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LEARNING CURVES: IGNORE THEM AT YOUR OWN PERIL!

WHAT IS A LEARNING CURVE?

- Exponential growth due to feedback
- Individual, but macro effects are multi-person
- Pseudonyms
  - + Network Effect
  - + Viral
  - + “Free Market”

EXAMPLES IN ELECTRONICS/INFORMATION

Images removed due to copyright restrictions. Please see:

Countdown to Singularity

Moore's Law - The Fifth Paradigm

Random Access Memory

Magnetic Storage Data

From Kurzweil, Ray. "The Law of Accelerating Returns." KurzweilAI, March 7, 2001.

HOW DOES A LEARNING CURVE WORK?

- Iterative Innovation
  - Technology (understanding old and new principles)
  - Application (wants, needs: computing power per $)
  - Implementation (how things are made; how can they be made in future; how to make economically viable; societal and politic influences)
- Important to Recognize:
  - We all “Stand on the Shoulders of Others”
  - Self-correcting (don’t fret ‘bad actors’, unless they are fascists!)
  - Do not ignore either innovation process or historical learning curves
    - Innovation does not happen in a room by yourself
    - Fighting progress of mankind is not useful

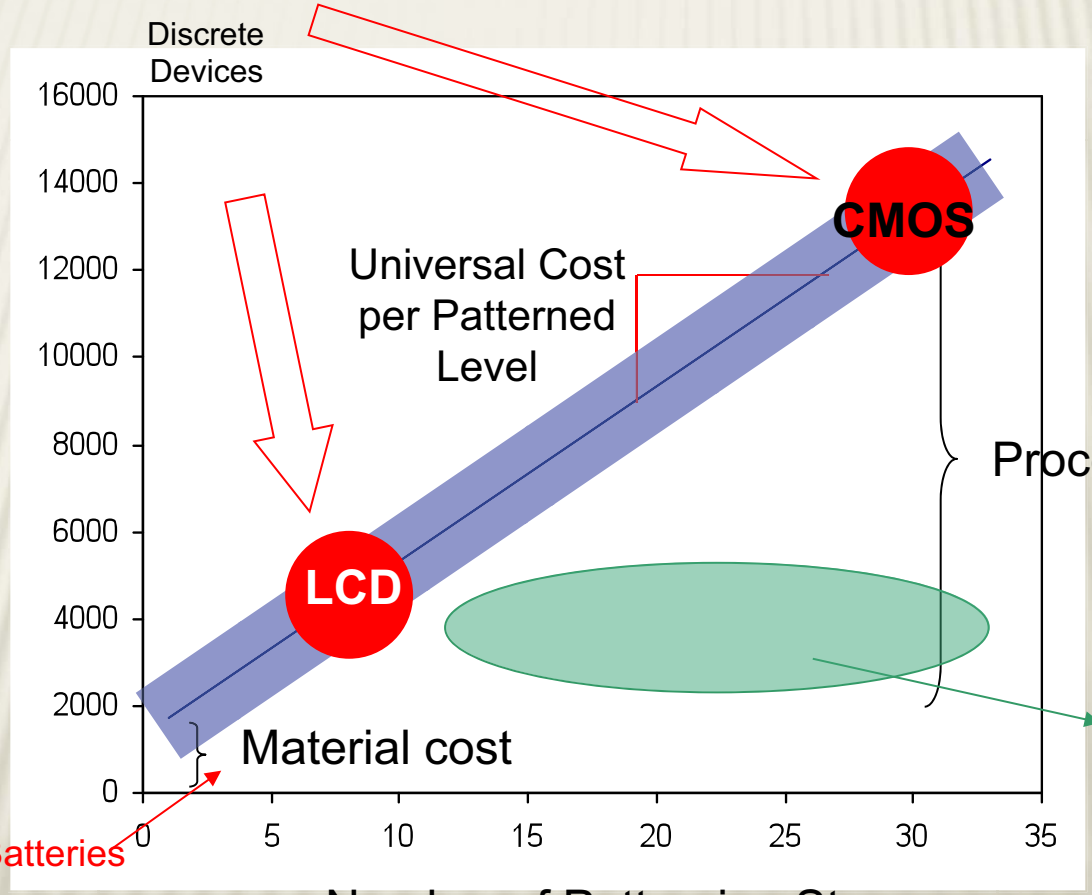
EXAMPLE OF IMPORTANCE OF RECOGNIZING GLOBAL LEARNING CURVES

- Premise: Roll-to-Roll Electronics
- It is the new paradigm
  - Print electronics like newspaper, on plastics
  - Inexpensive, new manufacturing paradigm
- But how does it fit into current paradigm quantitatively?
  - How do we make current electronics?
  - How do other planar processes work? Is there a common framework to analyze?
- Interesting planar process industries
  - Solar
  - Batteries (roll-to-roll)
  - Silicon CMOS Electronics
  - LCD Display Screens

