,[4] which is named in memory of former SIAM President Nicholas Higham, who passed away in 2024.[5] The initial funds to support this prize were generously donated by MathWorks,[6] maker of MATLAB and Simulink, and nAG,[7] creators of the nAG Library. SIAM is incredibly grateful for these substantial gifts and looks forward to recognizing and celebrating the important work of researchers in our community through this prize. We are also thankful to Desmond Higham and Françoise Tisseur for their assistance in fundraising for the prize's endowment.

Another important 2025 milestone in prize funding was the full endowment of the John von Neumann Prize,[8] which honors John von Neumann — a founder of modern computing. SIAM awards the prize annually for distinguished contributions to applied mathematics and the effective communication of these ideas to the community. This endowment was made possible due to the generous gifts of Robert V. Kohn, Samuel Gubins, and Eleanor Gubins. We are so appreciative of their support for this prestigious lecture.

This past summer, the Development and Corporate Relations team hosted the second annual Donor Appreciation Reception during the Third Joint SIAM/CAIMS Annual Meetings,[9] which took place in Montreal, Québec, Canada. It was a pleasure to see so many donors and supporters in one room, and we look forward to hosting another reception next year at the 2026 SIAM Annual Meeting[10] in Cleveland, Ohio.

SIAM Senior Development Officer Aleisha Kehm (left) and SIAM Director of Development and Corporate Relations Abby Addy pose during the Donor Appreciation Reception at the Third Joint SIAM/CAIMS Annual Meetings, which took place this past summer in Montréal, Québec, Canada. SIAM photo.

In 2025, SIAM continued to collaborate with many outstanding organizations through our conference sponsorship and exhibits program.[11] This year, we were proud to partner with industry leaders like ExxonMobil, IBM, Google, and Jane Street, as well as government laboratories, tech startups, and academic institutions that helped to make our SIAM conferences the best they can be! Conference sponsorship enables these organizations to connect with our amazing SIAM community and receive benefits such as public recognition, complimentary conference registration, and exhibit space. At the same time, their support allows us keep registration costs down for our valued conference attendees.

In July, External Relations Officer Erica Lipton celebrated her one-year anniversary with SIAM. She is excited to continue to build long-term relationships with SIAM's corporate partners and work collaboratively with SIAM membership to grow these essential societal relationships. If you think that your organization—or an organization with which you are connected—would benefit from increased visibility and engagement within the applied mathematics and computational science community, we encourage you to contact us about a potential SIAM sponsorship.

Due to this relationship-building work, SIAM has received a $20,000 grant from the Hilda & Preston Davis Foundation[12] to support the MathWorks Math Modeling Challenge[13] by fully funding the SPARK Awards for the next two years. These awards celebrate the accomplishments of high-performing teams from Title I eligible schools in the U.S., providing scholarships for students and stipends for teachers to spend on additional educational resources.

I hope that this small sample of the Development and Corporate Relations team's work has been inspiring. We are only able to continue our efforts through the support of the SIAM community and dedicated members like you. If we haven't had the chance to catch up this year, I look forward to connecting soon.

If you're considering a philanthropic donation to SIAM in 2025 but haven't yet made your gift, there's still time! Gifts of all sizes have tremendous impact, and you can direct your contribution to your preferred area of support. To make a gift, visit SIAM's online giving page[14] or send a check payable to SIAM to the following address:

SIAM Development
c/o Abby Addy
3600 Market Street, 6th Floor
Philadelphia, PA 19104

Please don't hesitate to contact me at **(267)-648-3529** or **aaddy@siam.org** with any questions or comments, for assistance with your contribution, or just to chat. Wishing you and your family a holiday season filled with joy!

Abby Addy is the Director of Development and Corporate Relations at SIAM.

[1] https://www.siam.org/programs-initiatives/programs/siam-postdoctoral-support-program
[2] https://www.siam.org/publications/siam-news/articles/siam-establishes-the-life-sciences-and-dynamical-systems-travel-fund
[3] https://www.siam.org/publications/siam-news/articles/obituary-mary-ann-horn
[4] https://www.siam.org/programs-initiatives/prizes-awards/major-prizes-lectures/nicholas-j-higham-prize-for-research-impacting-scientific-software
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[11] https://www.siam.org/conferences-events/about-siam-conferences-and-events/for-sponsors-and-exhibitors
[12] https://hpdavis.org
[13] https://m3challenge.siam.org
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Former SIAM President Receives Prestigious Blaise Pascal Medal

Susanne C. Brenner, a Boyd Professor at Louisiana State University who served as SIAM President in 2021 and 2022, received the prestigious 2025 Blaise Pascal Medal in Computational and Information Sciences[1] from the European Academy of Sciences (EurASc). The prize, which also recognized Brenner as a member of EurASC, honors "an outstanding and demonstrated personal contribution to science and technology and the promotion of excellence in research and education."

Susanne C. Brenner.

"It is an honor to receive the Blaise Pascal Medal," Brenner said. "I look forward to participating in events organized by the European Academy of Sciences."

A longtime member of SIAM, Brenner has served the Society in multiple capacities both before and beyond her time as president. She currently sits on the editorial boards of the *SIAM Journal on Numerical Analysis* and SIAM's *Classics in Applied Mathematics* book series; she has been editor-in-chief of the latter since 2018. Brenner became a SIAM Fellow in 2010, later served on the SIAM Fellows Selection Committee, and was awarded the AWM-SIAM Sonia Kovalevsky Lecture in 2011.

Congratulations on this achievement!

