Computing and the Future

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Gresham College (20 October 2016 – 12 June 2018)

Four years ago, I told Gresham College that I was worried about software

Modern society is dependent on computers. Less than 70 years after the first successful program … we are on the verge of the "internet of things", where almost everything could contain intelligence and be network connected. …

But all this progress is dependent on a software industry that is still at the craft stage, 45 years after the phrase "software engineering" first came into common use.

My lecture programme will explore the state of software today, how we got to where we are, and what we shall need to do to shore up the foundations of a digital society that is increasingly built on sand.

Key points from the lectures

1. **Should we trust computers?**

Only with good evidence! Get the evidence first, and only then trust the software

2. **A brief history of computing 1948 - 2015**

Hardware development has become professional engineering. Software remains a craft

3. **How can software be so hard?**

Software is very complex. It contains the inherent complexity of the application - and more!

4. **Computers, people and the real world**

There is no such thing as an "IT Project". Ask the staff in the front line.

5. **Cybersecurity**

Cybersecurity is mainly a problem of badly designed software

6. **Big data and the broken promise of anonymity**

It is usually impossible to anonymise data about individuals

Key points from the lectures

7. Are you the customer or the product?

The data you reveal will be used to make hidden decisions that affect you.

8. Safety-critical systems

International standards for safety-critical software need urgent revision

9. The dilemmas of privacy and surveillance

Policing of cyberspace must be effective but shown always to be proportionate

10. What really happened in Y2K?

Y2K was a genuine threat and nearly a disaster. The lessons have not been learnt

11. Making software correct by construction

Mathematically formal software development is practical and cost effective

12. Artificial intelligence

An AI system will one day be able to do everything that a human can—but not in my lifetime.

Key points from the lectures

13. Is society ready for driverless cars?

Society is not ready — and neither are the technology and regulation

14. Will bitcoin and the blockchain change the way we live and work?

Distributed ledger technologies are more significant than cryptocurrencies

15. Computer bugs in hospitals - a new killer

Safety assurance and regulation of medical devices and systems are not fit for purpose.

16. Should we vote online?

Voting is a uniquely difficult question for computer science and currently unsolved

17. The internet of things

Our cyber-enabled society needs rigorously engineered foundations or it will fail

18. Computers and warfare

The threat of cyberwar needs a much stronger and more strategic response

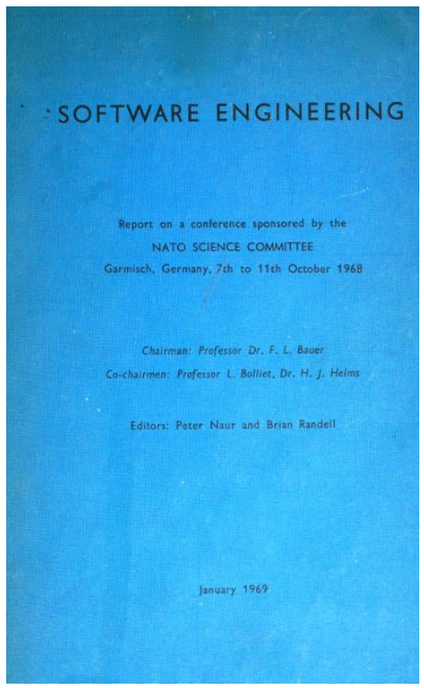
19. Computers and the future

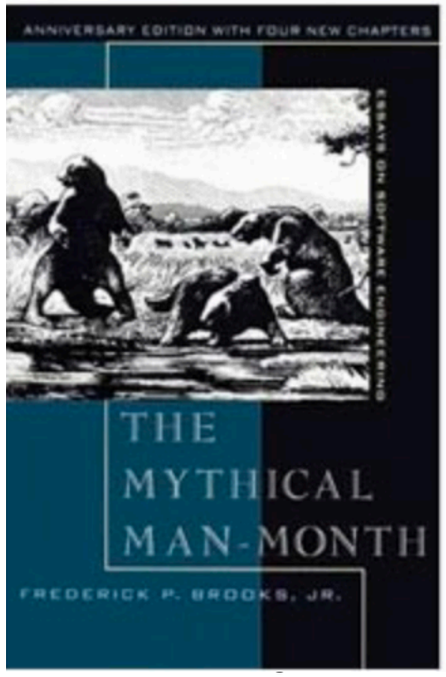
“Those who cannot remember the past are condemned to repeat it.”

