Title: A quantum-themed play & (separately) quantum reservoir computing

Speakers: Anna Knörr

Collection/Series: Machine Learning Initiative

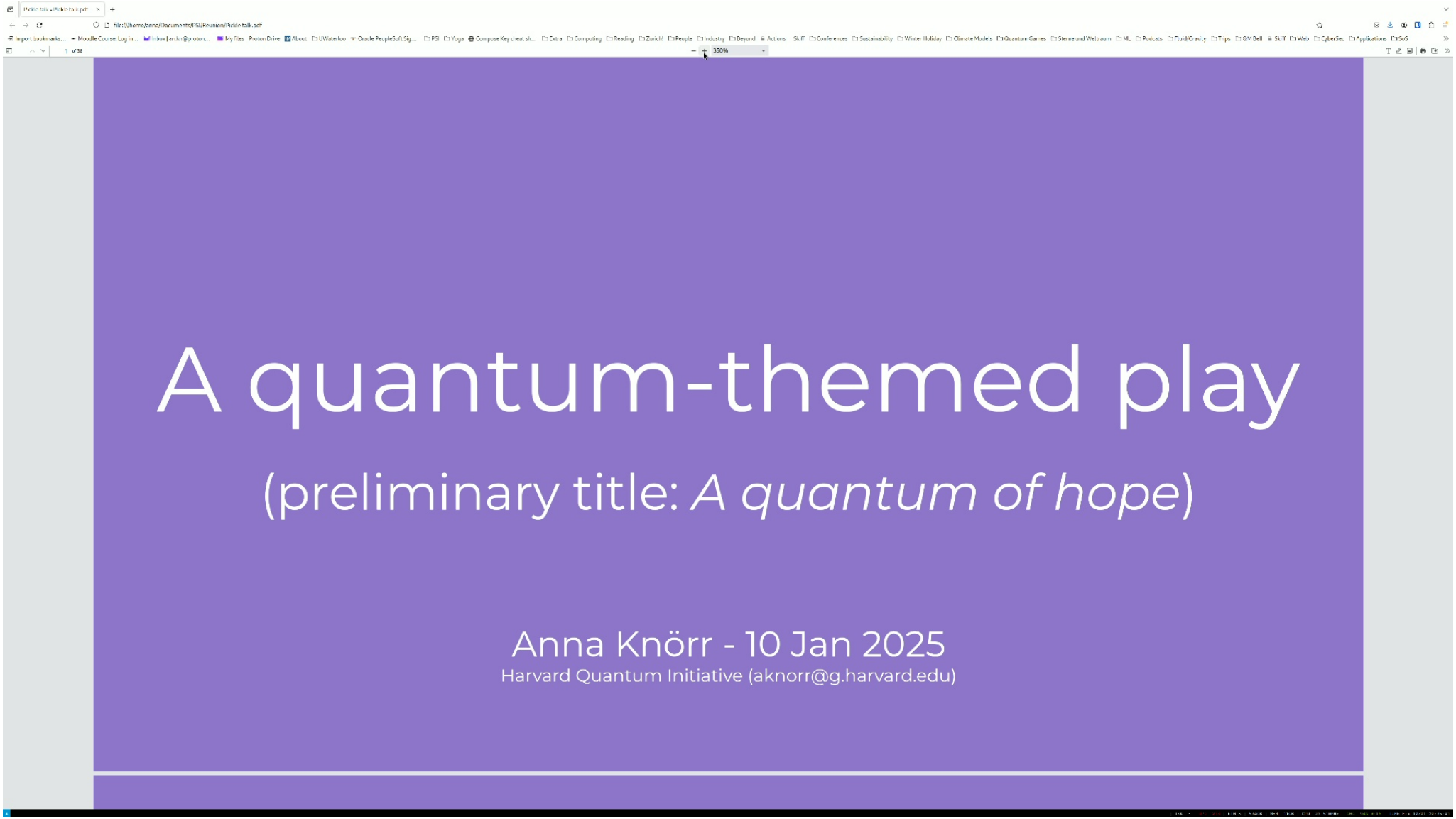
Subject: Other

Date: January 10, 2025 - 2:30 PM

URL: https://pirsa.org/25010070

Abstract:

In this talk I will give updates on two projects: Firstly, Perimeter and Two Small Fish Ventures are currently supporting a group of five PSI alumni in writing a play themed around quantum science & technology, with the goal of enriching public discourse on these fields. On the one hand, we aim to inform the audience about key quantum concepts in an entertaining setting. On the other hand, we are exploring questions such as "Will we really have fault-tolerant quantum computers in five years? Which quantum research is better pursued in industry vs. academia? Who will benefit from commercialization? What drives scientists to do quantum research - for scientific understanding, or because 'today's theoretical physics is tomorrow's technology'?". Five characters debate different takes on these questions in a Douglas-Adams-inspired sci-fi setting.
Secondly, I will review recent developments in classical and quantum reservoir computing.


