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# IEEE Quantum Computing Summit

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# Introductions

- **Bill Tonti, IEEE Future Directions Committee**
  - Bill proposed the activity and is responsible for funding
- **Travis Humble, Oak Ridge**
- **Scott Holmes, Booz-Allen Hamilton**
  - Technical Organizers
- **Terence Martinez, IEEE Future Directions Committee**
  - Meeting arrangements
- **Lee Gomes**
  - Writer
- **Everybody else**
  - Let's go around the room and have everybody state their name and affiliation

# Outline

- **Context, goals, objectives, and resources**
- **Quantum Computer Scale up**
- **Schedule of the Meeting**

# Summit Overview

## Context

- Quantum Computing is getting increased attention
- IEEE seems expected to play role in quantum computing
  - But IEEE is a blank slate right now; no commitments to anybody
- Objectives
  - Propose a position for IEEE on what's realistic
  - Propose future activities for IEEE
  - Propose a follow-on to this summit; we have a budget

# Format of Summit

## Guided working group

- Not a meeting for participants to present their work
- Five plenary presentations to provide context

Three 2-hour periods of three tracks, total 9 sessions

- Each group discusses one issue per session
- Create a couple PowerPoint slides and out brief
- Create some notes for Lee Gomes
- We'll jointly organize sessions so common interests are sequential in time (hardware/software/etc.)

Participants don't have to follow the issues as defined

# Google Doc

The agenda is an editable Google Doc

- Google Docs is a double-edged sword
- [https://docs.google.com/document/d/1gwQlhNbkMGiZEyHSmfimcYQsrWdY2c\\_Ly3uMP3b0yGQ/edit](https://docs.google.com/document/d/1gwQlhNbkMGiZEyHSmfimcYQsrWdY2c_Ly3uMP3b0yGQ/edit)

Erik DeBenedictis has a directory with some files

- <http://www.debenedictis.org/erik/qc-summit/>
- If you forget the Google Docs link, it is in [agenda.pdf](#) in the directory

We're not going to use the Google Doc for much longer

# Additional Logistics

A day-and-a-half

- All day Thursday; until 2 PM Friday
- I'm not leaving until later; could continue

Lunch and break provided

- Dinner on your own (but we may organize on the fly)

Lee Gomes will create the whitepaper

- The group will review the whitepaper and fix it or supply additional content as needed

# Erik's View on Type of Things IEEE Can Do; Debate if you Disagree

IEEE ought to be an honest broker, neutral on issues where members compete

- IEEE should have no opinion on which qubit is better

IEEE can have opinions on some issues

- Examples: Ethical conduct awareness, blockchain

IEEE can offer its traditional services

- Conferences and publications on quantum engineering

IEEE Standards Organization

- IEEE Standards are ways companies can communicate with some legal implications
- Terminology, metrics, etc.



# Quantum Computing or QIS, etc.?

Academic communities embrace the following hierarchy

- Quantum information sciences, comprised of
  - Quantum computing
  - Quantum communications
  - Quantum Sensors
- Post Quantum Cryptology

As far as I can tell...

- IEEE will cover it all at some point
- Quantum computing is in-your-face and urgent
- This group can issue a finding to rescope (question 10)

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# Classical and Quantum Scale Up I

Top level issue (my view)

- The hype around Moore's law is amplifying hype about quantum computers
- I believe "hype control" will be the top-level contribution for IEEE

Technical origin and solution

- Moore's law doesn't apply to all integrated circuits, just ones that have been carefully designed to scale
- Qubits won't scale until one is carefully designed so it does
- Problem is that society jumps over the hard work

# Classical and Quantum Scale Up II

A little more detail

- Moore's wrote his famous paper after industry redesigned one form of integrated circuit so it scaled
- Forget "is Moore's law ending?"; the first integrated circuit was bipolar and stopped scaling long ago
- Other people figured out how to make MOS, FinFET, etc. scale, but not GaAs

Quantum computers

- We've been making scalable device families for years; so why not a scalable qubit?

# Quantum Computer Scale Up I

## Classical

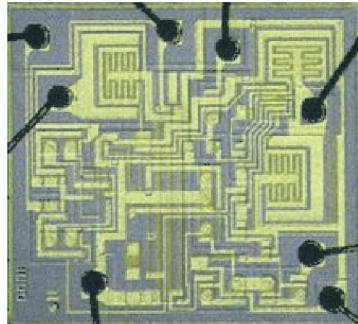
“Flying wire” integrated circuit



<http://www.computerhistory.org/revolution/digital-logic/12/276/1417>

**Fragile structure  
in the third  
dimension,  
scaling probably  
not possible**

555 Timer (1971)



[https://en.wikipedia.org/wiki/555\\_timer\\_IC](https://en.wikipedia.org/wiki/555_timer_IC)