[1] https://www.eurasc.eu/2025-award-recipients

Boomers, Doomers, and Artificial General Intelligence

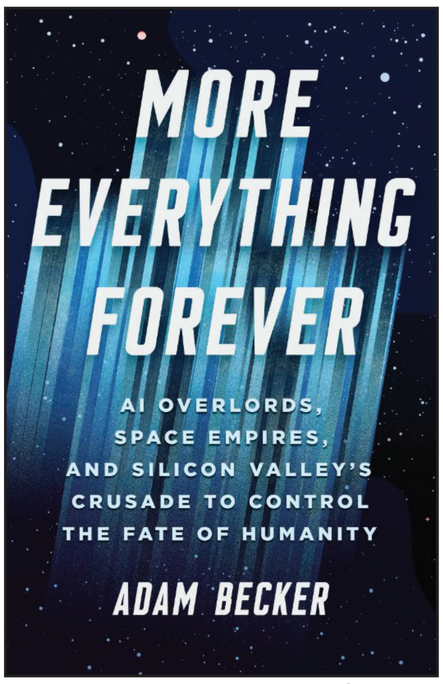
More Everything Forever: AI Overlords, Space Empires, and Silicon Valley's Crusade to Control the Fate of Humanity. *By Adam Becker. Basic Books, New York, NY, April 2025. 384 pages, $32.00.*

BOOK REVIEW
By Devdatt Dubhashi

Artificial intelligence (AI) has taken the world by storm, especially given the arrival of ChatGPT[1] in November 2022. The resulting social discourse is split between two different ideological groups that science journalist Adam Becker calls *boomers* and *doomers* in his new book, *More Everything Forever: AI Overlords, Space Empires, and Silicon Valley's Crusade to Control the Fate of Humanity*. Becker defines a "boomer" as someone who believes that AI will transform society into a world of great prosperity and human flourishing. In contrast, a "doomer" feels that AI signals the end of humanity; the associated probability for this mindset is "p(doom)." According to Becker, boomers and doomers are often two sides of the same coin, in that members of both camps populate OpenAI,[2] Google, and other Silicon Valley companies that serve as the powerhouses behind AI technologies like ChatGPT.

Becker's perspective is somewhat similar to investigative reporter Karen Hao's account of OpenAI's troubling culture and subsequent consequences in her recent text, *Empire of AI: Dreams and Nightmares in Sam Altman's OpenAI* [2]. However, his narrative focuses specifically on the intellectual and philosophical currents of boomers versus doomers. In particular, Becker identifies two distinct but related viewpoints—*effective altruism* (EA) and *rationalism*—that constitute the core of his book.

The central figure of the rationalist movement in *More Everything Forever* is Eliezer Yudkowsky: a self-educated maverick who is based in Silicon Valley. Per Becker's account, Yudkowsky was an unusual child who found his calling in *artificial general intelligence* (AGI), or *superintelligence*. In 2000, he founded the Singularity Institute for Artificial Intelligence (SIAI) to hasten the arrival of AGI and *singularity*: the point at which AI would surpass humanity in its power and lead to a flourishing society. But several years later, Yudkowsky's outlook changed; he now felt that AGI would be an "existential threat" to humanity unless it properly "aligned" with human values. He subsequently decided to change the name of SIAI to the Machine Intelligence Research Institute[3] (MIRI) and created a blog called *LessWrong*[4] that focuses on AI's perceived existential threat. Contributors to the blog started their own blogs, some of which became very influential — including Scott Alexander Siskind's *Slate Star Codex* (now *Astral Codex Ten*[5]).



More Everything Forever: AI Overlords, Space Empires, and Silicon Valley's Crusade to Control the Fate of Humanity. By Adam Becker. Courtesy of Basic Books.

The leading argument of this group was captured by philosopher Nick Bostrom in his famed *paper clip thought experiment*. Consider a hypothetical AI system that is trained to maximize the production of paper clips, a seemingly harmless goal. But as it becomes "superintelligent," it creates instrumental subgoals to optimize its fulfillment of the original goal. One such subgoal might be to eliminate all of humanity, since humans consume resources that could otherwise go towards the production of paperclips. Rationalist enthusiasts have since envisioned many scenarios wherein misaligned AI systems could destroy humanity — none more voluminous and bizarre as the recently released *AI 2027* report,[6] which predicts that "the impact of superhuman AI over the next decade will be enormous, exceeding that of the Industrial Revolution" [3]. In September, Yudkowsky (together with coauthor Nate Soares) released a book that was featured on *The New York Times* Best Sellers list the following month [5].

Conversely, EA is the brainchild of philosopher William MacAskill and his colleagues. EA advocates for charitable donations in a manner that most effectively helps humanity. At first glance, this idea seems undoubtedly admirable; who would object to optimized altruism and good deeds? Perhaps the most high-profile adherent to this idealism was cryptocurrency entrepreneur Sam Bankman-Fried. Once hailed as a great entrepreneur and philanthropist, Bankman-Fried was found guilty of massive fraud in November 2023 after his FTX cryptocurrency exchange spectacularly collapsed and he filed for bankruptcy the previous year; in March 2024, he was sentenced to 25 years in federal prison.

The collapse of Bankman-Fried's company highlights some of the basic problems with the EA movement. For example, EA supporters use a strange, deranged version of utilitarianism to realize their values. They believe that the most effective way to do good is to secure a lucrative job, earn as much as possible, and give away as much as possible to worthy causes. MacAskill offered Bankman-Fried this very advice when the latter was a student at the Massachusetts Institute of Technology; it ultimately led him down the path to FTX and eventual fraud.

