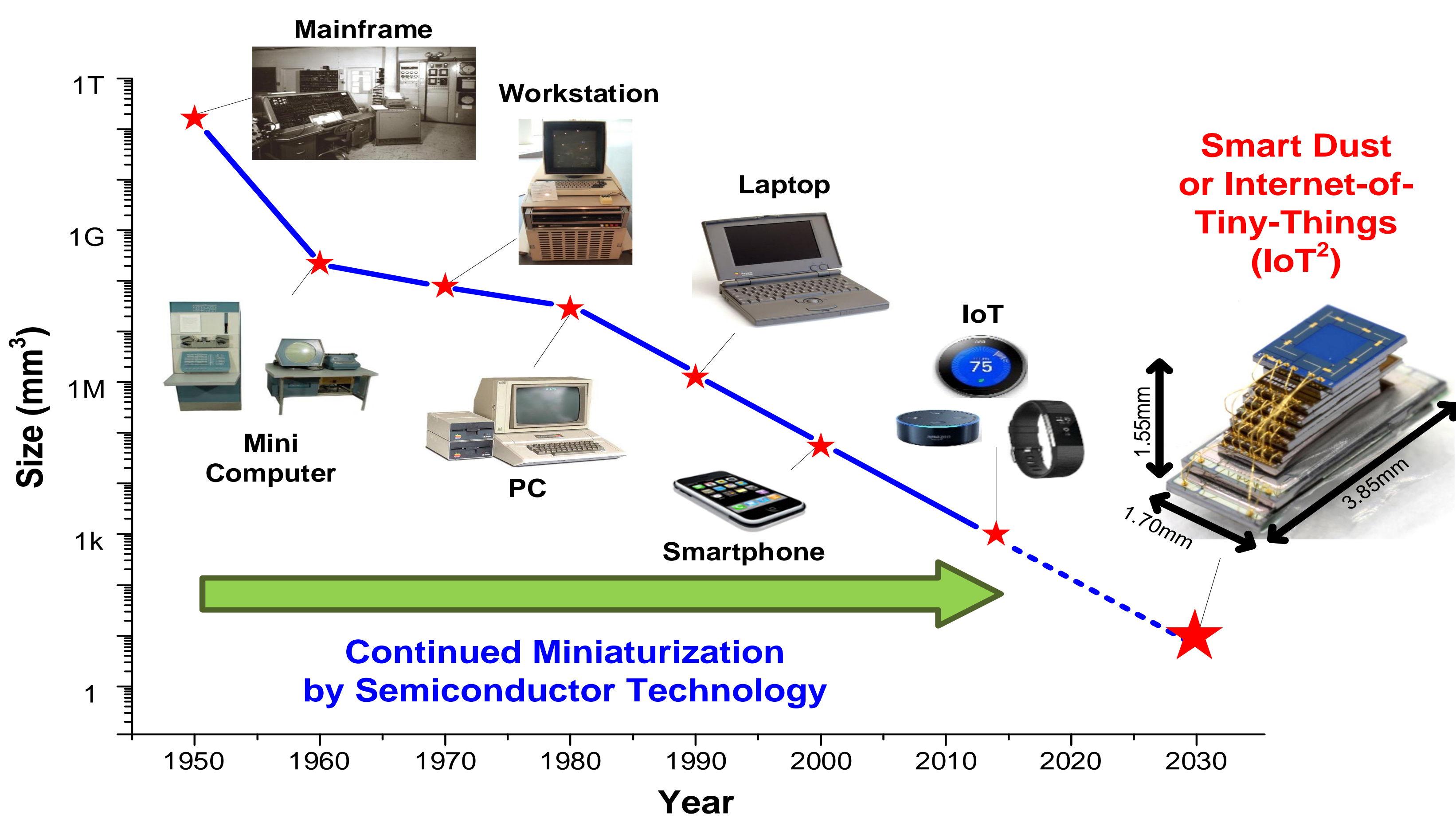