A quantum-themed play
(preliminary title: A quantum of hope)
Anna Knörr - 10 Jan 2025
Harvard Quantum Initiative (aknorr@g.harvard.edu)

Project origin

Jaime (Niels Bohr Institute, Kopenhagen)

Anna K (Harvard)

Manu (MIT)

Anna B (MIT)

Shawn
(University of Leibniz Hannover)

Science → technology?

1 Sept 2021 - very first day at PI :)

Science → technology?

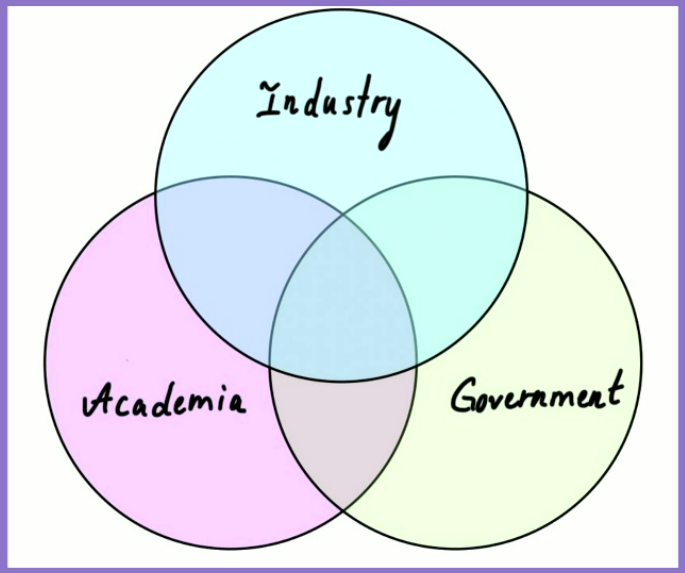
1 Sept 2021 - very first day at PI :)

What motivates researchers?

What motivates research funding?

Quantum science & technology

Quantum ecosystem:



Particularly pertinent & timely case of people with different motivations & visions intersecting.

Themes from 'government' perspective

1) **national security & prestige**, boosting **economy** through innovation

US example:

⟨quantum|gov⟩

FAST FACTS

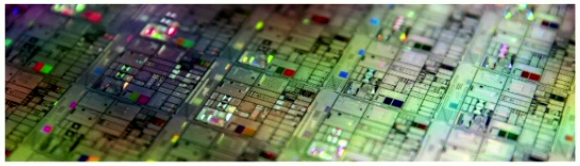
23
Federal agencies involved in the National Quantum Initiative

2018
Year the National Quantum Initiative Act became law and the National Strategic Overview for Quantum Information Science was released

$2.6B
Total U.S. Government investment in the National Quantum Initiative

14
Major National Quantum Initiative Research Centers and Institutes

NATIONAL QUANTUM INITIATIVE



OVERVIEW

Quantum-based technologies have already transformed society and the American economy. Examples include the Global Positioning System (GPS) for navigation, magnetic resonance imaging (MRI) for medical imaging, semiconductors for computer chips, and lasers for telecommunications. Quantum information science (QIS) holds promise for another revolution in technology, with new, more powerful approaches to computing, networking, and sensing. **The National Quantum Initiative (NQI) is a whole-of-government approach to ensuring American leadership in QIS**.

Themes from 'government' perspective

1) **national security & prestige**, boosting **economy** through innovation & job creation

e.g. at US state level:

Source

Boston Consulting Group for the Chicago Quantum Exchange, 2024.