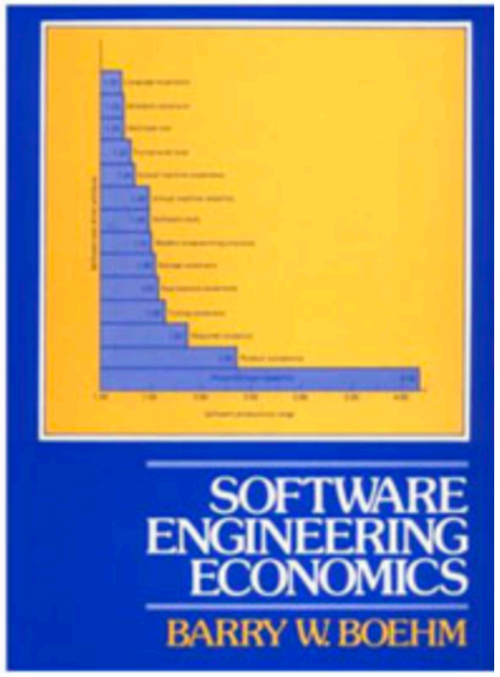
–*George Santayana.* The Life of Reason: Vol 1 - Reason in Common Sense

Despite the fast-moving technology of computing, it is rare to encounter a completely new mistake – they are almost always versions of mistakes that others have experienced before.

It is important to know the history of one’s profession







Gresham's Law

(of computing)

Bad software drives out good

"There is almost nothing in this world that some man cannot make a little worse and sell a little more cheaply. He who buys on price alone is that man's lawful prey"

– attributed to John Ruskin (probably wrongly)

Careless software costs lives …

and destroys businesses, and wealth and jobs …

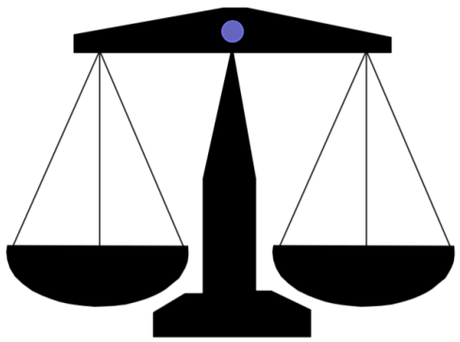
- When a civil engineer designs something – a block of flats, a bridge, a dam … other people must trust her competence and methods. Testing would not be enough.

- Designing *software* that others must trust also calls for competence and the use of strong methods with scientific foundations.

- A software engineer should deliver evidence that their software is trustworthy - evidence from testing alone is insufficient. Analysis and reasoning are essential.

Testing software shows only that the tests work …

… if they are run under these conditions, with this version of the software …



Continuous behaviour means you can interpolate between test results

Discrete behaviour means that you can't!

It is easy to write programs that work for some input values and fail for others that fall in the same ranges.

Most programmers do this all the time.

Don’t ask your Gynaecologist to fix your teeth

- **Professionals specialise.** Engineers specialise in engineering areas (civil, mechanical, electrical, chemical …) and in application domains (rail, reservoirs, aircraft, nuclear, offshore…).

- Most engineering projects need a team of different specialists

- recognition of the need for specialist skills is a measure of the maturity of a profession

- Software engineers should specialise too– don’t expect a database specialist to be able to design secure cryptography, or a website designer to design a safe control system …. or vice versa

What does the future hold?

- Many innovative products and services … …
- There could be huge benefits if the software is developed professionally and shown to be secure and effective …
- … or we can continue as usual and risk losing everything

“The future is already here — it's just unevenly distributed”

–William Gibson, quoted in The Economist, December 4, 2003

Robots

What is the truth?

