~~Applied~~ Antineutrino ~~Physics~~ *Engineering Approaches*

A perspective

Jim Lund: last job, engineering management at Sandia National Laboratories

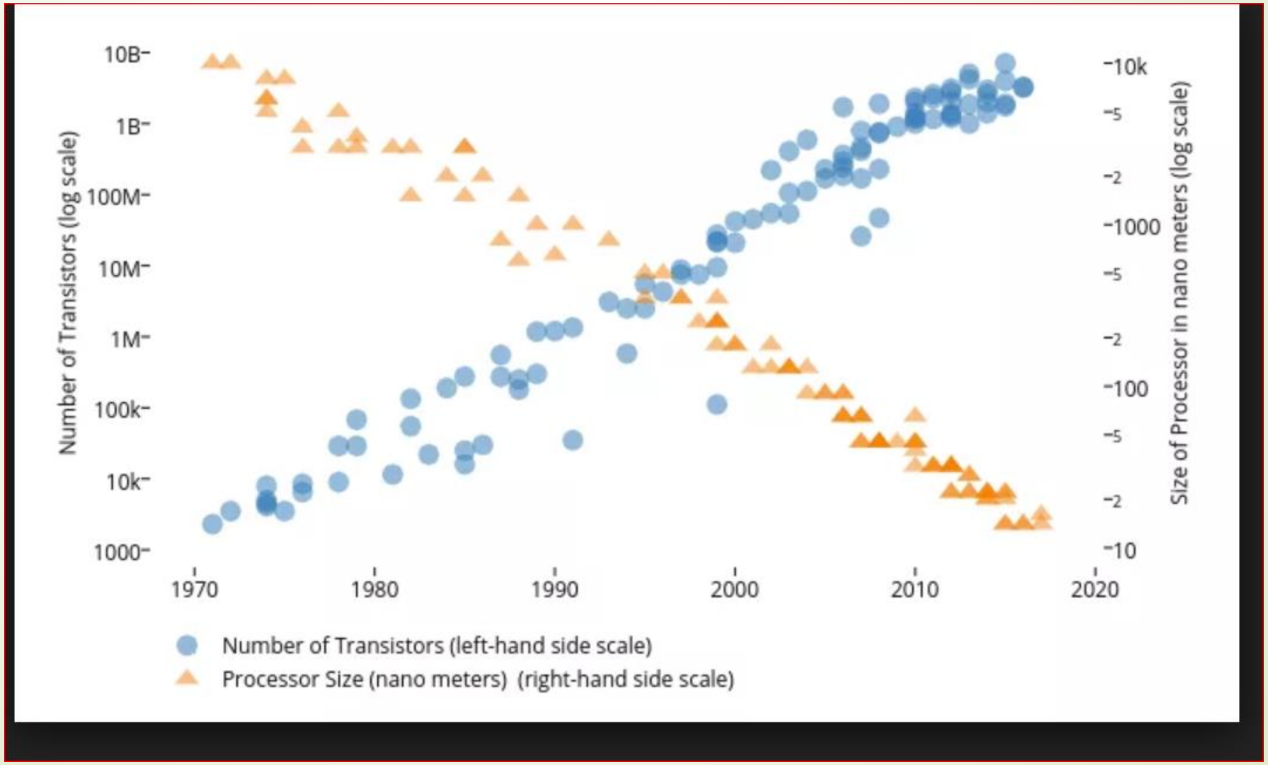
Outline

- The importance of defining success (or failure)
- Progress in engineering and applied science
- Engineering approaches
- Measuring progress and outcomes
- Measuring antineutrino detector progress
- Summary