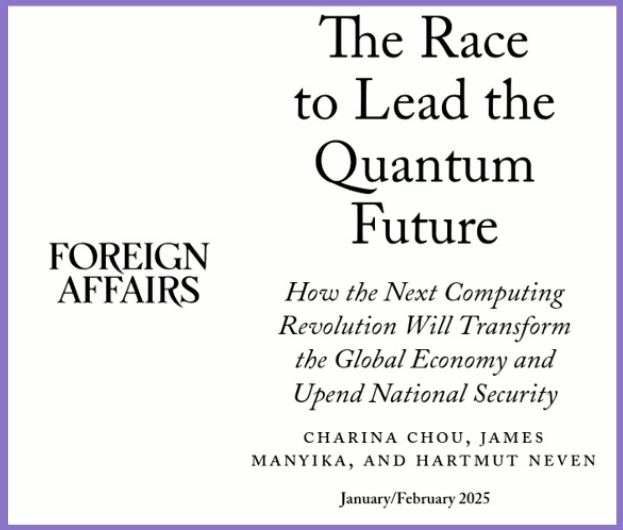
The workforce debate:

On the one hand, yes, we do want to be inclusive.

On the other hand, can this promise of creating that many jobs 'for everyone' be fulfilled?

Themes from 'government' perspective

2) **geopolitical race**



"There are multiple futures for a world with quantum computers. The best one would see liberal democracies leading both the technology's development and its collective management. A worse one would have the United States and its international partners, through inaction or insufficient actions, cede dominance of the new technology to China and other autocratic countries"

Themes from 'government' perspective

2) **geopolitical race** - not just talk

FOR IMMEDIATE RELEASE
September 5, 2024
https://www.bis.gov

BUREAU OF INDUSTRY AND SECURITY
Office of Congressional and Public Affairs
Media Contact: OCPA@bis.doc.gov

Department of Commerce Implements Controls on Quantum Computing and Other Advanced Technologies Alongside International Partners

In today's IFR, BIS is implementing worldwide export controls on specific types of items, including:

- **Quantum Computing Items**: quantum computers, related equipment, components, materials, software, and technology that can be used in the development and maintenance of quantum computers.

Cybersecurity & Tech | Foreign Relations & International Law

Technology Controls to Contain China's Quantum Ambitions Are Here

Elias X. Huber | Thursday, August 22, 2024, 8:00 AM

Share On:

They are neither effective nor desirable.

Themes from 'government' perspective

3) flipside: international equity - **avoid exacerbating 'digital divide'**

(based CERN, Geneva)

State-of-play in the governance of quantum computing for the SDGs

ACCESS – mitigating the risk of a new digital divide

- Initially coined to highlight gaps in internet connectivity, the term 'digital divide' is increasingly used more broadly to encompass the world's unequal access to digital technologies[26]. These inequalities exist between countries, regions, and specific populations according to age, gender, and socioeconomic factors. At the multilateral level, the U.N. Secretary-General's call to develop a Global Digital Compact[27] and the U.N. General Assembly's decision to appoint co-facilitators in support of this effort reflect, among other things, global concerns about the digital divide and the need for multi-stakeholder action to foster an inclusive and sustainable digital future for all.
- Quantum computing has been recognized as a technology that could exacerbate the digital divide. Investment in quantum computing is polarized[28]. The fastest-moving countries are adopting national quantum strategies to coordinate efforts between academia and industry, repatriate enabling technologies, and educate a quantum-ready workforce.

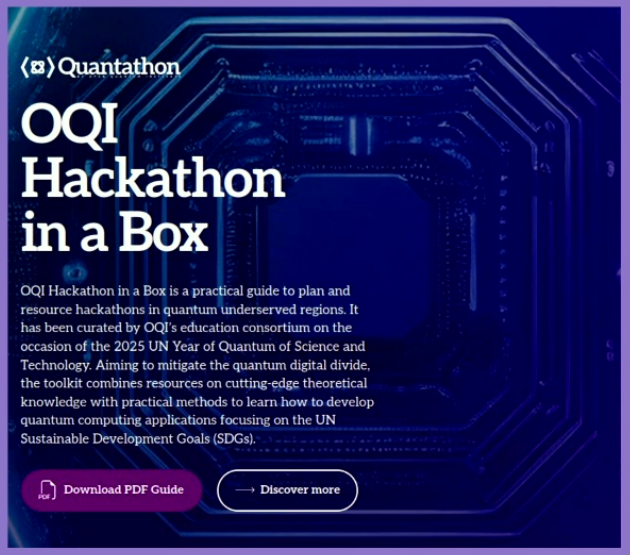
Source:
OQI's "Intelligence Report on the multilateral governance of quantum computing for the SDGs." (2023)