Throughout *More Everything Forever*, Becker thoroughly demonstrates the absurdity of the EA enterprise, with its cavalier exercises in crude utilitarian calculations and ridiculous hubris of imagining that one can presently determine the best long-term course of action for all of humanity. To elaborate, EA is associated with a movement called *longtermism*. The concept may initially sound somewhat banal; the lives of future humans are as important as ours, so we have a responsibility to bequeath a better world to the next generation. This is hardly a new insight, as many environmental activists regularly call upon this moral doctrine. But longtermism—as espoused in MacAskill's book, *What We Owe The Future* [4]—is not concerned with the next 100 or even 1,000 years, but rather millions of years in the future. A consequence of this utilitarian calculus of the welfare of trillions of future humans is a singular focus on *existential risk*. In a 2013 paper, philosopher

See **General Intelligence** *on page 7*

[1] https://chatgpt.com
[2] https://openai.com
[3] https://intelligence.org
[4] https://www.lesswrong.com/about
[5] https://www.astralcodexten.com
[6] https://ai-2027.com

Simply on Maupertuis' Principle

More than a century after the discovery of Maupertuis' principle, Jacobi wrote that "*This principle is presented incomprehensibly, in my view, in almost all textbooks, including the best ones, such as those by Poisson, Lagrange and Laplace*"[1] [1].

In its simplest form, Maupertuis' principle states a remarkable fact: *The trajectory $\gamma_{\rm actual}$ of a point mass with a prescribed energy E that flies in a potential force field is a minimizer[2] of $\int_\gamma v\,ds$ among all other paths γ that share endpoints with $\gamma_{\rm actual}$. Here, v is the speed as a function of position that is determined when energy E is prescribed, and s is the arc length along the path.*[3]

In other words, trajectories with prescribed energy are geodesics in the (Jacobi) metric $v ds$.

Deriving Maupertuis' Principle

A key part of the explanation lies in a simple geometrical fact illustrated in Figure 1: the distance from a fixed point to a moving point changes at the rate

[1] The actual quote is "Dies Princip wird fast in allen Lehrbüchern, auch in den besten, in denen von *Poisson, Lagrange* und *Laplace*, so dargestellt, dass es nach meiner Ansicht nicht zu verstehen ist."

[2] Or more precisely, makes critical. The trajectory minimizes if it is short enough, i.e., if there are no two conjugate points on this segment of the trajectory.

[3] So that $v=\sqrt{2(E-U)/m}$, where the potential energy U is the function of position.

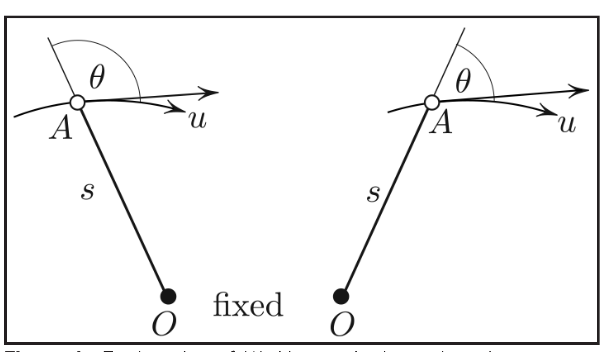


Figure 1. *Explanation of (1). Here, u is the arclength parameter of point A on a curve. Distance $s=OA$, where O is fixed. The rate of change of distance ds/du is given by the projection $\cos\theta$ of the unit vector of A's velocity (where u plays the role of time) onto line OA.*

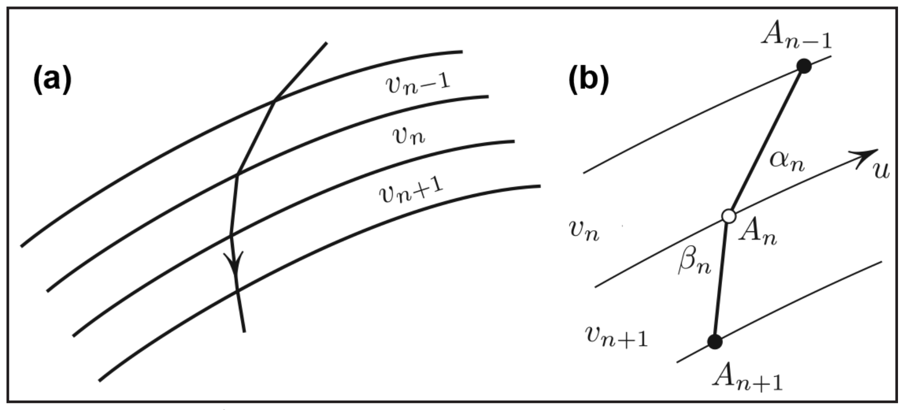


Figure 2. *Derivation of Maupertuis' principle.*

$$\frac{ds}{du}=\cos\theta, \tag{1}$$

where the meaning of terms and the reason for (1) are explained in the caption.

For future reference, $ds/du<0$ if θ is obtuse (see Figure 1). Let us now discretize the potential by replacing it with constant in strips between neighboring level curves (see Figure 2). The particle's speed v_n is constant throughout the nth strip; it is known because the particle's total energy E is prescribed. Upon crossing each level curve of the potential, the speed changes in a jump. Crucially, however, the tangential component of the speed does not change (see Figure 2b):

MATHEMATICAL CURIOSITIES
By Mark Levi

$$v_{n+1}\cos\beta_n - v_n\cos\alpha_n = 0. \tag{2}$$

I claim that (2) amounts to saying that action is stationary for our trajectory. Indeed, let us fix points $A_{n\pm1}$ and allow A_n to vary along its level curve, where arc length parameter $u=0$ corresponds to A_n's unperturbed position. According to (1), the lengths $s_n=A_{n-1}A_n$ and $s_{n+1}=A_nA_{n+1}$ satisfy at $u=0$:

$$\frac{ds_n}{du}=-\cos\alpha_n,$$

$$\frac{ds_{n+1}}{du}=\cos\beta_n.$$

We can thus rewrite Newton's law (2) as

$$\frac{d}{du}\left(v_ns_n+v_{n+1}s_{n+1}\right)=0 \text{ at } u=0. \tag{3}$$

Since this holds for all points of the trajectory, we conclude that the sum $\sum_{n=0}^N v_ns_n$ is stationary. This sum is an approximation of the action integral $\int v\,ds$, thus completing the explanation of Maupertuis' principle.