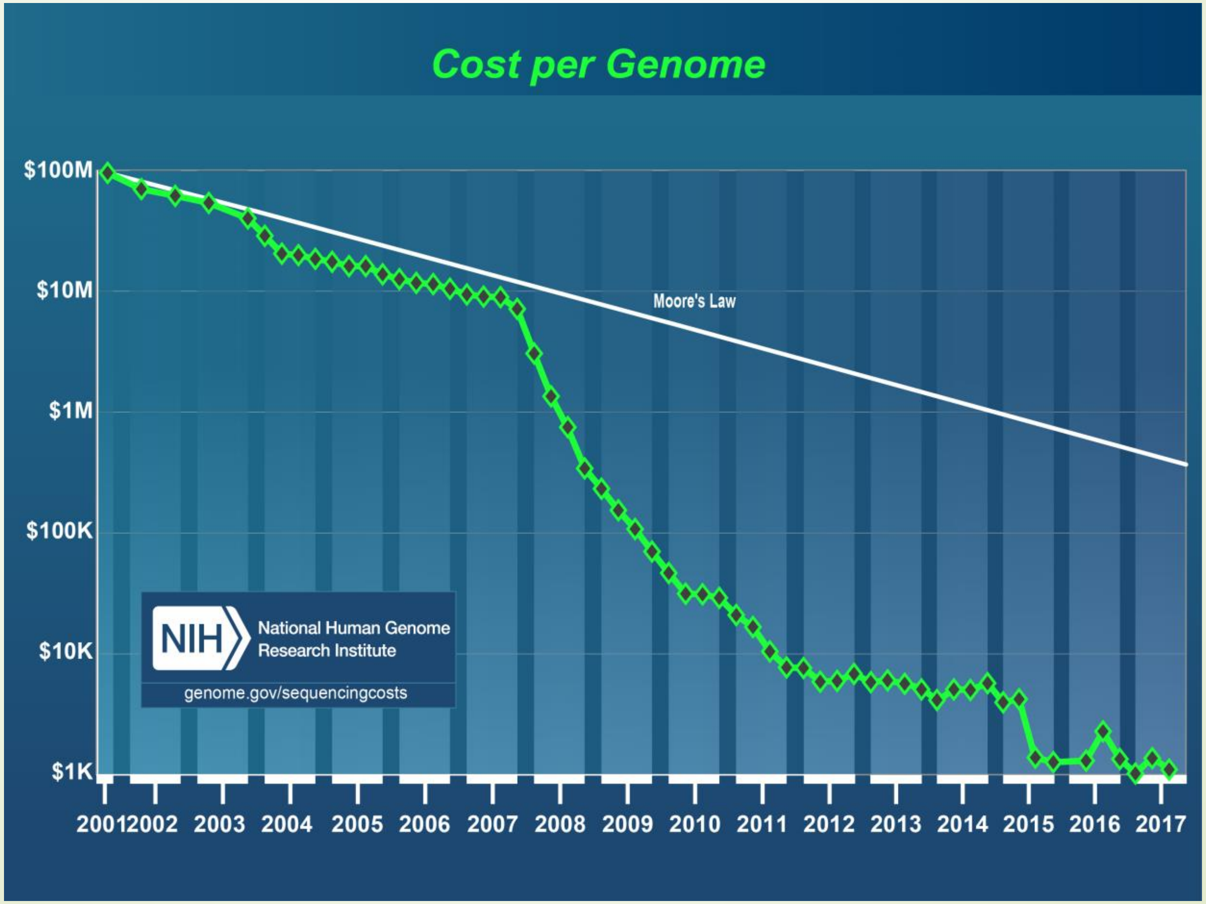
The importance of defining success

- It helps sponsors see the big picture
- It helps motivate researchers in the long slog
- It promotes honesty and candor
- It can help attract researchers to your field
- It works! Projects that define success before they start have a much higher likelihood of success.
- Even in projects that fail, much more is learned if the goal is clear from the beginning.