Themes from 'government' perspective

3) flipside: international equity - **avoid exacerbating 'digital divide'**

OQI
Open Quantum
Institute

(based CERN, Geneva)



Themes from 'government' perspective

3) flipside: international equity - **avoid exacerbating 'digital divide'**

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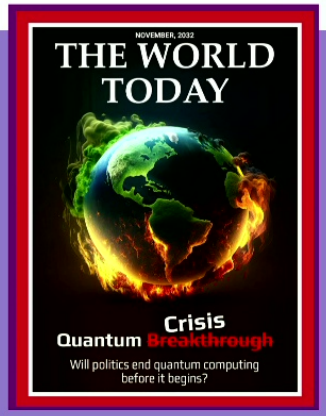
Let's anticipate!

Quantum computing represents a complete change in the way computation has been practiced by humanity so far. For specific applications, quantum computers might, in principle, solve problems that are today intractable by conventional computers. How can we make sure quantum computing to benefit all in the best way? How to co-shape collectively the future governance of the technology?

This serious game on quantum computing multilateral governance brings challenges and opportunities to life in a fictional scenario. It is open to the public and designed to promote science diplomacy in an anticipatory, action-oriented, and inclusive manner and foster public-private partnerships.

The Story.

The year is 2032. Large-scale quantum computing has been achieved, but the costs of running these systems are still too high for general commercial use. Quantum computers are capable of processing orders of magnitude more data, more quickly than conventional computers, making them suited for complex, computationally-expensive tasks. Several nation states have quantum computer systems operated by research institutions, but the technology is still inaccessible for most.



Themes from 'industry' perspective

1) **NISQ-era hype** about 'having practical quantum utility now': often generated in partnership with end-user companies,

e.g. energy utilities

Note: It's absolutely true that our power grid is becoming much more complex, e.g. due to variability of renewables, bi-directional flow etc.

Utilities are certainly innovating, e.g. by building foundation models to optimize the grid. But no, current NISQ hardware & optimization algorithms won't help us with that.

*NISQ = Noisy Intermediate-Scale Quantum Devices

Themes from 'industry' perspective

1) **NISQ-era hype** about 'having practical quantum utility now':
often generated in partnership with end-user companies,

e.g. energy utilities

In reality:

no value (in terms of performance or economic) through using a QPU so far.

*NISQ = Noisy Intermediate-Scale Quantum Devices

Themes from 'industry' perspective

2) **Techno-optimist hype** about 'quantum solving our biggest problems':

e.g.

Difference to 1):

- Emphasis in 1 is on non-existent value of NISQ for real-world applications.
- Emphasis in 2 is suggestive *down-playing of many other factors* (e.g. political will, inertia of infrastructure, financing of existing technologies)

→ shoutout to Brian Lasher for decarbonizing PI's heating infrastructure!

Themes from 'industry' perspective

3) What about pursuit of (useful) **FTQC**?

Yes, **significant breakthroughs** have been achieved.
(both in academia, as well as industry - see Physics World Breakthroughs 2024 awarded to Misha Lukin, Dolev Bluvstein & collaborators @ Harvard → 48 logical qubits,
and Hartmut Neven & collaborators @ Google Quantum AI → QEC below surface threshold)

*FTQC = Fault-Tolerant Quantum Computers

Themes from 'industry' perspective

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> Willow's performance on this benchmark is astonishing: It performed a computation in under five minutes that would take one of today's fastest supercomputers 10^{25} or 10 septillion years. If you want to write it out, it's 10,000,000,000,000,000,000,000,000 years. This mind-boggling number exceeds known timescales in physics and vastly exceeds the age of the universe. It lends credence to the notion that quantum computation occurs in many parallel universes, in line with the idea that we live in a multiverse, a prediction first made by David Deutsch.

