

Visioning New Grand Challenges for Computing



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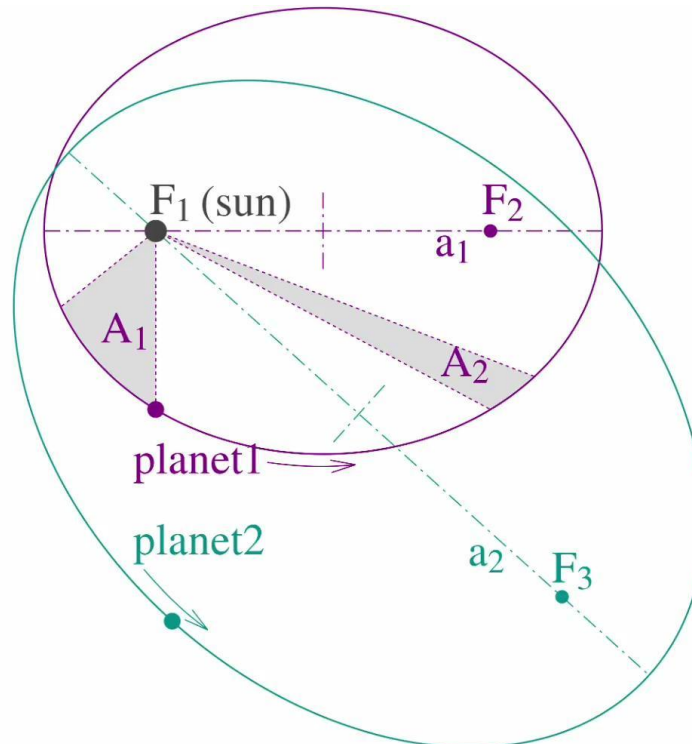


**CCC Grand
Challenges**
Task Force

Welcome!

Visioning New Grand Challenges for Computing

Parallel Track: Research



Kepler's laws of Planetary Motion

Goal: describe the orbits of planets around the Sun in a manner consistent with observed data.

Introducing the CRA CCC Grand Challenges Task Force

The Computing Community Consortium (CCC) fosters new research directions through visioning workshops and conference sessions for the computing research community as well as policy and funding leaders. CCC is a Programmatic Committee of CRA.

Grand Challenges - A CCC Task Force

- Goal: Develop a framework to identify and explore grand challenges in computing
- Activities:
 - Community Feedback (March 2024)
 - 4 Virtual Roundtables (May 2024)
 - Snowbird session (July 2024)
 - White paper/Workshop (2024-2025)



David Jensen
UMass Amherst



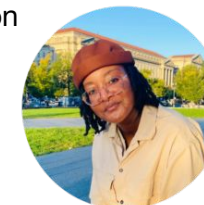
Dan Lopetri
Lehigh



Mona Singh
Princeton



Holly Yanco
UMass Lowell



Petruce Jean-Charles
CCC

Plan for this session

- What is a Grand Challenge?
- Small group discussions (20 mins)
- Report out from groups
- Summary
- Next steps

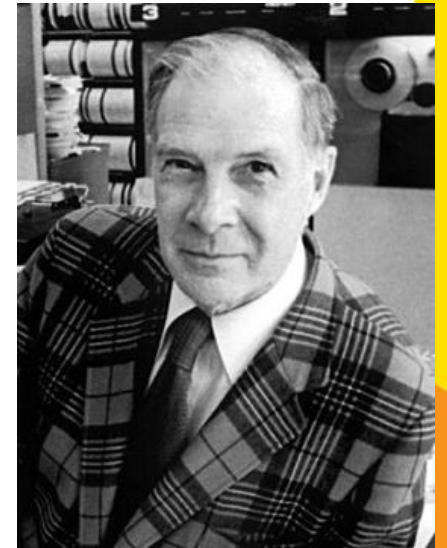
Framing this session

- What makes a challenge “grand”?
- What is a “computing research challenge” vs a “challenge that requires computers”?
- How do we know if we have solved the challenge? What is the objective?
 - challenge accepted, responded to and then solved?

The Hamming Question:

What are the important problems in your field... and why aren't you working on them?

— Richard Hamming (1915-1998)
ACM Turing Award 1968



Framing Using The Heilmeier Catechism

1. What are you trying to do?

Articulate your objectives using absolutely no jargon.