**Solid-state  
structure,  
except bonding  
pads, probably  
possible**

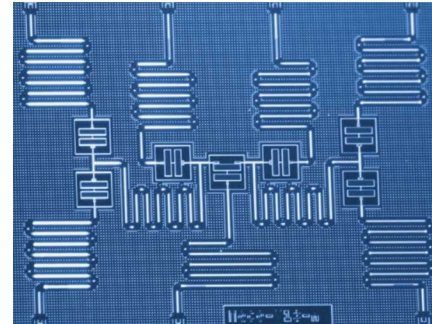
## Quantum

Quantum “chandelier”



<https://spectrum.ieee.org/computing/hardware/europe-will-spend-1-billion-to-turn-quantum-physics-into-quantum-technology>

IBM 7 qubit chip

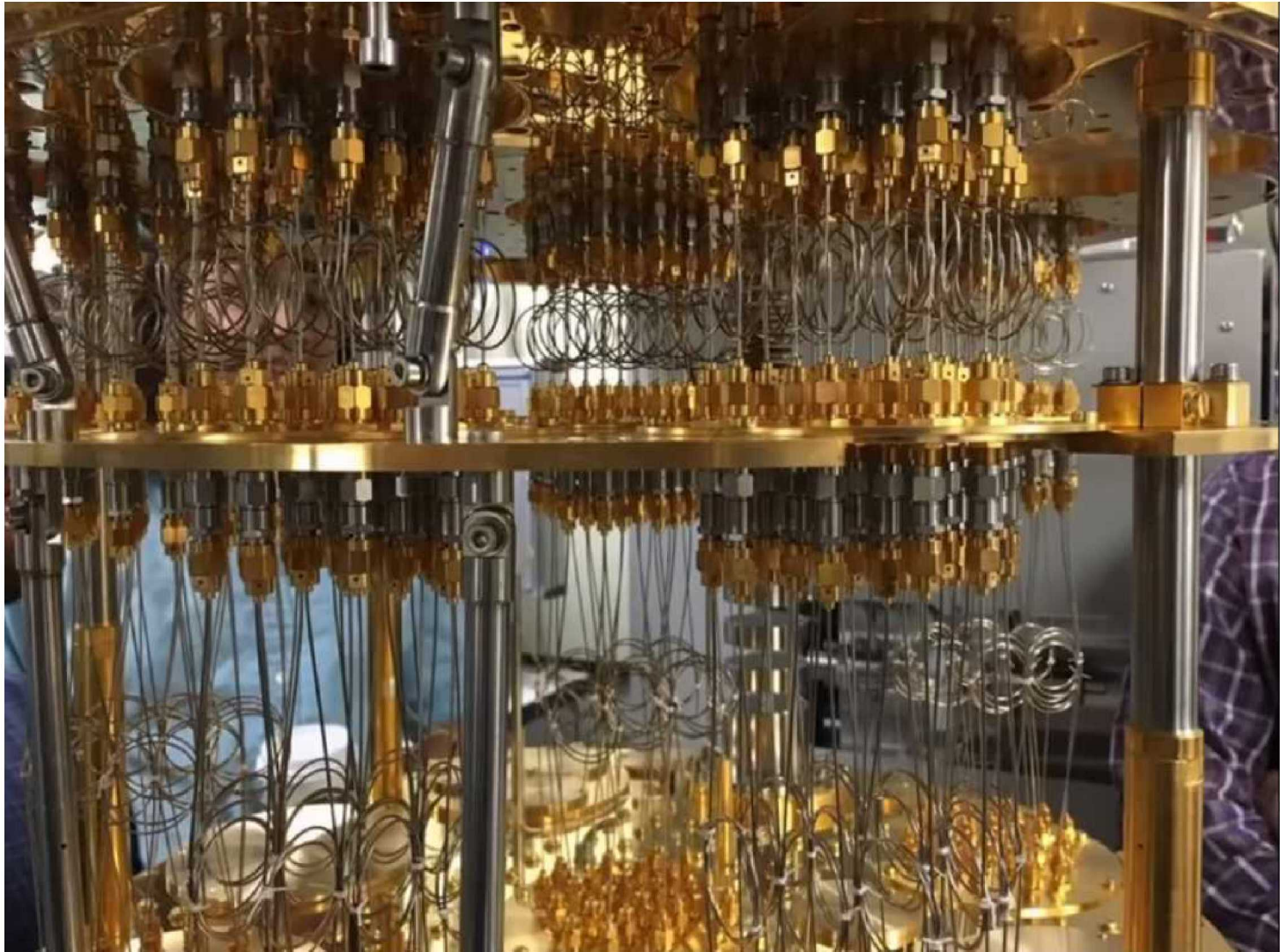


<https://spectrum.ieee.org/tech-talk/computing/hardware/tiny-quantum-computer-simulates-big-molecules>

