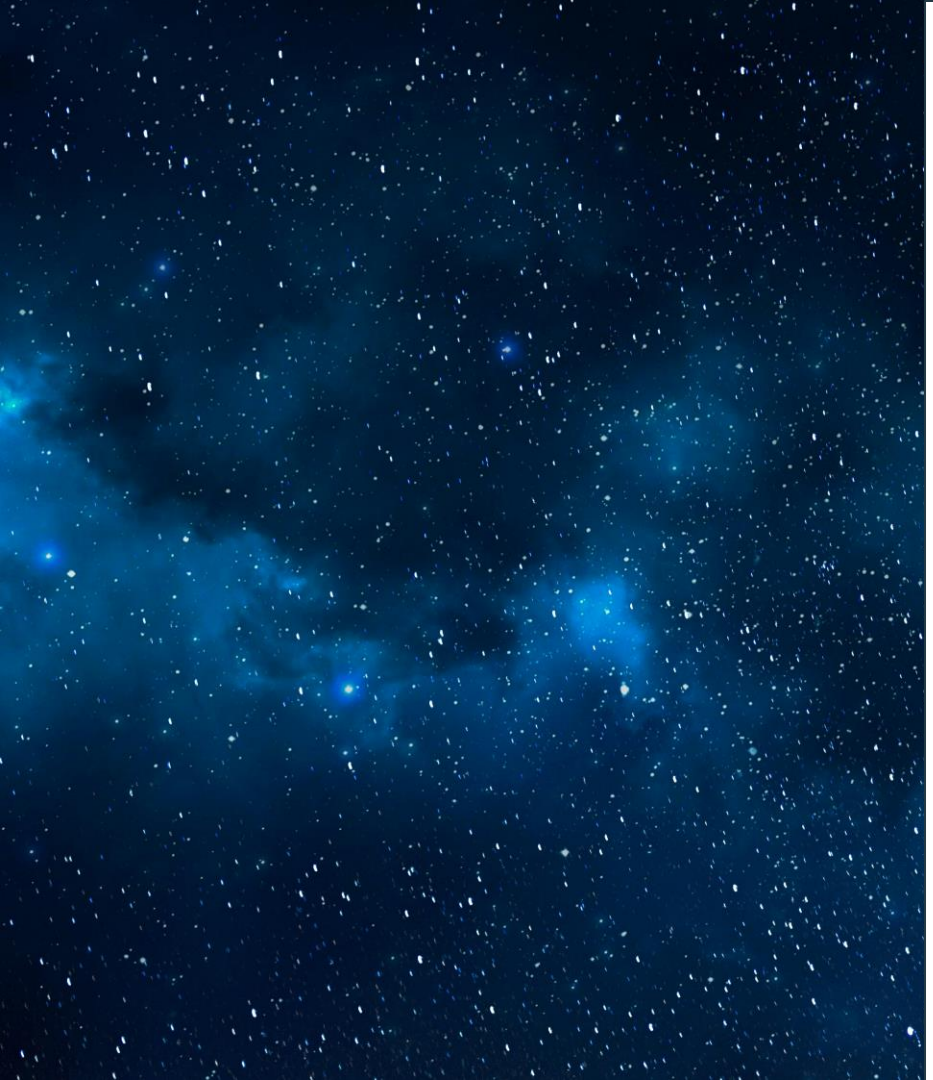
# Institute for Computer-Aided Reasoning in Mathematics

**Jeremy Avigad**
**Director**
**September 8, 2025**



# Overview of the Institute

Institute for Computer-Aided Reasoning in Mathematics

# Overview

The *Institute for Computer-Aided Reasoning in Mathematics* will support:

- Interactive Proof Assistants and Formalization
- Automated Reasoning and Symbolic AI
- Machine Learning and Neural AI

In the press, these are, collectively, “AI for Mathematics.”

# Overview

The digital library, Mathlib, has more than 225K theorems and 1.9M lines of code.