Source: "Meet Willow, our state-of-the-art quantum chip",
by Hartmut Neven, Founder & Lead of Google Quantum AI

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Themes from 'industry' perspective

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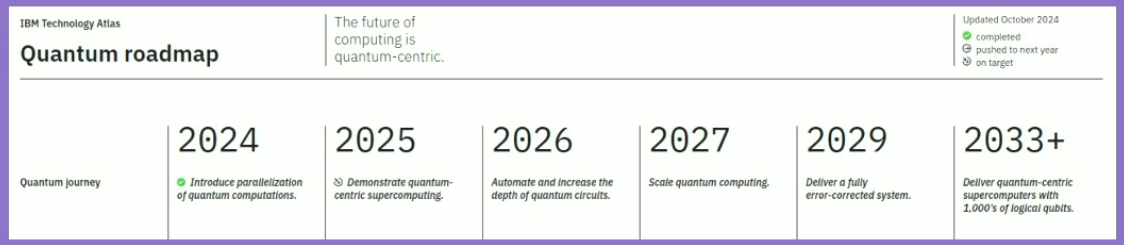
Also, flourish of corporate quantum **roadmaps** now provide more accountability moving forward ('era of delivery') - will they **deliver on time?**
(e.g. IBM aiming for ~1000 logical qubits by 2033+. This would indeed start unlocking applications, e.g. calculating binding affinities in chemistry, but also cracking RSA 2048)



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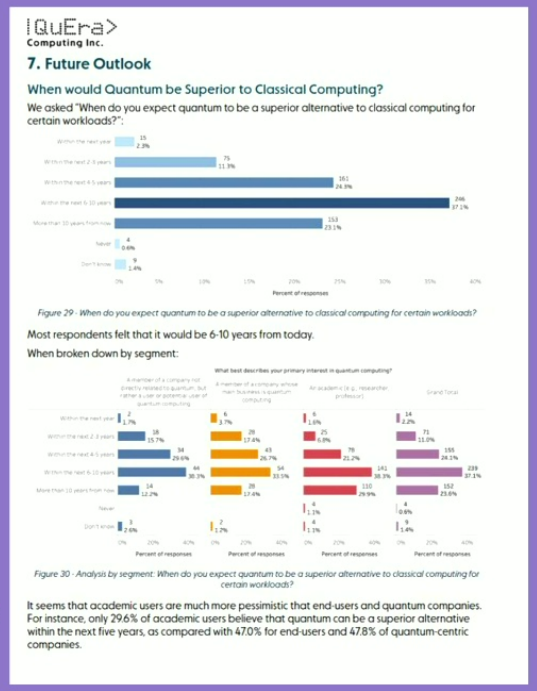
DARPA Quantum Benchmarking Initiative (QBI) has likely also had a sobering effect.

"'Our opening position is skepticism,' said Dr. Joe Altepeter, the DARPA program manager leading the charge on this exploration. "Specifically, skepticism that a fully fault-tolerant quantum computer with a sufficient number of logical qubits can ever be built. We will walk into the room and say, 'We're pretty sure whatever you're doing is not going to work.' I will bring a small army of scientists and engineers, we will listen to your evidence, and we will double and triple check using our own analysis. And if we're convinced the technology you're developing checks out and you're onto something big, we'll tell the rest of government and become a strong advocate for your approach."

Themes from 'academia' perspective

1) Generally, **more skepticism** that we will reach the FTQC milestones on those timescales.



QuEra Computing Inc.

7. Future Outlook

When would Quantum be Superior to Classical Computing?

We asked "When do you expect quantum to be a superior alternative to classical computing for certain workloads?":

Figure 29 - When do you expect quantum to be a superior alternative to classical computing for certain workloads?

Most respondents felt that it would be 6-10 years from today.

When broken down by segment:

Figure 30 - Analysis by segment: When do you expect quantum to be a superior alternative to classical computing for certain workloads?

It seems that academic users are much more pessimistic that end-users and quantum companies. For instance, only 29.6% of academic users believe that quantum can be a superior alternative within the next five years, as compared with 47.0% for end-users and 47.8% of quantum-centric companies.

Engaging with the public communication of your institution

Quantum vs. classical computers | Beginner's guide

PERIMETER INSTITUTE

previously:

Climate modelling and weather forecasting

Quantum computers could improve climate modelling and weather forecasting by more precisely simulating the complex interactions within the Earth's atmosphere. This could lead to better predictions of extreme weather events, helping communities prepare and respond more effectively.

now changed to:

Climate modelling and weather forecasting

Quantum computers could improve climate modelling and weather forecasting by more precisely simulating the complex interactions within the Earth's atmosphere. If implemented alongside new policy measures, this could lead to better predictions of extreme weather events, helping communities prepare and respond more effectively.