To summarize, we only used three facts: (i) energy conservation, which determines v_n; (ii) a consequence (2) of Newton's law; and (iii) a simple geometrical observation (1).

Some History

Maupertuis' principle was discovered by Leibniz around 1707 and published by Euler around 1744, the same year that Maupertuis' paper appeared [2]. In this paper, Maupertuis considered the refraction of light rays that cross the interface between air and water. He assumed that the light in the air moves more slowly[4] since $v_{\rm air}<v_{\rm water}$ and stated—relying on a metaphysical argument—that the rays minimize the action

$$v_{\rm air}s_{\rm air}+v_{\rm water}v_{\rm water}. \tag{4}$$

From this assumption, Maupertuis derived the law of refraction

[4] Contrary to what Fermat and Huygens believed several decades earlier.

$$v_{\rm air}\sin\alpha_{\rm air}=v_{\rm water}\sin\alpha_{\rm air},$$

where α are the angles with the normal to the interface. This answer would have been correct had velocities been replaced by their reciprocals:

$$\frac{v_{\rm air}}{\sin\alpha_{\rm air}}=\frac{v_{\rm water}}{\sin\alpha_{\rm water}}. \tag{5}$$

I wrote Snell's law in a slightly unconventional way by putting velocities in the numerator because both sides of (5) have a direct physical meaning, as stated in the caption of Figure 3. Snell's law is a consequence of the fact that the wavefront only touches the surface at one point at each moment. Both sides of (5) are different expressions of the same thing.

The figures in this article were provided by the author.

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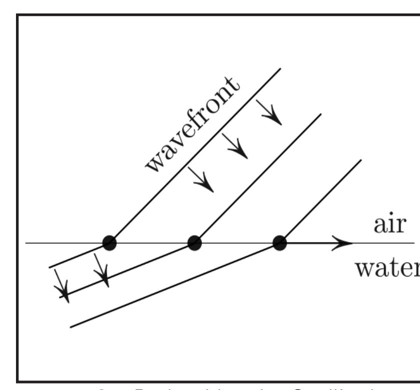

Figure 3. *Both sides in Snell's law (5) express the speed of the break point's propagation along the interface.*

General Intelligence

Continued from page 6

Nick Bostrom writes that given a one percent chance of quadrillions of people existing in the theoretical future, "the expected value of reducing existential risk by a mere *one billionth of one billionth of one percentage point* is worth one hundred billion times as much as a billion human lives" [1]. The single-minded focus of longtermism is thus to increase the odds, however slightly, of humanity's long-term survival. And according to EA philosophers, the single biggest threat to this goal—far greater than nuclear Armageddon or climate change—is AGI. This focus on AGI as the most serious threat to humanity's survival merges the EA and rationalist movements into one.

The penultimate chapter of *More Everything Forever* focuses on the opposite viewpoint: the boomers or *accelerationists* who are represented by billionaires like Marc Andreessen and Jeff Bezos. Andreessen—a businessman, venture capitalist, and former software engineer—seeks to throw caution to the wind and use as much energy as possible to reach AGI, while Bezos—founder and former chief executive officer (CEO) of Amazon—wants to colonize space to produce thousands of modern-day prodigies.

Several common threads appear throughout Becker's book. First, the EA and rationalist movements primarily attract philosophers and computer software gurus. Additionally, many of their arguments are based on philosophical puzzles that more closely resemble science fiction rather than hard science and substantive evidence. In fact, Becker humorously notes that several of the key players in his narrative are long-term fans of science fiction. Because these individuals are often close to very important centers of power and policy, their somewhat distorted ideologies can quickly gain traction. For example, Dominic Cummings—who served as chief advisor to former U.K. Prime Minister Boris Johnson—is a champion of EA.

But how do these groups come to have such an inflated influence? Becker addresses this apparent contradiction in his final chapter:

> Without billionaires, fringe philosophies like rationalism and effective accelerationism would stay on the fringe, rather than being pulled into the mainstream through the reality-warping power of concentrated wealth.

The EA movement and its institutes at the University of Oxford are funded by billionaire money—i.e., the Open Philanthropy fund[7]—while Yudkowsky's institute was backed by both Open Philanthropy and venture capitalists such as Peter Thiel. Similarly, OpenAI was initially backed by its cofounder Elon Musk and CEO Sam Altman, who has close connections to a vast network of Silicon Valley billionaires [2]. Given the alleged problematic impact of such billionaires on contemporary society, Becker outlines several measures that may ultimately inspire a world that is free of their influence. This type of important discussion needs broader attention and a wider audience, and *More Everything Forever* is a valuable contribution to the ongoing conversation.

[7] https://www.openphilanthropy.org

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[2] Davis, E. (2025, October 1). OpenAI: Extraordinary accomplishments, but at what cost? *SIAM News, 58*(8), p. 11.

[3] Kokotajlo, D., Alexander, S., Larsen, T., Lifland, E., & Dean, R. (2025, April 3). *AI 2027*. Retrieved from https://ai-2027.com.

[4] MacAskill, W. (2022). *What we owe the future*. New York, NY: Basic Books.

[5] Yudkowsky, E., & Soares, N. (2025). *If anyone builds it, everyone dies: Why superhuman AI would kill us all*. New York, NY: Little, Brown and Company.

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A Year of Mathematical Excellence and Professional Preparation at SIAM Conferences

By Richard Moore

In 2025, SIAM delivered a dynamic and intellectually rich calendar of conferences that emphasized the power of applied mathematics, computational science, and data science across disciplines and industries.