High-profile formalizations of contemporary research in Lean:

- the Polynomial Freiman–Ruzsa Project
- a strengthening of Carleson's Theorem

High-profile uses of symbolic AI:

- refutation of the Kaplansky unit conjecture
- the empty hegaxons problem

High-profile advances in neural AI:

- DeepMind's AlphaProof and AlphaGeometry
- results in representation theory, knot theory, graph theory

JUNE 8, 2024 | 12 MIN READ

# AI Will Become Mathematicians' 'Co-Pilot'

Fields Medalist Terence Tao explains how proof checkers and AI programs are dramatically changing mathematics

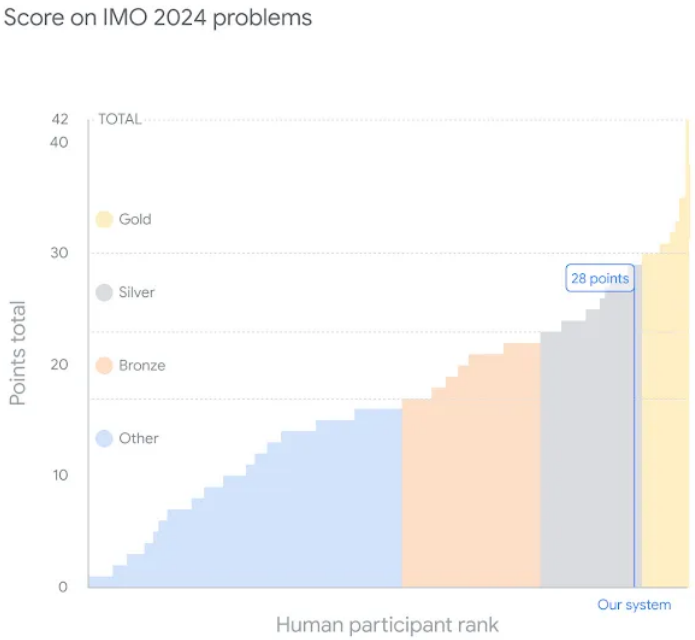
BY CHRISTOPH DRÖSSER

# Tao’s Predictions

“I think in the future, instead of typing up our proofs, we would explain them to some GPT. And the GPT will try to formalize it in Lean as you go along. If everything checks out, the GPT will [essentially] say, ‘Here’s your paper in LaTeX; here’s your Lean proof. If you like, I can press this button and submit it to a journal for you.’”

# Tao's Predictions

"There could be collaborative projects where we don't know how to prove the whole thing. But people have ideas on how to prove little pieces, and they formalize that and try to put them together. In the future, I could image a big theorem being proven by a combination of 20 people and a bunch of AIs each proving little things. And over time, they will get connected, and you can create some wonderful thing. That will be great."




Graph showing performance of our AI system relative to human competitors at IMO 2024. We earned 28 out of 42 total points, achieving the same level as a silver medalist in the competition.

## AlphaProof: a formal approach to reasoning

# AlphaProof and AlphaGeometry

“It’s a fairly safe bet that if Google DeepMind can solve at least some hard I.M.O. problems, then a useful research tool can’t be all that far away.”

– Timothy Gowers, Rouse Ball Professor of Mathematics at the University of Cambridge

# *A.I. Is Coming for Mathematics, Too*

For thousands of years, mathematicians have adapted to the latest advances in logic and reasoning. Are they ready for artificial intelligence?



# *Move Over, Mathematicians, Here Comes AlphaProof*

A.I. is getting good at math — and might soon make a worthy collaborator for humans.

# Overview

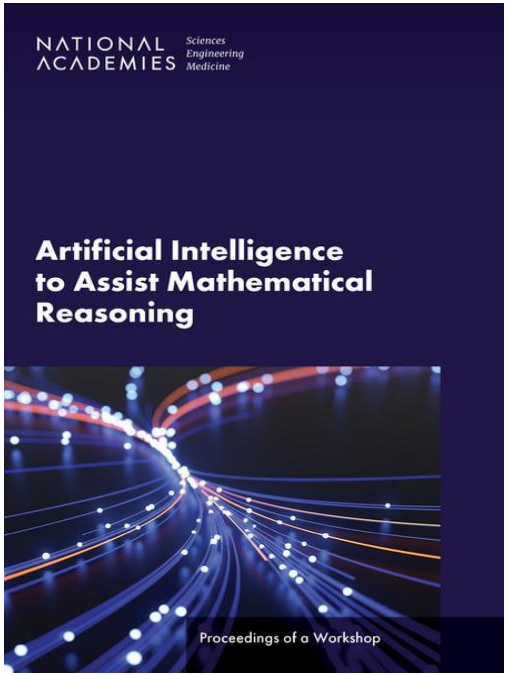
These technologies will impact mathematics:

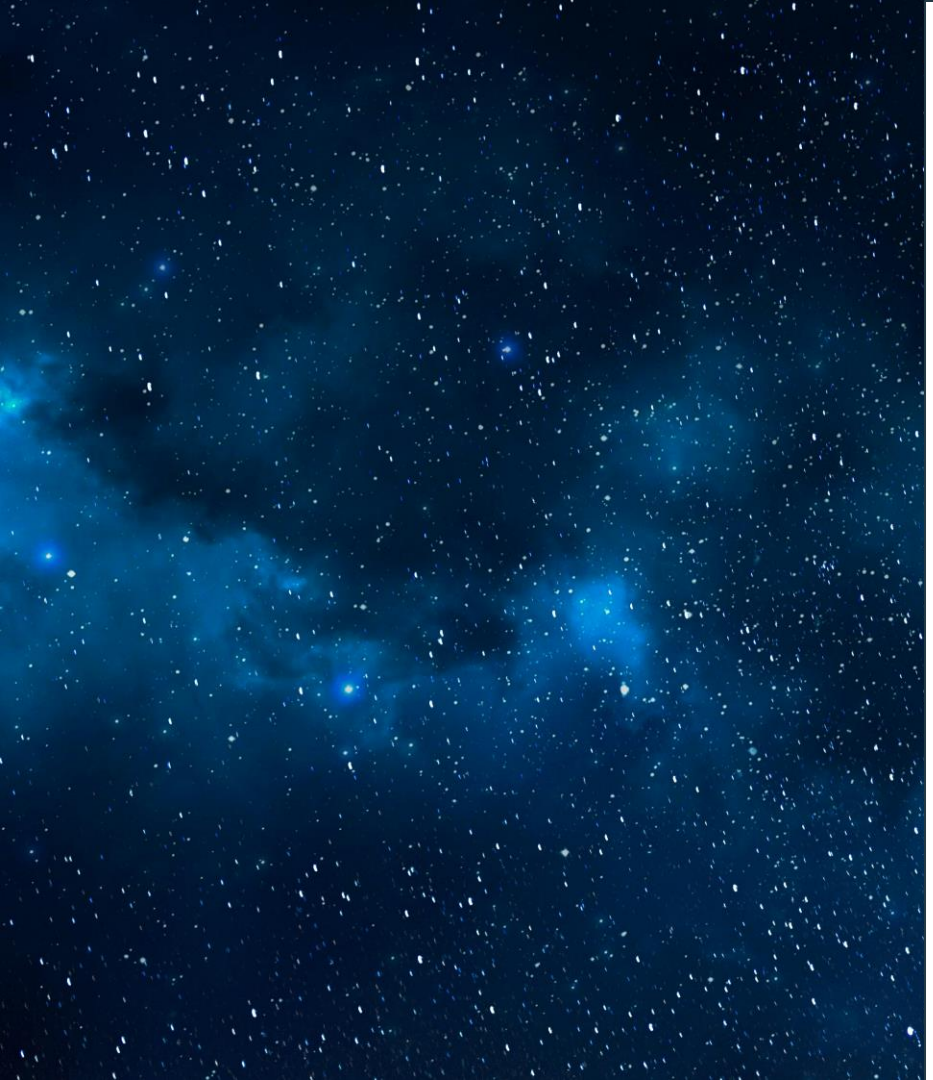
- verification of mathematical results and mathematical computation
- communication and collaboration
- mathematical reference and search
- exploration and discovery of new mathematics
- teaching and learning

# Overview

In 2023, a workshop by the *National Academies for Science, Engineering, and Medicine* explored the promise of these technologies and the challenges that lie ahead.

The *Institute for Computer-Aided Reasoning in Mathematics* is designed to meet the challenges.





# Challenges

Institute for Computer-Aided Reasoning in Mathematics

# Challenges

The transformation is being driven by forces outside the core mathematical research community:

- Technological advances are coming from computer science.
- AI and formal methods are developed by industry (AWS, OpenAI, DeepMind, X.AI, Harmonic, …).
- Lean is developed by the Lean Focused Research Organization.
- Early adopters are overwhelmingly postdocs, PhD students, or younger.

