On the enabling role of industry in fundamental research in physics.

Edward H “Ned” Allen
Chief Scientist
Lockheed Martin Corporation
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Archimedes’ Principle and the votive crown…

European electric companies and the obscure professor…

Some necessary extensions of mathematics: P = NP + QC

Lessons I’ve learned … applied to the ILC … some speculations…

LOCKHEED MARTIN
100 YEARS OF ACCELERATING TOMORROW

Archimedes of Syracuse (ca. 287-ca. 212 BC)

- "… Legend has it that Archimedes discovered … that the buoyancy force is equal to the weight of the liquid *[or gas]* displaced, while taking a bath … Archimedes' geometric proofs were actually motivated by mechanical arguments which led him to the correct answer." (Wikipedia: Archimedes, April 2013).

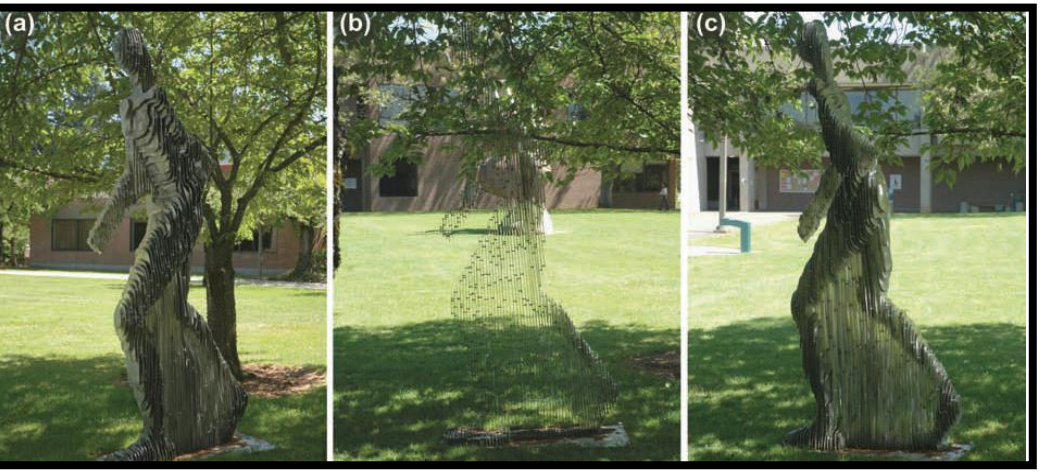
A votive crown wreath of the type thought to have been Archimedes challenge.

- Archimedes may have been first to exploit the intimate entanglement of physics with mathematics by using physical experimentation and tangible allegory to find solutions for hard mathematical problems.
- Archimedes' story teaches that key discoveries in science and mathematics are often motivated and financed by commercial enterprise. His buoyancy work, a logical extension of his leverage work, was reportedly so motivated and financed.

Quantum computing today is the direct descendent of Archimedes' allegorical methods

An obscure professor, Max Planck…

- "…commissioned by electric companies to create maximum light from lightbulbs with minimum energy. [In 1900], relying on Boltzmann's statistical interpretation of the second law of thermodynamics …as … 'an act of despair ... I was ready to sacrifice any of my previous convictions about physics' [he said]… his new derivation … [based on] the supposition … that electromagnetic energy could only be emitted only in quantized form…" This discovery, enabled by an R&D contract from the lighting industry seeking a better light bulb, was the birthing of quantum mechanics, sparking quantum physics.

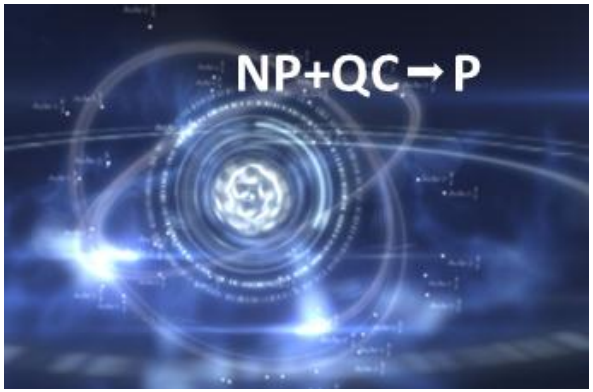


Three views of Julian Voss-Andreae's *Quantum Man* illustrate the significance of position of view to the object viewed, a fundamental mystery of quantum physics called the 'measurement problem' (Maryhill Museum of Art in Goldendale, WA (© Julian Voss-Andreae 2007).

- This bit of history, like Archimedes' story, conveys the significance of industrial requirements, desirements, resources and **<u>focus</u>** for achieving pivotal advances in fundamental science.
- There are more than 100 institutes of advanced scientific studies named after Max Planck…

Necessary extensions of mathematics: P = NP + QC…

- Stephen Arthur Cook, American-Canadian computer scientist and mathematician, formulated the "**P = NP?**" question – perhaps the most significant, still open question in mathematics.
  - Intuitively a formalization of Hilbert's 1900 question, "Is the axiom of solvability of every problem a peculiar characteristic of mathematical thought alone, or is it possibly a general law inherent in the nature of the mind that all questions which it asks must be answerable?"
- Today at LM we are demonstrating not that **P ≠ NP**, but instead, **P = NP + QC** for ***many*** problems in order that we may ***mitigate*** the "halting problem" which imposes such unacceptable limits to systems engineering…
- At LM, we are driven by economic necessity: reducing the **complexity** and thus cost of verification and validation of **cyber-physical** systems…



A screen shot from the LM website on quantum computing (April 2013, with NP + QC →P inserted for clarity).

"Anyone not shocked by quantum mechanics has not yet understood it." - Niels Bohr
"Nobody understands quantum mechanics." Richard Feynman

Lessons I've learned…
… applied to the ILC … some speculations…

- …an ultimate vision of the utility your effort promises for improvement of the human condition…and one that is unique (that no other investment of time and resources could achieve…) is helpful…
- Technology spin-offs are seldom offer enough promise by themselves (they attract only surplus funds) – have thought about dedicated offset programs?

- What will the ILC enable that **only** the ILC will enable and is necessary for societal survival and the well-being of human kind? Can you find and schedule such experiments on the ILC? (e.g.: Deeper bioinformatics? Archimedean allegories? Quantum nucleonics? Functional nanomaterials? Etc….)

Jason Thielke's
"Visionary" 2009

…End