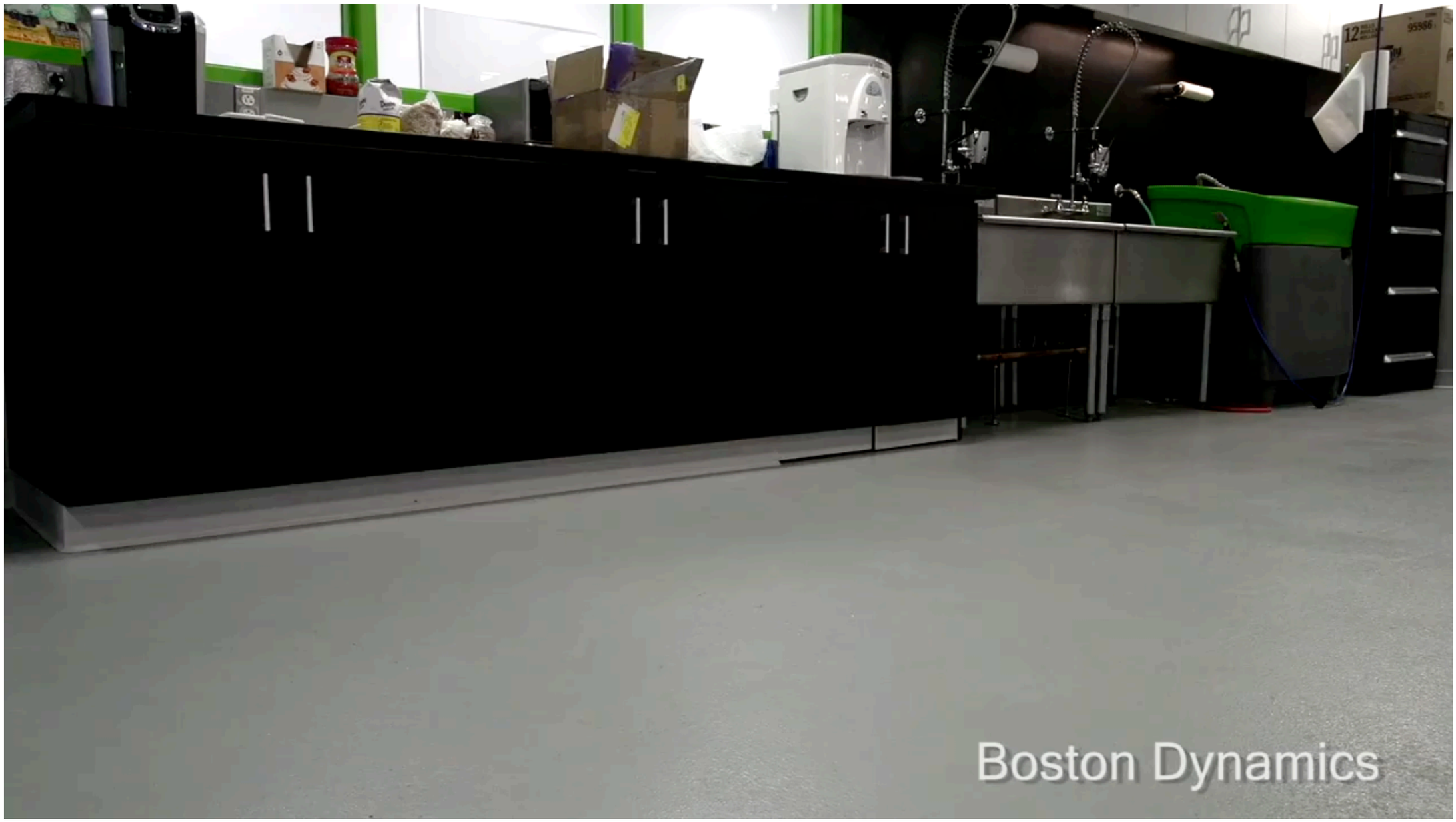
Quantum Computing

Artificial Life

Robots: Increasingly capable

“Introducing Handle”

“Hey, buddy, can you give me a hand?”