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PERIMETER INSTITUTE

previously:

From securing our digital lives and advancing medical research to optimizing financial systems and improving climate models, quantum computers promise to revolutionize many aspects of our world.

The future of computing is quantum, and it may be closer than you think.

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Stephan Rasp

Senior Research Scientist at Google

Munich, Germany

Email

Twitter

GitHub

Google Scholar

LinkedIn

Lorenz '96 is too easy! Machine learning research needs a more realistic toy model.

launch binder *Clicking on the Binder button will open an interactive notebook, in which you can reproduce all visualizations and results in this post.*

Ed Lorenz was a genius at coming up with simple models that capture the essence of a problem in a much more complex system. His famous butterfly model from 1963 jump-started chaos research, followed by more sophisticated models to describe upscale error growth (1969) and the general circulation of the atmosphere (1984). In 1995, he created another chaotic model that shall be the topic of this blog post. Confusingly, even though the original paper appeared in 1995, most people refer to the model as the Lorenz 96 (L96) model, which we will also do here.

The Lorenz 96 model

Let's briefly introduce the model. Here, I will use the notation from Schneider et al. 2017. In its simplest version the model is described by a periodic system of K (k=1,...,K) ODEs:

$$\frac{dX_k}{dt} = \underbrace{-X_{k-1}(X_{k-2} - X_{k+1})}_{\text{Advection}} \underbrace{-X_k}_{\text{Diffusion}} \underbrace{+F}_{\text{Forcing}}$$

The first term on the right hand side is an advection term, while the second term represents damping. F represents an external forcing term, which is set to 10. Because this is a periodic system we can visualize it's evolution in a circular plot:

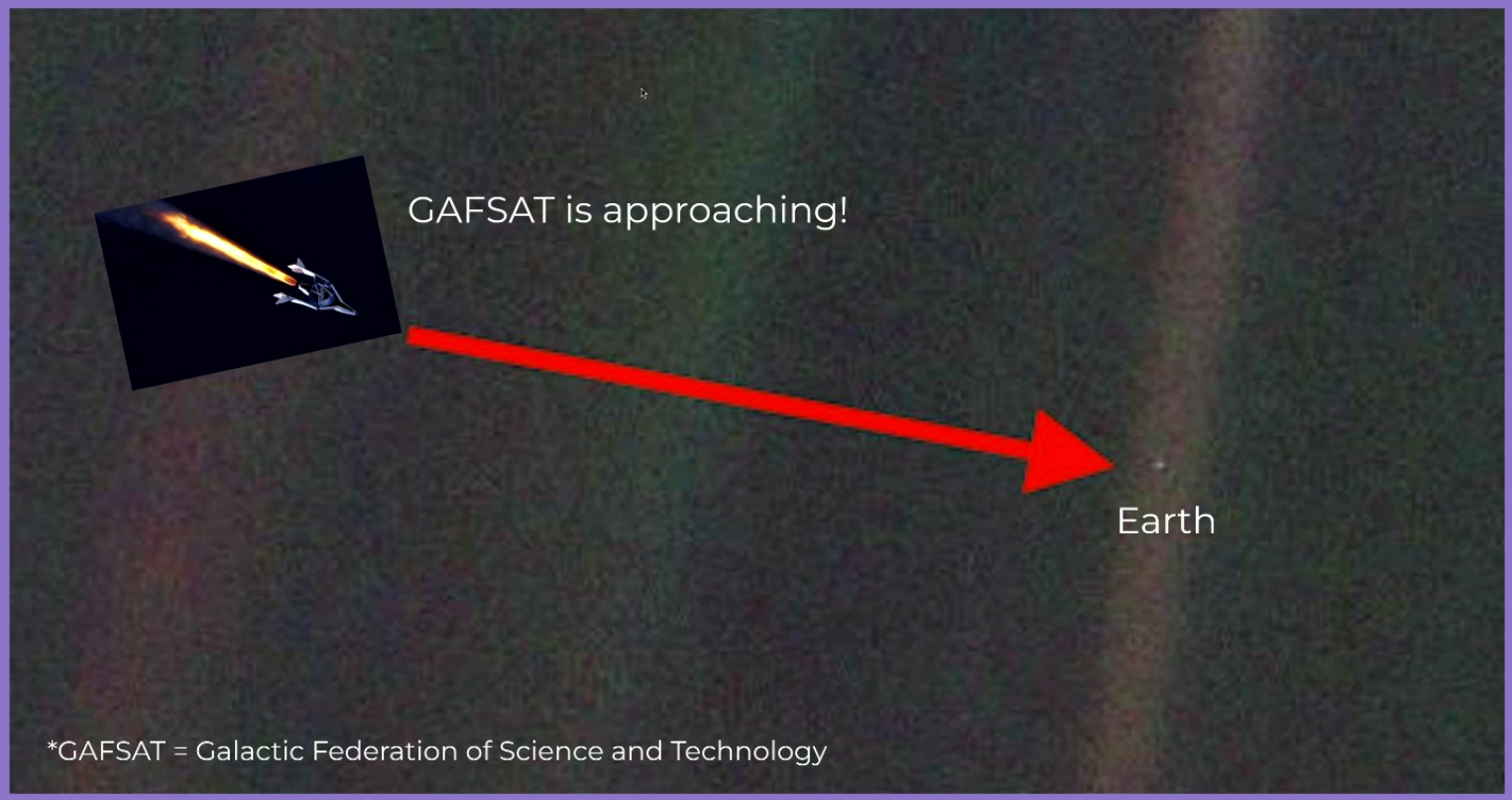
For parameter estimation or parameterization research, it is most common to use the two-level version of the L96 model. For this we add another periodic variable Y with its own set of ODEs. The X and Y ODEs are linked through coupling term which is the last term in both equations below. Each X has J Y variables associated with it.