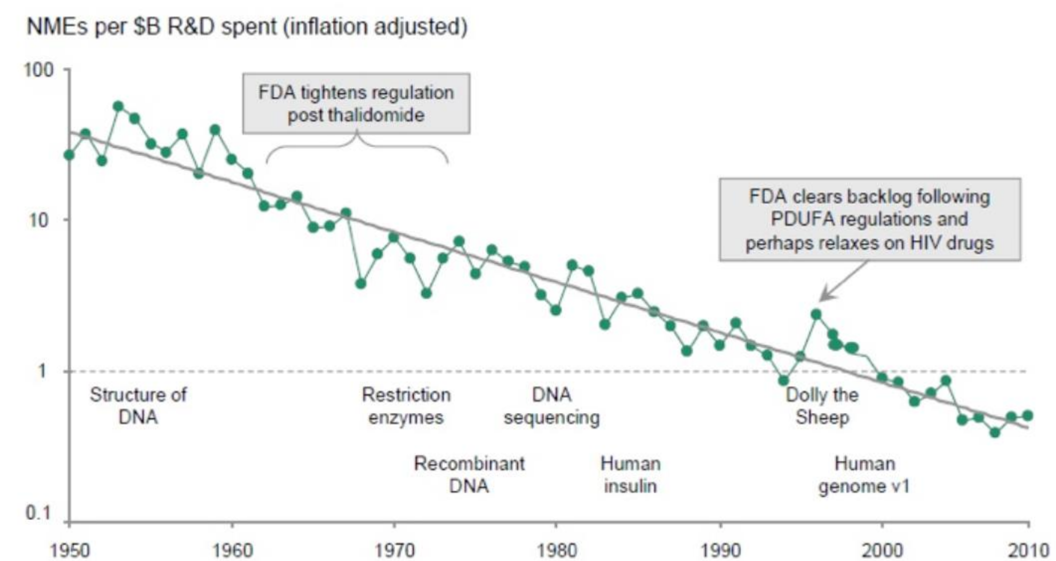
An example of progress over time (microprocessor development)