The academic mathematical community *must* be centrally involved.

# Challenges

There isn't a sharp distinction between *developing* AI for mathematics and *using* AI for mathematics.

- Mathematicians have to figure out how to use current technology to do useful things, and how the technology can be improved.
- Computer scientists then have information and feedback, and are incentivized to improve the technology (impact).

It's a virtuous cycle, but only if mathematicians are involved.

# Challenges

Computer science and industry excel at developing technology and putting it to good use, but they have different outlooks and incentives.

Mathematics takes the long view: it is designed to help us

- think better
- think bigger
- share ideas precisely

Mathematics is important to all of us, and only mathematicians understand what is important for mathematics.

# Challenges

Machine learning and large language models raise a host of concerns:

- reliability
- explainability
- alignment.

Mathematical language, concepts, and rigor are needed to supplement these.

There is a growing awareness that a combination of neural and symbolic methods is the key to general intelligence, and that AI for mathematics is the frontier.

# *Is Math the Path to Chatbots That Don't Make Stuff Up?*

Chatbots like ChatGPT get stuff wrong. But researchers are building new A.I. systems that can verify their own math — and maybe more.

Listen to this article · 6:40 min Learn more

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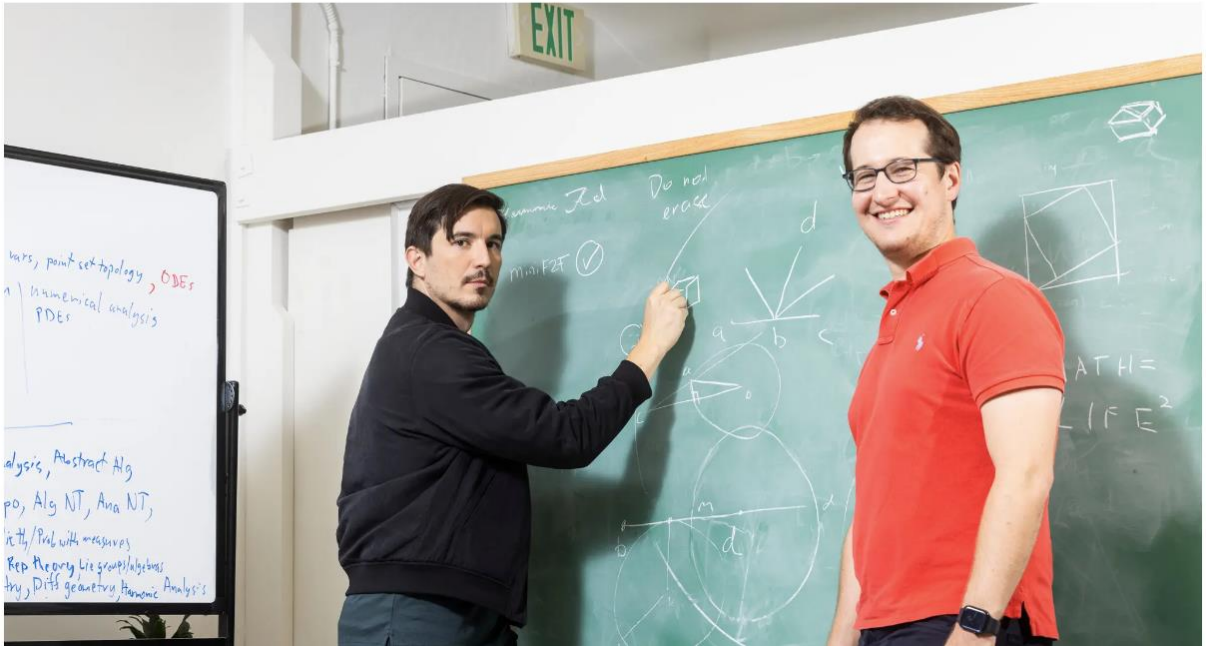