$$\frac{dX_k}{dt} = \underbrace{-X_{k-1}(X_{k-2} - X_{k+1})}_{\text{Advection}} \underbrace{-X_k}_{\text{Diffusion}} \underbrace{+F}_{\text{Forcing}} \underbrace{-hc\bar{Y}_k}_{\text{Coupling}}$$

$$\frac{1}{c}\frac{dY_{j,k}}{dt} = \underbrace{-bY_{j+1,k}(Y_{j+2,k} - Y_{j-1,k})}_{\text{Advection}} \underbrace{-Y_{j,k}}_{\text{Diffusion}} + \underbrace{\frac{h}{J}X_k}_{\text{Coupling}}$$

Again, we can look at a visualization to better understand what's happening.

Setting



The challenge

The challenge

Value(Earthen science) > Value(GAFSAT's science station)?

Earth gets five years to demonstrate the inequality.

For an absurd happen-chance reason, quantum gets chosen as the focus topic. Suddenly, Earth's fate hinges on how impressive quantum research will be in 2030...

The characters

- Spuck, the GAFSAT officer
- Puck, the helpful fairy
  (helps set up plot, narrates interludes on quantum history)

- The Council Members
  (Chosen by Puck - suspension of disbelief)
  - CM1: Herr Professor
  - CM2: CTO at Big Quantum Inc
  - CM3: Harvard's New Toy
  - CM4: Mid-career scholar
  - CM5: Co-founder at Small Quantum Inc

The proposals (in slogans)

#1: NISQ
'If we make NISQ devices easy to use, the applications will emerge… let's unlock the NISQ potential together!'

#2: Quantum Sensors
'By uplifting sensors and scientific measurements, we uplift all science!'

#3: Quantum simulation
'Look we know you don't think efficient batteries are sexy but have you seen the scope of the ensuing energy crisis?'

#4: FTQC
'The hurdles to quantum computing are overcomable engineering challenges'

#5: The ontological quest
'Let's get to the heart of quantum weirdness'