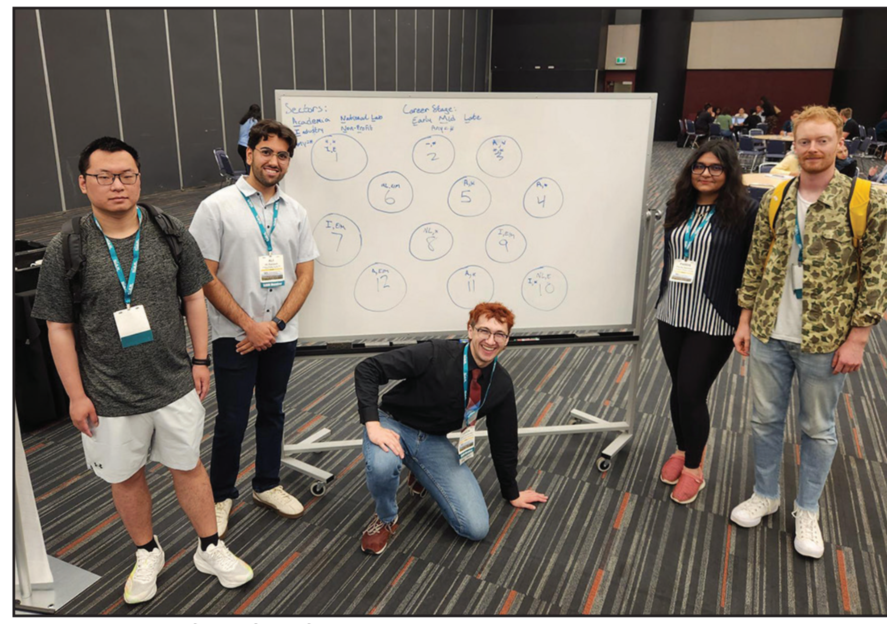
A highlight of the early part of the year was the 2025 SIAM Conference on Computational Science and Engineering[1] (CSE25), which took place in March in Fort Worth, Texas. This interdisciplinary gathering brought together researchers who are exploring a myriad of topics, including quantum algorithms for scientific computing, artificial intelligence, scalable solvers, digital twins, and high-performance computing. The conference also hosted the 2025 SIAM International Meshing Roundtable Workshop,[2] which accentuated the critical role of mesh generation in simulation accuracy.

A notable feature of CSE25 was the spring 2025 SIAM Career Fair,[3] which connected students and early-career professionals with employers from industry and government. Both the career fair and broader meeting included resume reviews, networking opportunities, and direct recruitment, reinforcing SIAM's commitment to professional development and workforce readiness for members of all experience levels.

In July, the 2025 SIAM Conference on Applied Algebraic Geometry[4] (AG25) was held in Madison, Wis. The conference—which convened experts in symbolic computation, representation theory, and algebraic combinatorics—showcased the application of algebraic methods to robotics, cryptography, biology, and machine learning. The AG25 Organizing Committee ensured a global representation of both theoretical and applied perspectives, creating a vibrant environment for emerging and established researchers alike. The structure of the sessions fostered collaboration across mathematical domains, and the meeting's welcoming atmosphere was particularly valuable for graduate students and postdoctoral researchers who are seeking to grow their networks and preparing to enter the workforce.

The centerpiece of SIAM's 2025 programming was the Third Joint SIAM/CAIMS Annual Meetings[5] (AN25), which took place from July 28 to August 1 in Montréal, Québec, Canada. This expansive event featured three co-located conferences: the 2025 SIAM Conference on Applied and Computational Discrete Algorithms,[6] the 2025 SIAM Conference on Control and Its Applications,[7] and the 2025 SIAM Conference on Computational Geometric Design.[8] AN25 and its associated meetings offered a panoramic view of applied mathematics and related fields, with sessions on quantum science, uncertainty quantification, mathematical biology, and optimization. The conference also involved an online component that allowed speakers who were unable to travel to Montréal to present their research remotely.

[1] https://www.siam.org/conferences-events/past-event-archive/cse25
[2] https://www.siam.org/conferences-events/past-event-archive/siam-imr25
[3] https://www.siam.org/programs-initiatives/professional-development/career-fairs
[4] https://www.siam.org/conferences-events/past-event-archive/ag25
[5] https://www.siam.org/conferences-events/past-event-archive/an25
[6] https://www.siam.org/conferences-events/past-event-archive/acda25
[7] https://www.siam.org/conferences-events/past-event-archive/ct25
[8] https://www.siam.org/conferences-events/past-event-archive/gd25



At the Third Joint SIAM/CAIMS Annual Meetings, which took place this summer in Montréal, Québec, Canada, volunteer helpers assist with the Career Opportunity Committee's resume-building workshop, which offered attendees one-on-one mentoring sessions. From left to right: Xiangrui Kong (University of British Columbia), Ali Balooch (University of Nevada, Las Vegas), Jason Torchinsky (Sandia National Laboratories), Pardis Semnani (University of British Columbia), and Lane Rogers (University of Tennessee, Knoxville). SIAM photo.

Beyond the usual minisymposia, invited talks, and prize sessions, AN25 also featured a rich suite of professional development events, including Industry Lightning Talks[9] and an industry career panel,[10] where professionals from companies like Amgen, Hydro-Québec, and Oak Ridge National Laboratory shared personal insights based on their experiences with applied mathematics careers outside of academia. A resume-building workshop and another career panel[11]—sponsored by SIAM's Career Opportunities Committee[12]—compared employment experiences within and beyond academia and offered practical advice and diverse perspectives on various paths in applied mathematics.