**Note: This  
is at the  
bottom of a  
“chandelier”**



# Quantum Computer Scale Up II



From <https://www.nextbigfuture.com/2018/02/ibm-doubling-qubits-every-8-months-and-ecommerce-cryptography-at-risk-in-7-15-years.html>

# First Example of Scaling

- The integrated circuit Nobel prize was for TI “flying wire” integrated circuit, which wouldn’t scale physically due to wiring in the third dimension
- The “planar” integrated circuit eventually scaled, but only after electrical design advances like isolation wells and insulating layers
- Materials defects limit scaling of bipolar and MOS, but it was not known at the beginning that materials defects would be worse in bipolar

# A Year Before Moore's Paper

- 10 articles in IEEE Spectrum special issue June 1964 →
- Moore's paper 1965
- The industry was reinvesting profits from improving avionics from discrete transistors to precursors to integrated circuits
- Is this the next few years of quantum computing?

<input type="checkbox"/>	<b>Integrated circuits</b>	
	Patrick E. Haggerty ; C. Lester Hogan ; Robert N. Noyce ; Leonard C. Maier ; J. E. Brown ; C. Harry Knowles	
	Publication Year: 1964, Page(s): 62	
	Cited by: <a href="#">Papers (1)</a>	
	<a href="#">©</a>   <a href="#">🔍</a>   <a href="#">▶Abstract</a>   <a href="#">📄PDF (4655 KB)</a>	
<input type="checkbox"/>	<b>Introduction</b>	
	Patrick E. Haggerty	
	Publication Year: 1964, Page(s): 63	
	Cited by: <a href="#">Papers (1)</a>	
	<a href="#">©</a>   <a href="#">🔍</a>   <a href="#">▶Abstract</a>   <a href="#">📄PDF (154 KB)</a>	
<input type="checkbox"/>	<b>Types of integrated circuits</b>	
	C. Lester Hogan	
	Publication Year: 1964, Page(s):63 - 71	
	Cited by: <a href="#">Papers (2)</a>	
	<a href="#">©</a>   <a href="#">🔍</a>   <a href="#">▶Abstract</a>   <a href="#">📄PDF (6591 KB)</a>	
<input type="checkbox"/>	<b>Integrated circuits in military equipment</b>	
	Robert N. Noyce	
	Publication Year: 1964, Page(s):71 - 72	
	<a href="#">©</a>   <a href="#">🔍</a>   <a href="#">▶Abstract</a>   <a href="#">📄PDF (477 KB)</a>	
<input type="checkbox"/>	<b>Integrated circuits in industrial equipment</b>	
	Leonard C. Maier	
	Publication Year: 1964, Page(s):72 - 75	
	<a href="#">©</a>   <a href="#">🔍</a>   <a href="#">▶Abstract</a>   <a href="#">📄PDF (3579 KB)</a>	

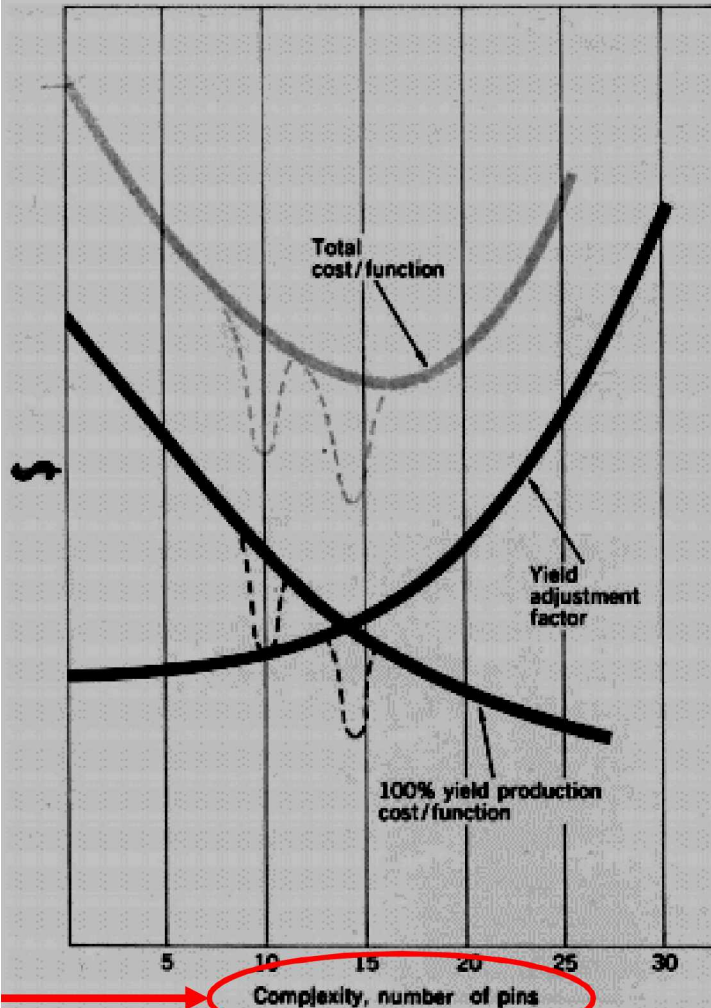


# Pre Gordon Moore

Before Moore's contribution

- Industry worked hard on improving integrated circuits so they scaled
- However, they didn't know they'd achieved a milestone because scalability had not been invented as a goal
- Note horizontal axis is number of pins