2. How is it done today, and what are the limits of current practice?

3. What's the new approach and why do you think it will work?

4. If you're successful, what difference will it make and to whom?

5. How much will it cost?

6. How long will it take?

7. What are the midterm and final "exams" to check for success?



Example: JFK Moonshot Speech, Sep 12, 1962



"But if I were to say, my fellow citizens, **that we shall send to the moon, 240,000 miles away from the control station in Houston, a giant rocket more than 300 feet tall, the length of this football field, made of new metal alloys, some of which have not yet been invented, capable of standing heat and stresses several times more than have ever been experienced, fitted together with a precision better than the finest watch, carrying all the equipment needed for propulsion, guidance, control, communications, food and survival, on an untried mission, to an unknown celestial body, and then return it safely to earth, re-entering the atmosphere at speeds of over 25,000 miles per hour, causing heat about half that of the temperature of the sun--almost as hot as it is here today--and do all this, and do it right, and do it first before this decade is out--then we must be bold.**"

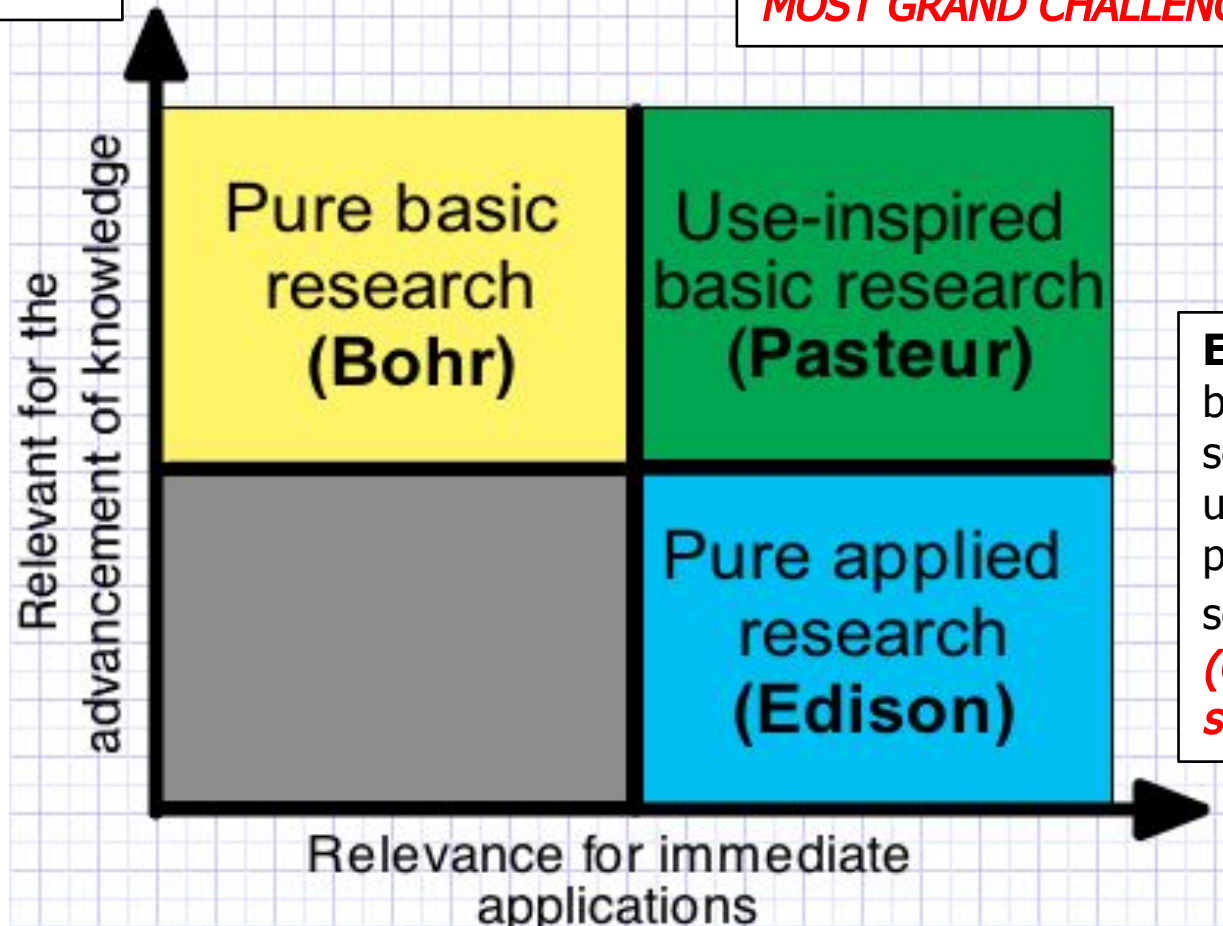
Framing Using Pasteur's Quadrant

Bohr – Guided solely by the quest for understanding without thought of practical use.

SOME GRAND CHALLENGES

Pasteur – Includes Basic Research that seeks to explain the frontiers of understanding, but is also use-inspired.

MOST GRAND CHALLENGES



Edison – Guided solely by applied goals without seeking a more general understanding of the phenomena of a scientific field.

(Could be required steps in a challenge.)