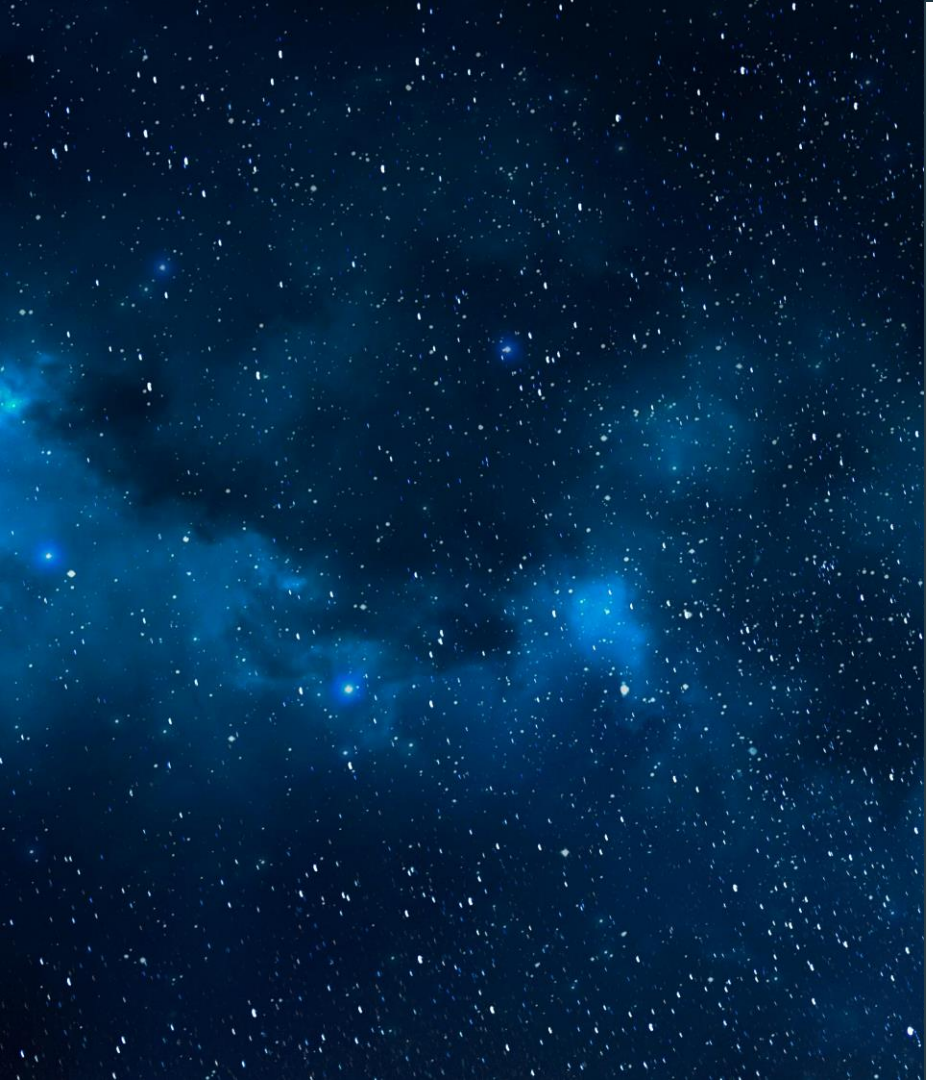
# Challenges

As long as we continue to reason, deliberate, and communicate with one another, mathematical language and concepts will be essential.

Mathematics is fundamental to human endeavors from science and technology to public policy and finance.

We need to preserve mathematical values and maintain a mathematical outlook, and pass them on to the next generation.

The new technologies must enhance our ability to do mathematics, not replace it.



# Meeting the Challenges

Institute for Computer-Aided Reasoning in Mathematics

# Meeting the Challenges

The mission of the *Institute for Computer-Aided Reasoning in Mathematics* is to:

- empower mathematicians to keep mathematics central to everything we do, in the face of technological change;
- unite mathematicians of all kinds, computer scientists, students, and researchers, to face the challenges together; and
- ensure that mathematics and the new technologies are accessible to everyone.

# Empowering Mathematicians

Some key challenges:

- Existing tools aren't designed for mathematicians.
- Documentation isn't written for mathematicians.
- Mathematicians don't have the relevant expertise
- Collaborations are needed between computer scientists and mathematicians.
- Nobody "owns" AI for mathematics; it falls through the cracks.
- Some of the work is tedious, doesn't yield academic credit.
- The mathematics community doesn't know how to support/assess mathematicians using AI.