Increasingly lifelike …

Robots

What is the truth?

Quantum Computing

Artificial Life

What is truth?

(re) creating history

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John F Kennedy's lost 'last' speech recreated

The voice of John F Kennedy has been used to reconstruct the speech he was due to deliver on the day he was assassinated.

President Kennedy was on his way to the Dallas Trade Mart to address the Citizen's Council when he was shot and killed on 22 November 1963.

Edinburgh company CereProc used audio and text from 831 of his speeches to recreate his words.

They were able to reproduce all 2,590 words from the 20-minute speech.

16 Mar 2018

Share

… and even create lip-synchronised video

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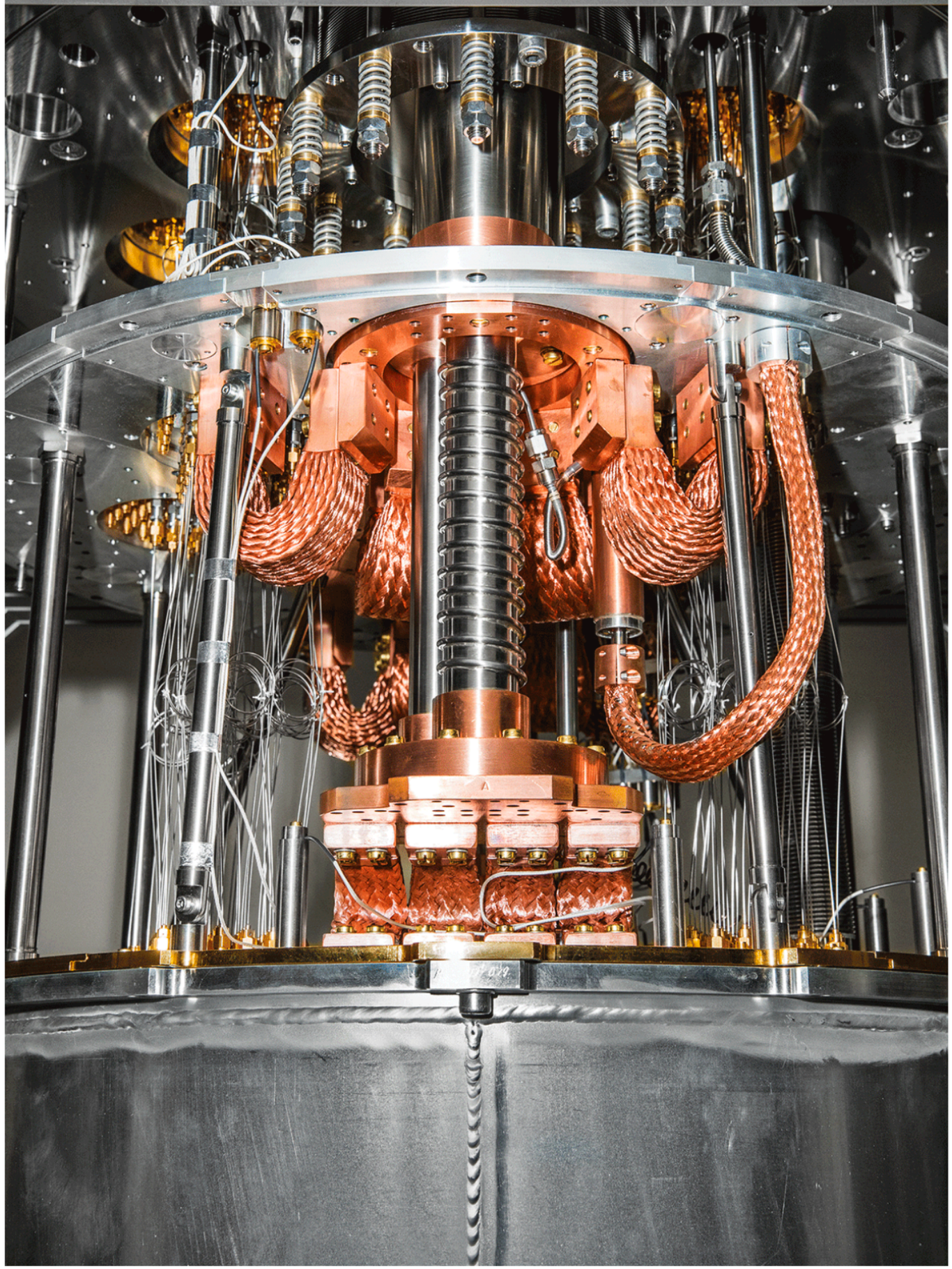