Molecular biological engineering

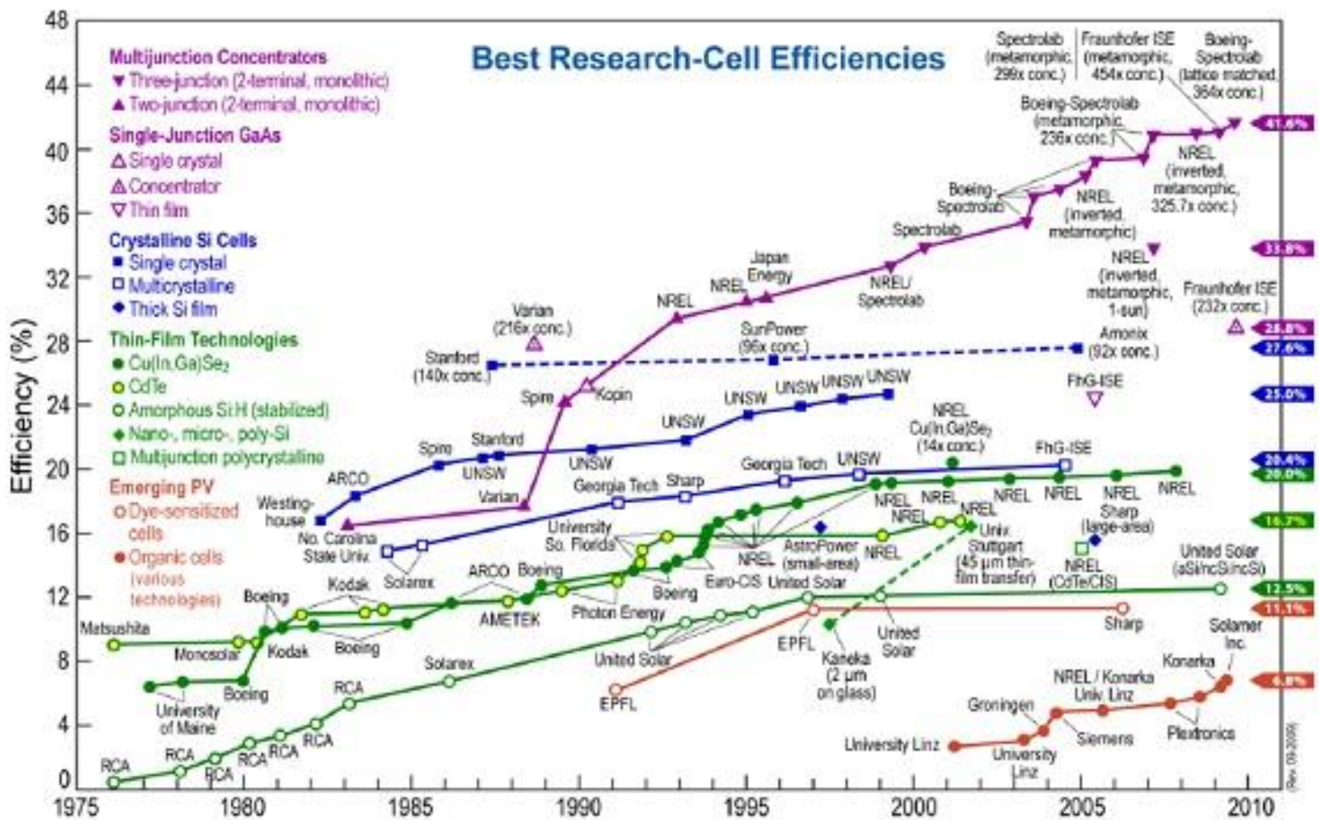


Of course sometimes there isn’t always progress (Eroom’s law)



Note: R&D costs are estimated from PhRMA annual survey 2009; NMEs are the total number of small molecule and biologic approvals by the FDA
Source: Bernstein Research “The Long View – R&D Productivity” (September 30, 2010)
Life sciences R&D: Changing the innovation equation in India THE BOSTON CONSULTING GROUP

Solar cell development (research devices)



Best research cell efficiencies 1975–2009
(Kazmerski 2009)

Progress measurement is tied to an “outcome” approach which is becoming the dominant approach in modern engineering

- Even in engineering it used to be all about the process:
  - What tools will I use ?
  - What formalism should I use?
- Now, in engineering, it is becoming far more outcome based:
  - How will we define success?
  - It is not so important that we define our process in advance. It is very important that we know exactly what we are aiming for and use whatever we think is appropriate to get there.

"Extreme Programming", an example of an outcome based approach

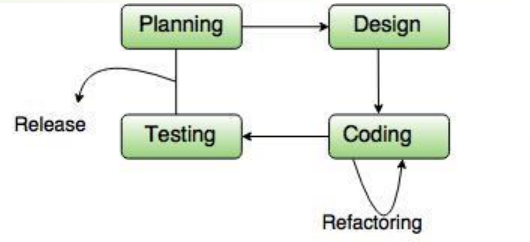


Fig. - The Extreme Programming Process

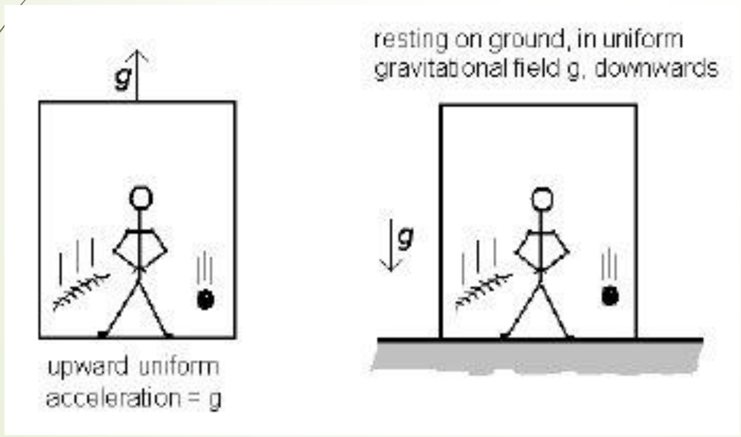
- Extreme Programming (XP) is a software engineering approach that emphasizes testing and iteration over process.
- XP and it's ilk are now widely and successfully used in complex engineering development.