# Empowering Mathematicians

We will maintain a staff of *innovation engineers* that will:

- help mathematicians learn to use the technologies
- answer questions and provide technical support
- maintain documentation, tools, infrastructure, and other community resources
- serve as liaisons to computer science and industry
- carry out essential tasks that academics don’t have time or incentives to do
- be community leaders in the use of technology
- gather resources and coordinate efforts.

# Bringing Us Together

We will also provide:

- workshops
- summer schools
- collaborative visits
- an annual conference

These will build a community of students, researchers, mathematicians, computer scientists, engineers, and others to address the challenges together.

We need a combination of perspectives and expertise.

# Improving Access

Technology can help improve access to mathematics:

- Students anywhere can find learning resources on the web.
- AI and formal systems provide immediate feedback.
- Online communities provide friendship and support.

But social, economic, and psychological factors can have the opposite effect:

- Mathematics may become restricted to those who master the technology.
- Some communities may not have the resources to support the next generation in learning to use the technology.

# Improving Access

AI and the digitization of mathematics can lead to greater democratization but it can also lead to greater inequities.

A central goal of ICARM is to ensure that all communities have the resources they need to participate in mathematics and take advantage of the new technologies.

Our original proposal included a summer school for college students, a workshop for graduate students, and an after-school program for high school students to address this challenge head on.

# Meeting the Challenges (Recap)

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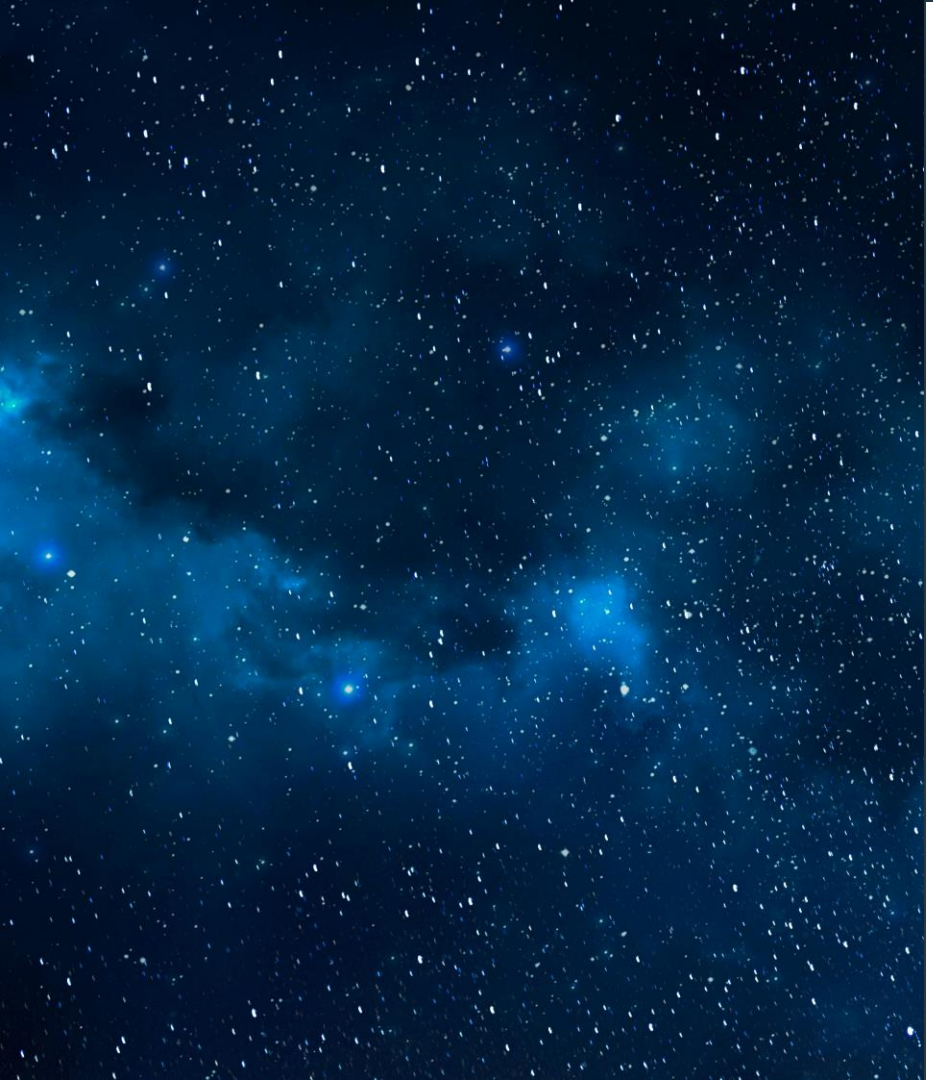
# Keeping the Focus on Mathematics

“Today we serve technology. We need to reverse the machine-centered point of view and turn it into a person-centered point of view: Technology should serve us.”