The chips inside IBM's quantum computer (at bottom) are cooled to 15 millikelvin.

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Quantum computing

- Richard Feynman said that much interesting behaviour in the world is quantum, so detailed simulations of this quantum behaviour will need quantum computing.

- Quantum computation using superposition and entanglement means that N qubits can represent 2^N states.

- IBM has built a 50 qubit machine - it's currently stable for only about 100 micro-seconds. Quantum computing is a scientific reality — but an engineering nightmare

- If we can achieve 3000 - 5000 qubits in a practical computer, we can tackle some problems that non-quantum computers could *never* solve — though there is a theoretical argument that even 400 qubits would exceed the maximum information that the universe can hold.

- Smaller quantum computers and Peter Shor's algorithm will break most existing online security and encryption, perhaps in the next 10 years. Post-quantum crypto is already important for highly sensitive secrets.

This lab at IBM houses quantum machines connected to the cloud.

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Robots

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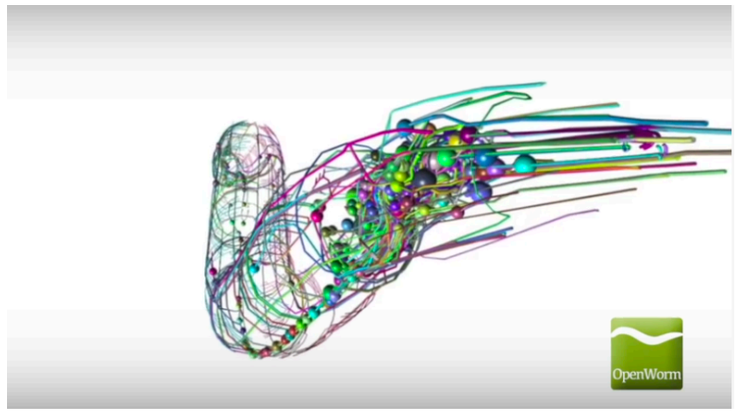
Life *in silico?*



- Caenorhabditis elegans (c. elegans) is a roundworm, about 1mm in length;

- its entire genome has been mapped and so has much of its proteome and it is a standard model organism for many biologists.

- The OpenWorm project aims to use the data to create the first digital life form.

- When someone succeeds, could they run an accelerated evolution? Where might that lead?

- Is it too soon to start considering the implications and how society should respond?

No shortage of topics for future Gresham IT Professors!

- growing adoption of facial recognition (China, Singapore, Notting Hill …) — despite a false positive rate of 90%.
- Commercial use of drones
- Brain-computer interfaces
- …

What sort of future do we want for ourselves and our children?

Conclusion

Digital systems have enormous potential to improve our prosperity, our leisure, our work, our healthcare and our overall quality of life but these benefits are threatened by the poor quality of so much software development and by the growing cybersecurity threat.

Strong software engineering — using science-based methods and tools — is practical and cost-effective. We should expect and accept nothing less.

Questions?

… and thanks for listening for the last three years

“ If men could learn from history,
what lessons it might teach us!
But passion and party blind our eyes
and the light which experience gives is
a lantern on the stern,
which shines only on the waves behind us!”

Samuel Taylor Coleridge (1772-1834)