In addition to these major events, SIAM's 2025 calendar included several other impactful conferences. January's 2025 ACM-SIAM Symposium on Discrete Algorithms[13] in Alexandria, Va., brought together computer scientists and mathematicians to explore advances in algorithm design, complexity theory, and combinatorial optimization. The 2025 SIAM Conference on Applications of Dynamical Systems,[14] which was held in Denver, Colo., in May, attracted mathematicians, scientists, and engineers who develop and apply dynamical systems techniques. Meanwhile, the 2025 SIAM Conference on Financial Mathematics and Engineering[15] in Miami, Fla., focused on mathematical modeling in finance and addressed topics such as risk management, derivatives pricing, and stochastic analysis. These specialized conferences enrich SIAM's offerings by connecting mathematical theory with real-world applications and providing specialized venues for researchers to share insights, build collaborations, and advance their fields.

The year's festivities concluded with the 2025 SIAM Conference on Mathematical & Computational Issues in the Geosciences[16] (GS25)—which took place in October in Baton Rouge, La.—and the 2025 SIAM Conference on Analysis of Partial Differential Equations[17] (PD25), which was held in Pittsburgh, Pa., in November. GS25 united applied mathematicians, engineers, and geoscientists who are tackling challenges that pertain to the Earth system, with topics ranging from porous media and coastal modeling to machine learning and uncertainty quantification. The event featured engaging plenary talks, minitutorials, and unique field experiences, such as tours of the Atchafalaya Basin and the ExxonMobil Refinery. The following month, PD25 highlighted cutting-edge developments in the theory and application of partial differential equations, including nonlinear waves, fluid dynamics, inverse problems, and control. It attracted a strong international presence and emphasized support for early-career researchers through SIAM travel awards and targeted mentoring sessions.

Across all of its 2025 conferences, SIAM demonstrated a deep commitment to accessibility, diversity, and professional development by offering child care grants,[18] countless career-building activities, and inclusive programming. As SIAM looks ahead to 2026, the ongoing momentum from 2025 promises even greater opportunities for discovery, dialogue, and impact within the global applied mathematics community.

Richard Moore is the Director of Programs and Services at SIAM.

[9] https://meetings.siam.org/sess/dsp_programsess.cfm?SESSIONCODE=85335
[10] https://www.siam.org/publications/siam-news/articles/an25-panel-considers-career-possibilities-in-industry-government-and-the-national-laboratories
[11] https://www.siam.org/publications/siam-news/articles/career-opportunities-panel-at-an25-compares-employment-experiences-within-and-beyond-academia
[12] https://www.siam.org/get-involved/connect-with-a-community/committees/career-opportunities-committee
[13] https://www.siam.org/conferences-events/past-event-archive/soda25
[14] https://www.siam.org/conferences-events/past-event-archive/ds25
[15] https://www.siam.org/conferences-events/past-event-archive/fm25
[16] https://www.siam.org/conferences-events/siam-conferences/gs25
[17] https://www.siam.org/conferences-events/siam-conferences/pd25
[18] https://www.siam.org/conferences-events/conference-support/child-care-grants

InsideSIAM
Conferences, books, journals, and activities of Society for Industrial and Applied Mathematics

SIAM | CONFERENCES

A Place to Network and Exchange Ideas

Upcoming Deadlines

siam 2026

ACM-SIAM Symposium on Discrete Algorithms (SODA26)

January 11–14, 2026 | Vancouver, Canada
siam.org/da26 | #SIAMDA26

SODA will be held jointly with:

- ***SIAM Symposium on Algorithm Engineering and Experiments (ALENEX)***
- ***SIAM Symposium on Simplicity in Algorithms (SOSA)***

PROGRAM COMMITTEE CO-CHAIRS
Kasper Green Larsen, *Aarhus University, Denmark*
Barna Saha, *University of California, San Diego, U.S.*

EARLY REGISTRATION RATE and HOTEL RESERVATION DEADLINE
December 8, 2025

The following conferences are co-located.
The application deadline for travel support is April 6, 2026:

SIAM Annual Meeting (AN26)

July 6–10, 2026 | Cleveland, Ohio, U.S.
siam.org/an26 | #SIAMAN26

ORGANIZING COMMITTEE CO-CHAIRS
Daniela Calvetti, *Case Western University, U.S.*
Charles Wampler, *University of Notre Dame, U.S.*

SUBMISSION DEADLINES
January 26, 2026: Minisymposium Proposal Submission
February 16, 2026: Contributed Lecture, Poster, Miniposterium, and Minisymposium Presentation Abstract Submissions

SIAM Conference on Mathematics of Planet Earth (MPE26)

July 6–8, 2026 | Cleveland, Ohio, U.S.
siam.org/mpe26 | #SIAMMPE26

ORGANIZING COMMITTEE CO-CHAIRS
Kenneth Golden, *University of Utah, U.S.*
Kara Peterson, *Sandia National Laboratories, U.S.*

SUBMISSION DEADLINES
January 12, 2026: Minisymposium Proposal Submission
February 2, 2026: Contributed Lecture, Poster, and Minisymposium Presentation Abstract Submissions

SIAM Conference on The Life Sciences (LS26)

July 6–9, 2026 | Cleveland, Ohio, U.S.
siam.org/ls26 | #SIAMLS26

ORGANIZING COMMITTEE CO-CHAIRS
Karin Leiderman, *University of North Carolina at Chapel Hill, U.S.*
Nessy Tania, *Pfizer Research & Development, U.S.*

SUBMISSION DEADLINES
January 12, 2026: Minisymposium Proposal Submission
February 2, 2026: Contributed Lecture, Poster (including Miniposterium), and Minisymposium Presentation Abstract Submissions

SIAM Conference on Applied Mathematics Education (ED26)

July 9–10, 2026 | Cleveland, Ohio, U.S.
siam.org/ed26 | #SIAMED26

ORGANIZING COMMITTEE CO-CHAIRS
Ariel Cintron-Arias, *Catawba College, U.S.*
Maeve McCarthy, *Murray State University, U.S.*

SUBMISSION DEADLINES
January 26, 2026: Minisymposium Proposal Submission Deadline
February 16, 2026: Contributed Lecture and Minisymposium Presentation Abstract Submissions

Information is current as of November 12, 2025. Visit *siam.org/conferences* for the most up-to-date information.