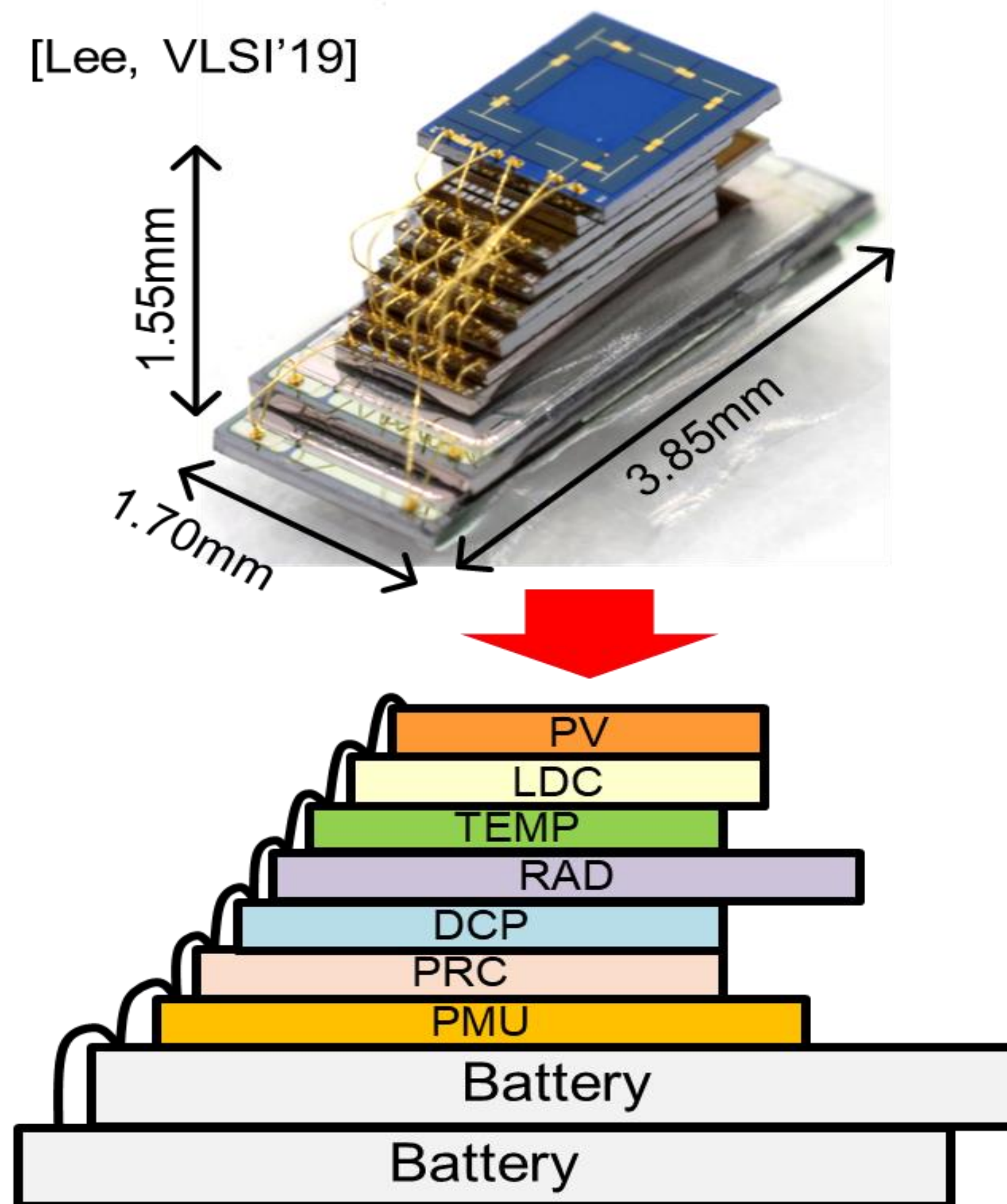# Millimeter-Scale Smart Sensing System