From *Things That Make Us Smart: Defending Human Attributes in the Age of the Machine,* by Donald A. Norman

The question is not “how can mathematicians use the technology” but rather “what can technology do for mathematicians.”



# Practicalities

Institute for Computer-Aided Reasoning in Mathematics

# Institute Leadership

- **Director:** Jeremy Avigad (Professor, Philosophy and Mathematical Sciences, CMU)
- **Associate Director, Scientific Activities:** Matthew Ballard (Professor, Mathematics, USC)
- **Associate Director, Operations:** Prasad Tetali (Head, Mathematical Sciences, CMU)
- **Assistant Director, Scientific Activities:** Marijn Heule (Associate Professor, Computer Science, CMU)
- **Assistant Director, Scientific Activities:** Sean Welleck (Assistant Professor, Language Technologies Institute, CMU)
- **Assistant Director, Educational Activities:** Irina Gheorghiciuc (Director of Undergraduate Research, Mathematical Sciences, CMU)
- **Assistant Director, Outreach:** Michael Young (Associate Dean for Community Engagement, Mellon College of Science, CMU)
- **Assistant Director, Outreach:** Aris Winger (Associate Professor, Mathematics, Georgia Gwinnett College and Executive Director, NAM)

# Governance

We will be overseen by:

- A scientific advisory board
- A strategic advisory board
- A university oversight board

We are in the process of establishing these.