	Sunpower	Evergreen Solar
Form factor	SPR-200 (200W) 1560 mm x 800 mm 1.25 m2 160 w/m2	EC-100 (100W) 1575 mm X 686 mm 1.08 m2 92.6 w/m2
Sunpower Advantage Module efficiency factor Cell efficiency (%) Cell efficiency factor	 1.73 21.5% (A-300 cell) 1.43	 1.0 15% (cell) 1.0
Estimated Mfg Cost S / W	$2.74/W	$2.50/W
Estimated Selling price $ / W	$4.83/W	$4.40/W

LOW COST MANUFACTURING?

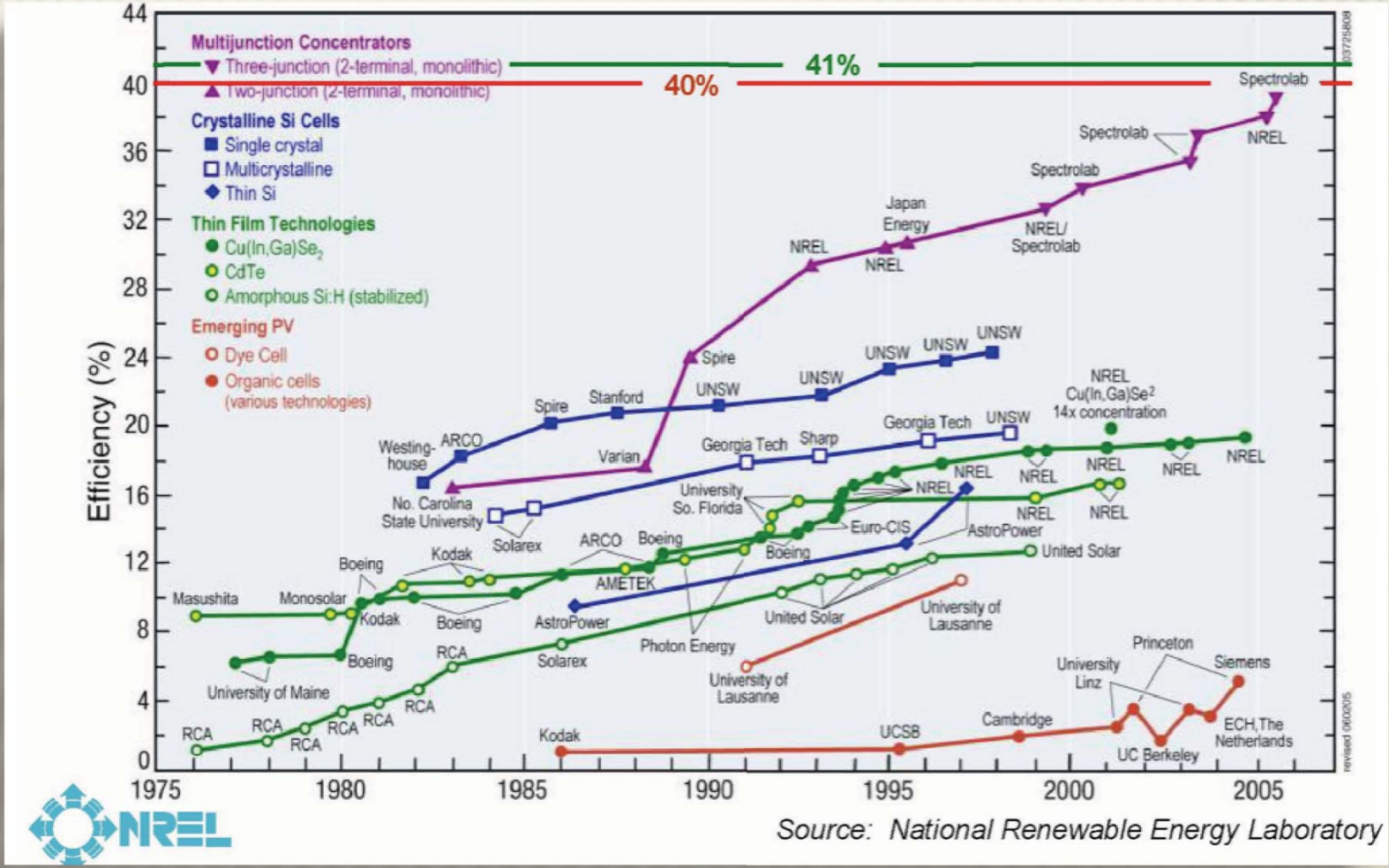
- 'universal manufacturing cost' at a point in time
  - + Process cost per area per patterning step
  - + Why is there a LCD industry?