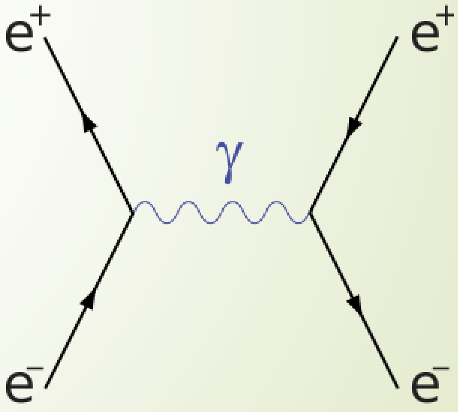
Engineering versus science research approaches: Outcome versus Process

- In a typical physics research program the criteria for selection is the proposed process that will be applied to the problem
  - Example: "We will utilize a highly segmented detector design that will allow differentiation from background events from reverse beta decay interaction."
- In modern engineering there is an increased emphasis on outcome:
  - Example: "We have defined a test that will fully validate candidate reverse beta decay detectors. We will put detector designs against this test. We may fail. Outcome will be determined in 18 months."

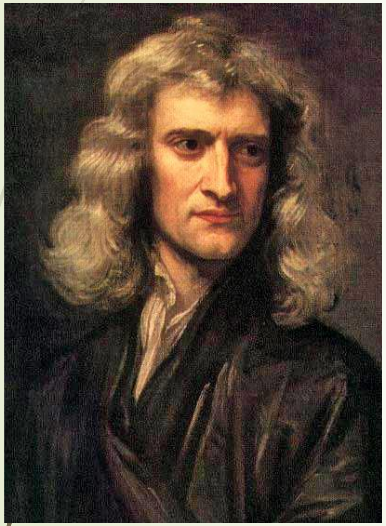
Two examples of outcome based approaches in theoretical physics

- The equivalence principle in General Relativity
- Renormalization in quantum field theories





An example from math: Calculus

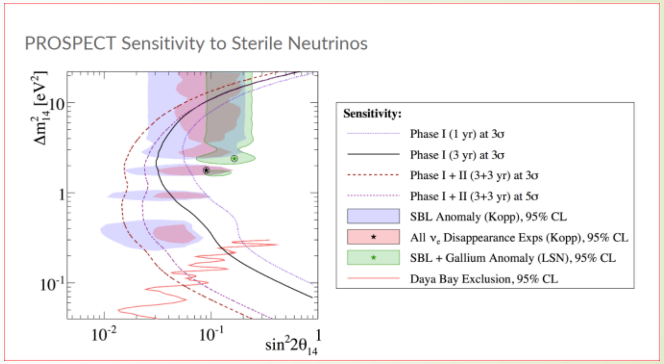


Newton and Leibnitz invent calculus circa 1680
It works (great!) to solve physics problems but has no sound formal basis

Karl Weierstrass proves calculus circa 1830

Measuring success in antineutrino detection

- For a given experiment, success is usually well defined in ν detection experiments.
- But let's talk about defining success more broadly across the field
- For instance, generally, is detector technology improving?
- Let's look to see the forest through the trees