Some Properties of Grand Challenges

1. **Impactful** — Does the challenge address a critical societal problem?
2. **Ambitious** — Is the challenge tackling a problem of substantial complexity?
3. **Barely Feasible** — Are there major technical obstacles that need to be overcome to address the challenge in a reasonable timeframe?
4. **Interdisciplinary** — Does the challenge require expertise from multiple fields of study and stakeholders from diverse backgrounds?
5. **Measurable** — Are there clear and meaningful indicators of success?

Key Questions for defining Grand Challenges

What is the challenge?

A 1-2 sentence description of the specific goal that embodies the challenge. The societal impact and tangible product(s) follow from this description.

Why is this a barely feasible, “grand”, challenge?

A brief description of how things are done today, what scientific/engineering limits need to be pushed, and why the challenge is hard and interdisciplinary.

How will we know if we succeeded?

Measures for success and progress.

Some of what we heard in our Roundtables

- Multilingual accessible AI with universal real-time translation
- Computer systems and AI for personalized healthcare
- Using AI to solve complex problems in CS, including P vs NP
- Align AI with human values
- Ubiquitous information provenance
- Consumer-Grade Quantum Computing
- Net zero computing
- Cybersecurity and sustainability in edge computing
- Make remote work as seamless and meaningful as in-person work

Net Zero Computing

What is the challenge?

Transform computing by finding the best balance between resource use, environmental impact, and societal benefits.

Why is this a barely feasible, “grand”, challenge?

This will require both technological advances as well as a culture change within the research community. Needs advances in hardware, systems software, algorithms, applications, and theoretical foundations (new analogs to space/time complexity).

How will we know if we succeeded?

Success will be achieved when we can quantify the true cost of running a program and make decisions informed by this knowledge. Is it justifiable to expend large computing resources to yield energy savings elsewhere? How can the research community be coaxed away from traditional success measures (error rates on a task) toward comprehensive measures that account for all costs / benefits?

Data-Driven Healthcare

What is the challenge?

Transform how doctors deliver healthcare by considering personal data (e.g., bloodwork labs, fitness trackers, symptoms, existing diagnoses and medicines, genomic information) in the context of data collected for all individuals seeking healthcare across the country/world in order to provide personalized treatments and recommendations.

Why is this a barely feasible, “grand”, challenge?

Privacy and security (sharing and computing on sensitive data); programming languages (interoperability of information arising from distinct hospital systems/coding systems); AI (recognizing shared patterns in data, foundation models); computational biology and medicine (genomic information, personalized medicine, pharmacogenomics)

How will we know if we succeeded?

Measured by the extent of adoption of precision health solutions leveraging knowledge from across the world personalized to individual's context

Ubiquitous Information Provenance

What is the challenge?

Develop technology to facilitate reliable, accurate, and ubiquitous tracing of the sources for the content of all news articles, photographs, video, and other internet artifacts by 2035. This would be an important tool for addressing the problem of disinformation.

Why is this a barely feasible, “grand”, challenge?

Needs new techniques in many CS areas including generative AI, cryptography, information retrieval, human-computer interaction, and systems.

How will we know if we succeeded?

Success is determined by the extent to which the technology is adopted and the error rate of the provenance techniques.

Align AI with Human Values

What is the challenge?

To be able to assess decision outputs of an AI system with respect to their equivalence with human-only decision making.

Why is this a barely feasible, “grand”, challenge?

We don't really understand how humans work, let alone AI; and not all human values are equivalent. If we don't get AI alignment correct we are in deep trouble.

How will we know if we succeeded?

AI will be doing only good and positive things; AI will be ethically equivalent to human decision makers.

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Yikes! What does any of this even mean??

Doesn't indicate any aspect of how it can be done.

Not currently measurable (not realistic); and is this really what we want?

Key Insights about this process

- Grand Challenges are about **both** the journey as well as the destination
- There are two types of “Challenge Destination”:
Conceptual (i.e., a scientific or mathematical hypothesis)
or Physical (i.e., an engineered artifact or tool)
- The impact of the Challenge comes from the journey
- Often there is a sense of urgency

Your turn!

- Break out into small groups of 4-6 people
 - Convene with your neighbors
- Each group will have several copies of a two-sided worksheet
 - One side has the three key questions you will answer per challenge
 - The other side lists properties of a grand challenge
- Breakout session (20 mins)
 - Introduce yourselves, select who will report out 1-2 ideas from the group (5 mins)
 - Ideate on one or more GCs, or where GCs might exist, what you see on the horizon; document findings (15 mins)
- Add a document to this folder if you don't want to use paper

Report out

For each small group:

- Briefly describe your Grand Challenges
- Reflection on the process

Thank you!

Pass your notes to the aisle

Next Steps

Workshop

Grand Challenges in Computing White Paper

If you want to be involved in next steps, complete this form:



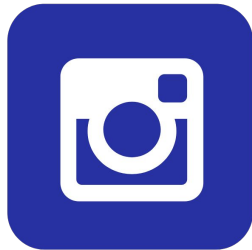


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