Upcoming SIAM Events

ACM-SIAM Symposium on Discrete Algorithms
January 11–14, 2026 | Vancouver, Canada
Sponsored by the SIAM Activity Group on Discrete Mathematics and the ACM Special Interest Group on Algorithms and Computational Theory

SIAM Symposium on Algorithm Engineering and Experiments
January 11–12, 2026 | Vancouver, Canada

SIAM Symposium on Simplicity in Algorithms
January 12–14, 2026 | Vancouver, Canada

SIAM Conference on Parallel Processing for Scientific Computing
March 3–6, 2026 | Berlin, Germany
Sponsored by the SIAM Activity Group on Supercomputing

SIAM International Meshing Roundtable Workshop 2026
March 3–6, 2026 | Berlin, Germany

SIAM Conference on Uncertainty Quantification
March 22–25, 2026
Minneapolis, Minnesota, U.S.
Sponsored by the SIAM Activity Group on Uncertainty Quantification

SIAM Conference on Nonlinear Waves and Coherent Structures
May 26–29, 2026
Montréal, Québec, Canada
Sponsored by the SIAM Activity Group on Nonlinear Waves and Coherent Structures

SIAM Conference on Optimization
June 2–5, 2026
Edinburgh, United Kingdom
Sponsored by the SIAM Activity Group on Optimization

SIAM Conference on Discrete Mathematics
June 22–25, 2026
San Diego, California, U.S.
Sponsored by the SIAM Activity Group on Discrete Mathematics

SIAM Conference on Mathematics of Planet Earth
July 6–8, 2026
Cleveland, Ohio, U.S.
Sponsored by the SIAM Activity Group on Mathematics of Planet Earth

SIAM Conference on the Life Sciences
July 6–9, 2026
Cleveland, Ohio, U.S.
Sponsored by the SIAM Activity Group on Life Sciences

2026 SIAM Annual Meeting
July 6–10, 2026
Cleveland, Ohio, U.S.

SIAM Conference on Applied Mathematics Education
July 9–10, 2026
Cleveland, Ohio, U.S.
Sponsored by the SIAM Activity Group on Applied Mathematics Education

FOR MORE INFORMATION ON SIAM CONFERENCES: *siam.org/conferences*

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Make the Most of Your Membership: Join a SIAM Activity Group!

SIAM activity groups (SIAGs) offer focused forums for members interested in specific areas of applied mathematics and computational science. Activity groups organize conferences and minisymposia, publish newsletters, host online communities on SIAM Engage, and award prizes. Benefits of membership include focused communications from peers, access to member directories and SIAG community archive, and additional discounts on SIAG-sponsored conferences.

Membership is open to SIAM members. Dues are $15/year. Student members receive two free SIAG memberships; outreach members receive one free SIAG membership.

Learn more and join SIAM activity groups at *siam.org/membership/activity-groups*.

Algebraic Geometry (SIAG/AG)
Chair: Giorgio Ottaviani (01/01/24–12/31/25)
Prize: SIAG/AG Early Career Prize

Analysis of Partial Differential Equations (SIAG/APDE)
Chair: Alexis Vasseur (01/01/25–12/31/26)
Prizes: SIAG/APDE Best Paper Prize, SIAG/APDE Early Career Prize

Applied and Computational Discrete Algorithms (SIAG/ACDA)
Chair: Jonathan Berry (01/01/25–12/31/26)
Prize: SIAG/ACDA Early Career Prize

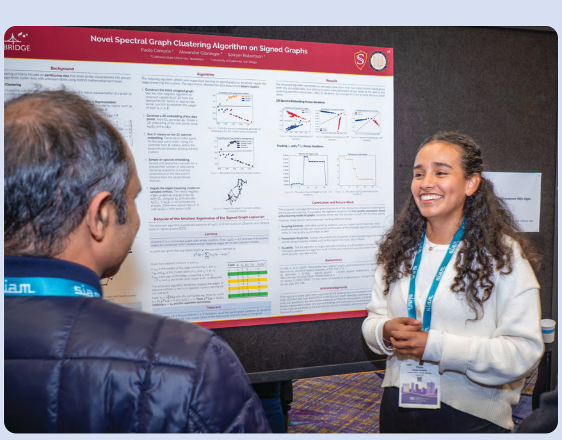
Applied Mathematics Education (SIAG/ED)
Chair: Allison Lewis (01/01/25–12/31/26)

Computational Science and Engineering (SIAG/CSE)
Chair: Julianne Chung (01/01/25–12/31/26)
Prizes: SIAG/CSE Early Career Prize, SIAG/CSE Best Paper Prize

Control and Systems Theory (SIAG/CST
Chair: Lorena Bociu (01/01/24–12/31/25)
Prizes: SIAG/CST Prize, SIAG/CST Best SICON Paper Prize

Data Science (SIAG/DATA)
Chair: Lars Ruthotto (01/01/24–12/31/25)
Prizes: SIAG/DATA Career Prize, SIAG/DATA Early Career Prize

Discrete Mathematics (SIAG/DM)
Chair: Maya Stein (01/01/25–12/31/26)
Prize: Dénes König Prize



Dynamical Systems (SIAG/DS)
Chair: Jonathan E Rubin (01/01/24–12/31/25)
Publication: free subscription to *SIAM Journal on Applied Dynamical Systems*
Prizes: Jürgen Moser Lecture, J. D. Crawford Prize, Red Sock Award

Equity, Diversity, and Inclusion (SIAG/EDI)
Chair: Tamara G. Kolda (01/01/23–12/31/25)

Financial Mathematics and Engineering (SIAG/FME)
Chair: Samuel Cohen (01/01/24–12/31/25)
Prizes: SIAG/FME Early Career Prize, SIAG/FME Conference Paper Prize