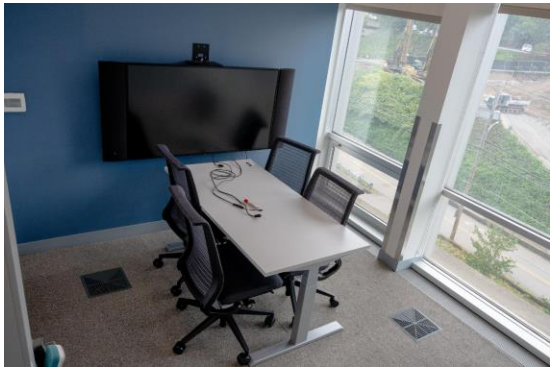
# A Supportive Environment

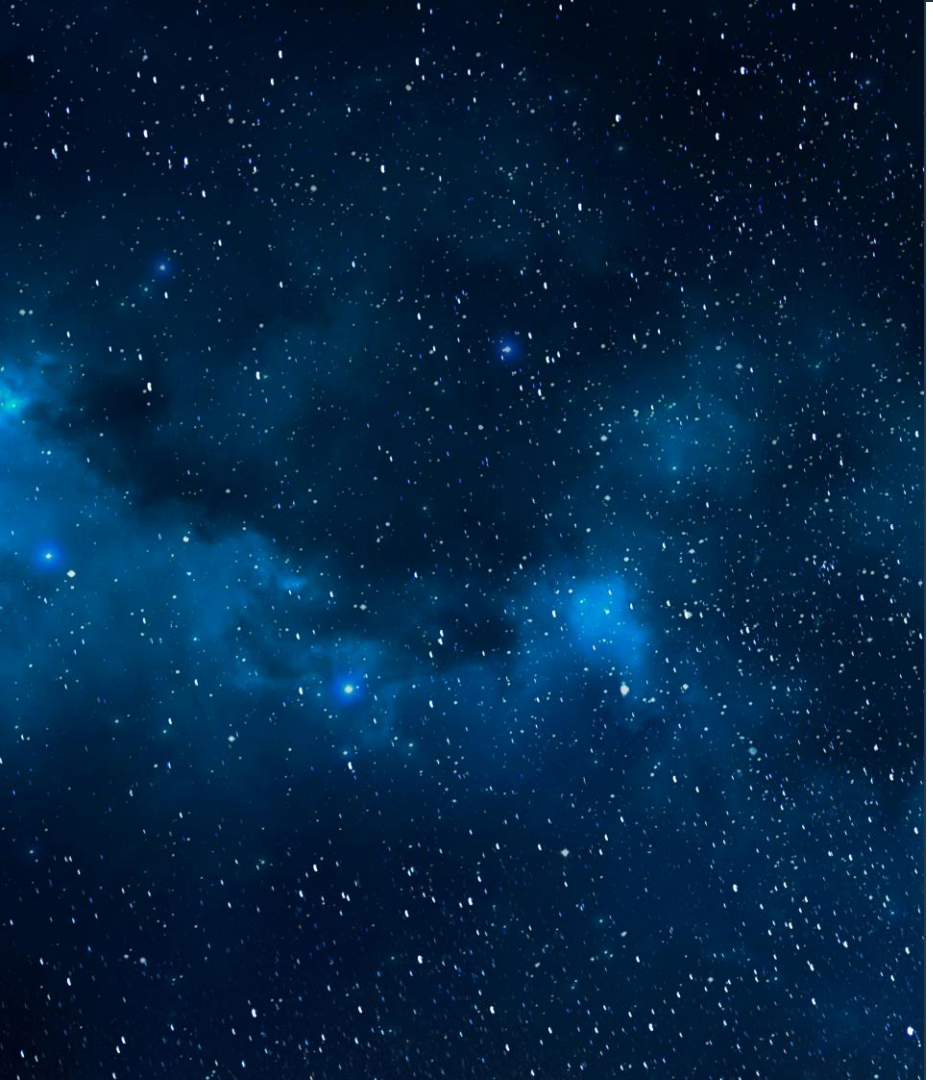
Carnegie Mellon and the University of Pittsburgh offer talent and expertise in

- Mathematics
- Computer Science
- Machine Learning and AI
- Formal Methods
- Engineering
- Cognitive Science and Education Science
- Human-Computer Interaction and Design
- Outreach and Broader Impact.

# Institute Space

- Temporary space in the Collaborative Innovation Center
- Centrally located on campus
- Offices for leadership and staff
- Offices for collaborative visits
- Room for a small workshop (30 people)
- Access to classrooms





# Where We Stand

Institute for Computer-Aided Reasoning in Mathematics

NSF News

# NSF invests over $74 million in 6 mathematical sciences research institutes

From improving medical care to detecting planets in other solar systems, the institutes will explore mathematical sciences with a broad range of applications

August 4, 2025

The U.S. National Science Foundation is investing over $74 million in six research institutes focused on the mathematical sciences and their broad applications in all fields of science, technology and many industries.

For over 40 years, NSF has funded Mathematical Sciences Research Institutes to serve as catalysts for U.S. research in mathematics and statistics and to produce mathematical innovations to rapidly address new and emerging challenges and opportunities. The institutes collectively investigate a wide range of mathematical research areas with potential impacts, including better patient outcomes in hospital emergency rooms, enhanced safety of semiautonomous vehicles, and detection of exoplanets using quantum physics. Previous research conducted at the institutes has had broad impacts, such as improved speed and accuracy of MRI imaging and the development of mathematical foundations of artificial intelligence-based technologies.

# Our Current Status

The institute has been launched as a three-year pilot:

- 2-3 administrative staff
- 3 innovation engineers
- At least two workshops each year
- At least one summer school each year
- A conference in the second year
- Collaborative visits

Additional funding from the Simons Foundation is pending.

# Getting Started

We are:

- Setting up administrative and financial infrastructure within CMU
- Constituting our governing boards
- Setting up our space
- Setting up our web pages and computing infrastructure
- Hiring staff and innovation engineers
- Starting to plan our first activities and events
- Collaborating with the other institutes

# Getting Started

Initial successes:

- We are supporting special semesters on PDEs at SLMath with experts in formalization
- We will hold tutorials on SAT solving at the Joint Mathematics Meetings
- We will host a speaker and tutorial on neural methods for combinatorics at an ICM satellite meeting at CMU

# Getting Started

Current priorities:

- Getting our first innovation engineer(s) hired and started
- Getting our first workshop scheduled (spring or summer 2025)
- Getting our first summer school scheduled
- Setting up mechanisms for collaborative visits

*Warning:* if you can help bring about our mission, we will come after you.

# Remember the Mission

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