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#5: The ontological quest
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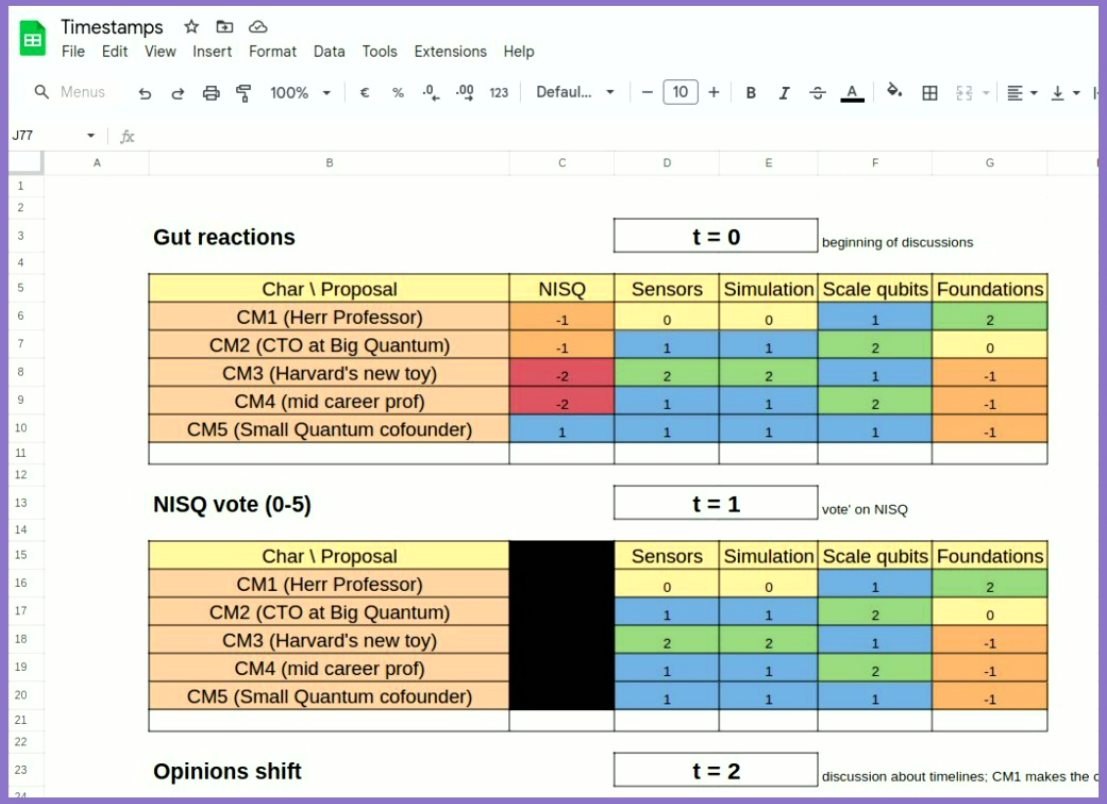
Throughout play: CMs **debate** the merits of each proposal (with personal tensions between them rising), **and vote**.
#1 is voted out due to lack of ambition, #5 due to foundations research being ill-suited to five year time pressure. 2, 3 and 4 remain, CMs can't agree.

→ **Play ends on audience vote**.
We'll be curious to see the sampled distribution over many performances :p

Physicist approach to writing the play...



Timestamps

File Edit View Insert Format Data Tools Extensions Help

Gut reactions — **t = 0** beginning of discussions

Char \ Proposal	NISQ	Sensors	Simulation	Scale qubits	Foundations
CM1 (Herr Professor)	-1	0	0	1	2
CM2 (CTO at Big Quantum)	-1	1	1	2	0
CM3 (Harvard's new toy)	-2	2	2	1	-1
CM4 (mid career prof)	-2	1	1	2	-1
CM5 (Small Quantum cofounder)	1	1	1	1	-1

NISQ vote (0-5) — **t = 1** vote' on NISQ

Char \ Proposal	[redacted]	Sensors	Simulation	Scale qubits	Foundations
CM1 (Herr Professor)		0	0	1	2
CM2 (CTO at Big Quantum)		1	1	2	0
CM3 (Harvard's new toy)		2	2	1	-1
CM4 (mid career prof)		1	1	2	-1
CM5 (Small Quantum cofounder)		1	1	1	-1

Opinions shift — **t = 2** discussion about timelines; CM1 makes the c

Staging inspiration

The Masterplan @ Soulpepper Theater, Toronto


Timeline
Reunion
Mini-workshop @ HQI
June 24
Sept 24
Dec 24
→ storyboard
→ characters
→ first round of feedback (from editor + friends)
→ draft script writing!
Staged reading @ PI's 25th anniversary celebration!
Feb 25
Sept 25
→ draft editing
→ production of accompanying material (proposal videos, proposal posters)