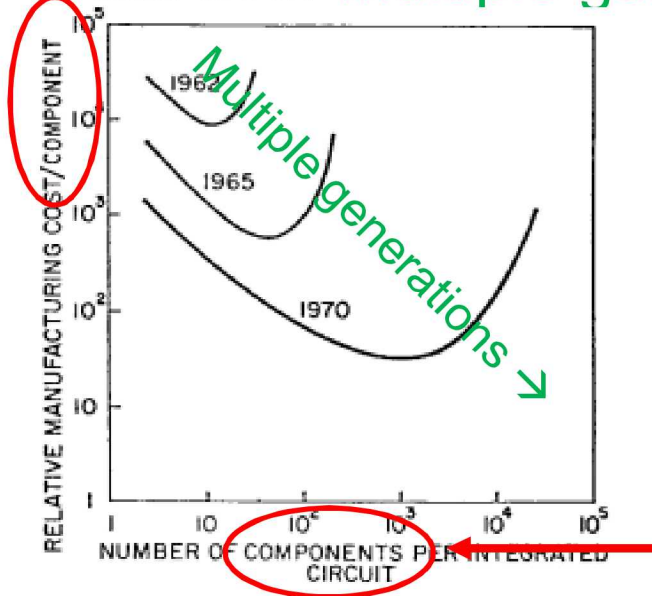
Fig. 19. Cost plotted as a function of complexity as evidenced by the number of pins in a package. Total cost per function is a minimum at a complexity of 10 to 14 pins.



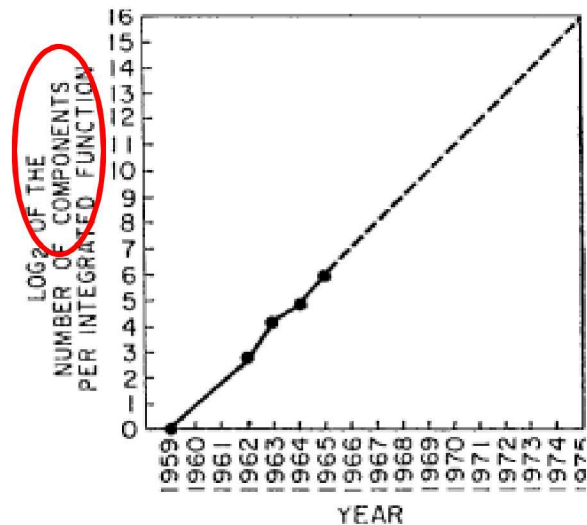
Complexity, number of pins

# Gordon Moore's Contribution I

- Assessed cost per **component** given reliability, material (silicon), yield, complexity, die size, interconnection space, heat, speed, power per unit area, design automation, linear, RF
- Data over **multiple generations** and extrapolated



Number of  
components



Moore, Gordon E. "Cramming more components onto integrated circuits. Electronics 38 (8): 114–117." (1965).

# Gordon Moore's Contribution II

Functional complexity evolves from

- Pins
- Components
- Next is quantum speedup

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# Schedule – Actual

- Thursday 8:30 AM Intro talk – Erik DeBenedictis
  - <http://www.debenedictis.org/erik/qc-summit/erik-intro.pdf>
- 9:15 AM Technical vision talk – Norbert Linke, hardware/physics
  - [http://www.debenedictis.org/erik/qc-summit/NML\\_talk\\_GATech\\_IEEE\\_Summit\\_compressed.pdf](http://www.debenedictis.org/erik/qc-summit/NML_talk_GATech_IEEE_Summit_compressed.pdf)
- 10:15 AM Technical vision talk – Andrew Sornborger, applications
  - <http://www.debenedictis.org/erik/qc-summit/IEEEQuantCompSummitATS.pdf>
- 11:00 AM Discussed deleting the proposed schedule and having an ongoing discussion group – passed by show of hands
- Noon: lunch
- 1:00 PM Continue discussion group (until 5:00 PM)
- 6:30 PM Two groups went to dinner
- Friday 8:30 AM Benchmarking discussion
- Noon: lunch
- 1:00 PM Continue discussion group (broke up 3:30 PM +/-)



# Picture of Meeting Room