Geometric Design (SIAG/GD)
Chair: Yongjie Jessica Zhang (01/01/25–12/31/26)
Prize: SIAG/GD Early Career Prize

Geosciences (SIAG/GS)
Chair: Sarah Gasda (01/01/25–12/31/26)
Prizes: SIAG/GS Career Prize, SIAG/GS Early Career Prize

Imaging Science (SIAG/IS)
Chair: Gabriele Steidl (01/01/24–12/31/25)
Prizes: SIAG/IS Best Paper Prize, SIAG/IS Early Career Prize

Life Sciences (SIAG/LS)
Chair: Ruth Baker (01/01/25–12/31/26)
Publication: free subscription to *SIAM Journal on Applied Dynamical Systems*
Prize: SIAG/LS Early Career Prize

Linear Algebra (SIAG/LA)
Chair: Laura Grigori (01/01/25–12/31/27)
Prizes: SIAG/LA Best Paper Prize, SIAG/LA Early Career Prize

Mathematical Aspects of Materials Science (SIAG/MS)
Chair: Lia Bronsard (01/01/25–12/31/26)

Mathematics of Planet Earth (SIAG/MPE)
Chair: Pedram Hassanzadeh (01/01/25–12/31/26)
Prize: SIAG/MPE Prize, SIAG/MPE Early Career Prize

Nonlinear Waves and Coherent Structures (SIAG/NWCS)
Chair: Paul A Milewski (01/01/25–12/31/26)
Prizes: Martin Kruskal Prize Lecture, T. Brooke Benjamin Prize in Nonlinear Waves

Optimization (SIAG/OPT)
Chair: Luis Nunes Vicente (01/01/23–12/31/25)
Publication: SIAG/OPT News and Views
Prizes: SIAG/OPT Best Paper Prize, SIAG/OPT Early Career Prize, SIAG/OPT Test of Time Award

Orthogonal Polynomials and Special Functions (SIAG/OPSF)
Chair: Howard S. Cohl (01/01/25–12/31/26)
Prize: Gábor Szegö Prize

Supercomputing (SIAG/SC)
Chair: Ulrike Yang (01/01/24–12/31/25)
Prizes: SIAG/SC Career Prize, SIAG/SC Early Career Prize, SIAG/SC Best Paper Prize

Uncertainty Quantification (SIAG/UQ)
Chair: Karen Veroy-Grepl (01/01/25–12/31/26)
Prize: SIAG/UQ Early Career Prize

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If you have already renewed, you can join an activity group anytime at: *siam.org/membership/activity-groups*.
And don't forget—students can join two activity groups for free and outreach members can join one activity group for free!

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GOT A PROBLEM?

SIAM is Seeking Problem Ideas for High School Math Modeling Competition

MathWorks Math Modeling Challenge
A program of siam

We're looking for real-world problems that will be of interest to young people and allow them to make meaningful progress toward a solution within 14 hours.

We welcome all problem suggestions! Anyone who submits an idea can work with experienced problem writers to refine it.

Honoraria

- $500 for problems selected to be used as "the" Challenge problem.
- $50 for problems selected to be practice problems posted on the M3 Challenge website. Authors may be invited to participate in a live webinar to discuss approaches to solving their problem.

Examples of past problems include:

- Mitigating risks associated with the increased frequency, intensity, and duration of heat waves, and the accompanying strain on the electrical grid
- Finding long-term solutions for the linked crises of homelessness and a shortage of affordable housing
- Predicting the future of remote work, both at a micro and macro level, and how it could affect government agencies, real estate values, the environment, population densities, and even career choices

About M3 Challenge

MathWorks Math Modeling Challenge (M3 Challenge) is an internet-based, applied mathematics contest. High school juniors and seniors in the U.S. and sixth form students (age 16-19) in England and Wales may compete in teams of three to five students. M3 Challenge takes place each year in late February/early March. Teams are given 14 hours to solve an open-ended, applied math-modeling problem related to a real-world issue. Winners receive scholarship awards totaling $100,000 (£75,000+). Registration and participation are free.

The goal of M3 Challenge is to motivate students to study and pursue careers in STEM disciplines, especially applied mathematics, computational science, data science, and technical computing. The problem is revealed to students only after they log in on their selected Challenge day. Solutions are judged on the approach and methods used, and the creativity displayed in problem solving and mathematical modeling. While coding is not required to compete, teams that code in MATLAB are eligible for additional MATLAB Technical Computing Awards.

Learn more about past problems: *m3challenge.siam.org/resources/archives*

Considering submitting a problem idea?

M3 Challenge welcomes all problem suggestions and can connect contributors with experienced problem writers to refine their ideas. Our problem development team will help shape each problem into the standard format and ensure it meets the desired criteria. **Problems don't need to be fully developed**—though the following information may help guide your ideas.

Problem structure

Within the problem statement, there should be three questions for teams to answer:

- Question One: A warm up — every serious team can answer.
- Question Two: The guts — framed so that every team can have some success and many teams will cover it well.
- Question Three: The discriminator — many teams will do something, while only a few will have striking results.
- Data — data that is provided or easily found is desirable to encourage students to use coding and technical computing in solution papers.

Check out past problems to see the typical format: *m3challenge.siam.org/resources/archives.*

Desired problem characteristics

- Topic of current interest involving interdisciplinary problem solving and critical thinking skills
- Accessibility to high school/sixth form students
- Suitability for solution in 14 hours
- Possibility for significant mathematical modeling
- Potential to extend and enhance model using technical computing if a team chooses to do so
- Availability of enough **data** for a variety of approaches and depth of solutions (but no easily found answers)
- References identified that will be helpful for getting students started

Contact SIAM for more information: m3challenge@siam.org

Email your ideas to: *m3challenge@siam.org*

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