SUMMARY OF "LOW COST ELECTRONICS"

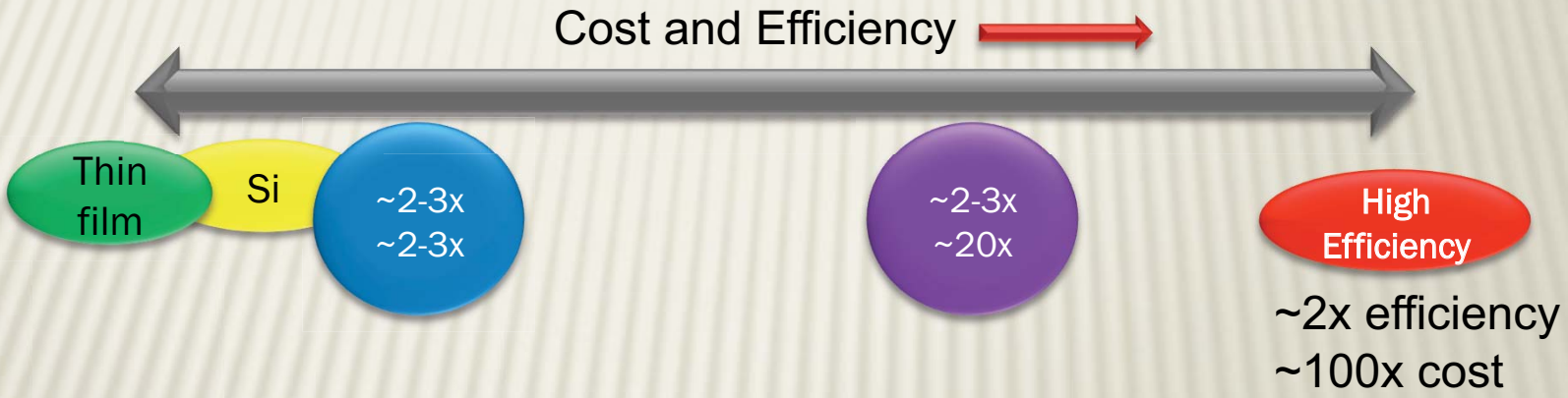
- Silicon CMOS defines lowest-cost way to build any device with even a modest number of patterning levels
- LCD infrastructure exists since the display at any time in history has required larger substrate area than the available silicon wafer area
- At any point in time, there is a manufacturing cost to beat defined by cost per area per patterned level
- Less expensive Large Area Electronics requires extremely high speed, fairly high resolution, aligned patterning capability

EXAMPLE 2: SOLAR CELLS
SOLAR BAND ENGINEERING: EFFICIENCY AND HIGH COST LEADER



EXAMPLE 2: SOLAR CELLS

- Our activities are composed of projects meant to increase efficiency on a silicon-based platform



HIGHER-LEVEL LEARNING CURVES

- If Innovation is a group sport, what about the 'lone inventor'?
  - Kuhn, "Structure of Scientific Revolutions", introduced term 'paradigm shift'
  - History is for making paradigm efficient, not for understanding non-linear network effects like the innovation process
- If you need to know everything in science and technology to be effective, then how come an MIT degree has been 4 years for many decades?

3.003 Principles of Engineering Practice

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