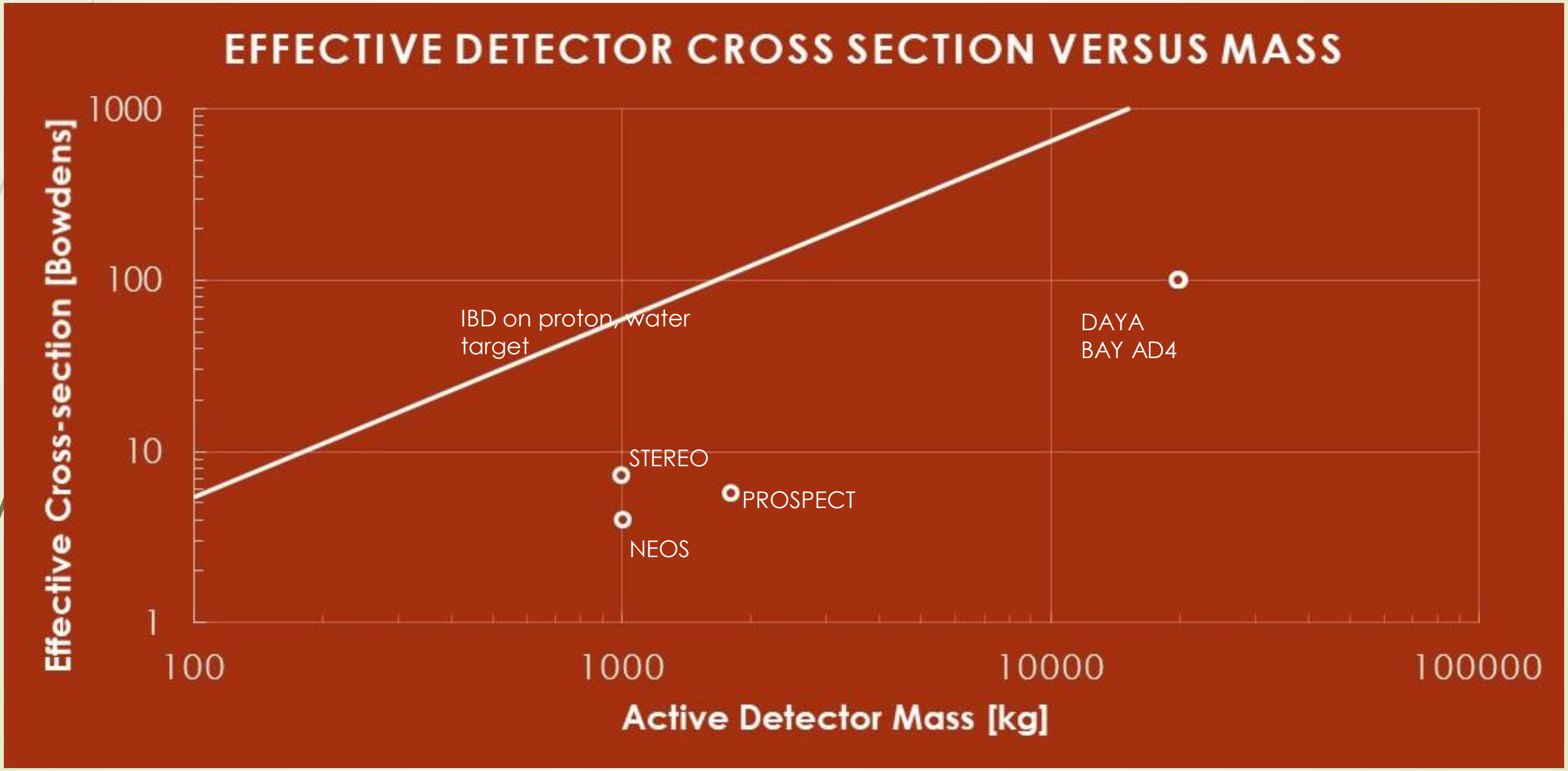
Derived units specific to antineutrino detection

- Let me propose the Bowden (B)
- A Bowden is the number of candidate antineutrino detection events a detector would see in one day at a distance of 10 meters from a 1 MW reactor.
- In other words, we will rescale the candidate antineutrino detection events as if the detector were 10 meters from a 1MW fission reactor.
- Assumptions:
  - Far-field approximation (inverse square law for scaling)
  - Assumes a generic beta (and anti-neutrino) spectrum from the reactor

Example of the use of a derived unit, the Bowden (B), to measure success and progress

Detector	R(meters)	N(Candidate events/day)	Reactor Power (MW)	Effective cross-section (B)
Daya Bay AD4	1550	73	17400	100
NEOS	23.7	1977	2800	4
STEREO	10	396	55	7.2
PROSPECT	8	757	85	5.7

Comparing anti-neutrino detector performance



Summary

- Anti-neutrino detection has matured considerably over it's history.
- It's time for the practitioners (and- perhaps more importantly- the sponsors) to consider an outcome based approach to future projects.
- All hail the Bowden as a new unit.
- Thanks for listening.