Inhee Lee, Assistant Professor, inhee.lee@pitt.edu
ECE Department, University of Pittsburgh, PA, USA

Miniaturization: Internet-of-Tiny-Things

Mainframe
Workstation
Laptop
Smart Dust or Internet-of-Tiny-Things (IoT²)
IoT
Mini Computer
PC
Smartphone
1.55mm
1.70mm
3.85mm

Continued Miniaturization by Semiconductor Technology

Size (mm³) vs Year

IoT² Semiconductor Device

[Lee, VLSI'19]

1.55mm
1.70mm
3.85mm
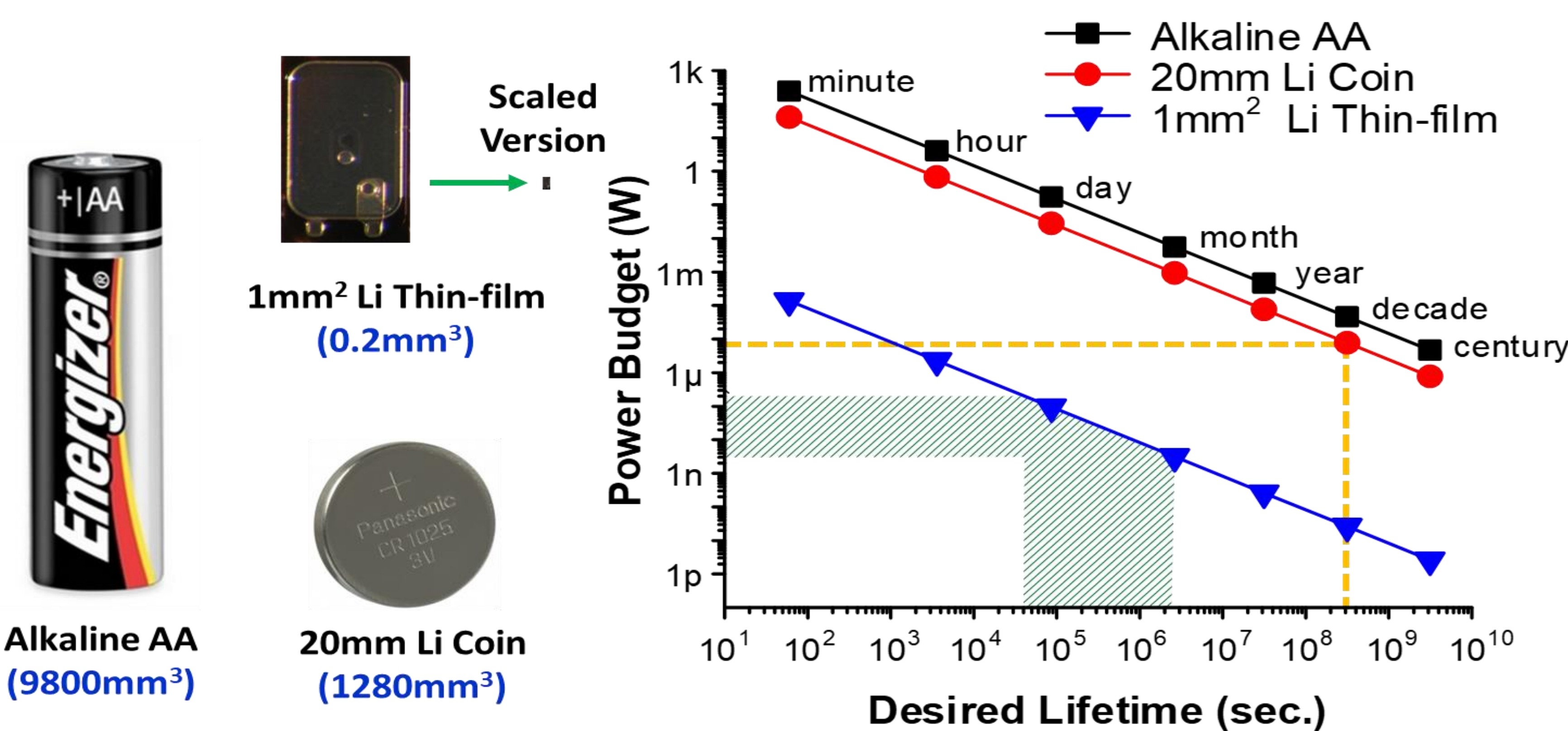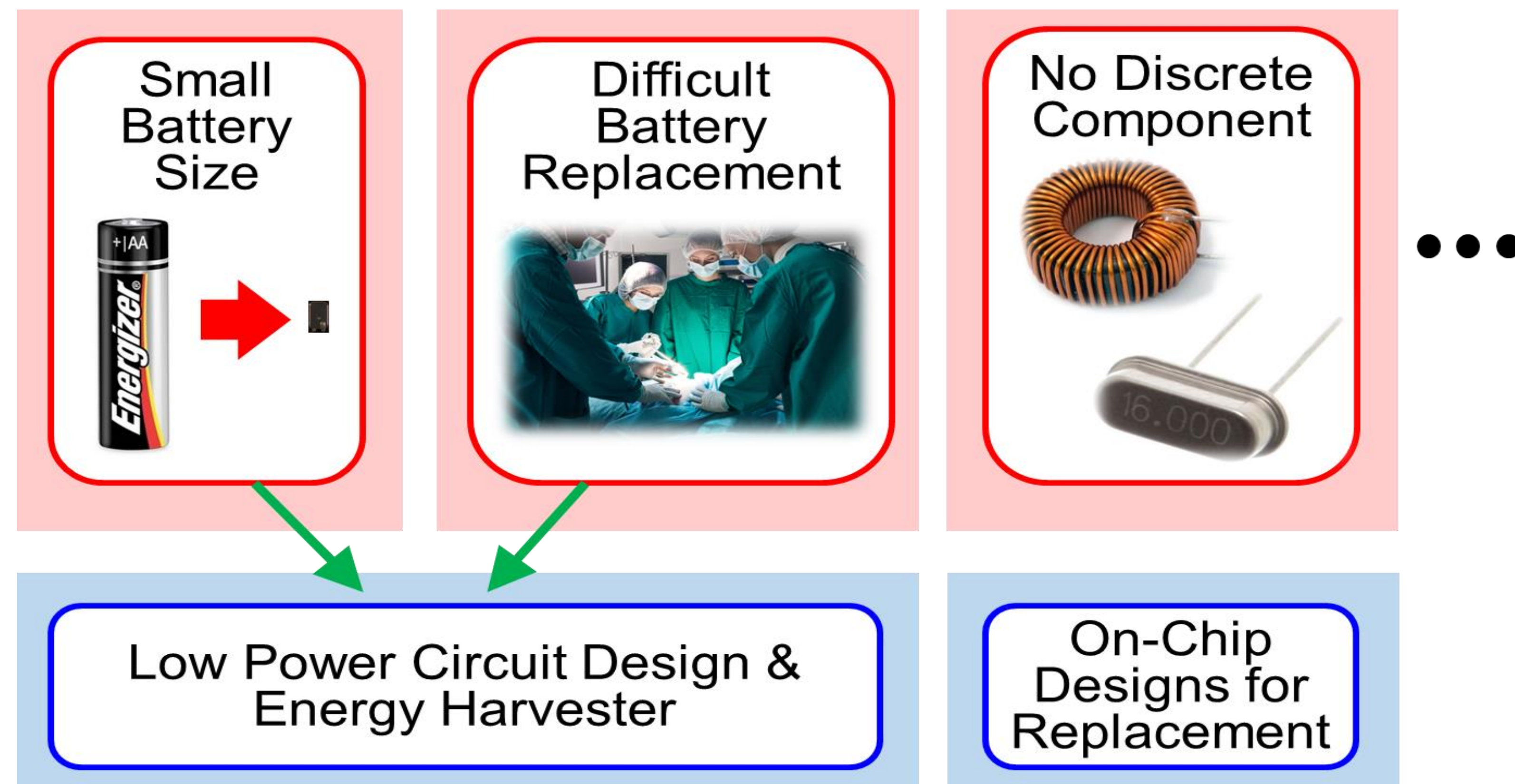
- Proposed in ISSCC 2012
- Modular die-stacked structure
- Maximize circuit design area per volume
- Enables diverse technology
- Swappable layers

Layers (top to bottom): PV, LDC, TEMP, RAD, DCP, PRC, PMU, Battery, Battery

- ~10µA active mode (< 100ms)
- ~10nA sleep mode (> 1min.)
  → Only turn on low-power management unit, optical receiver, wakeup timer, SRAM

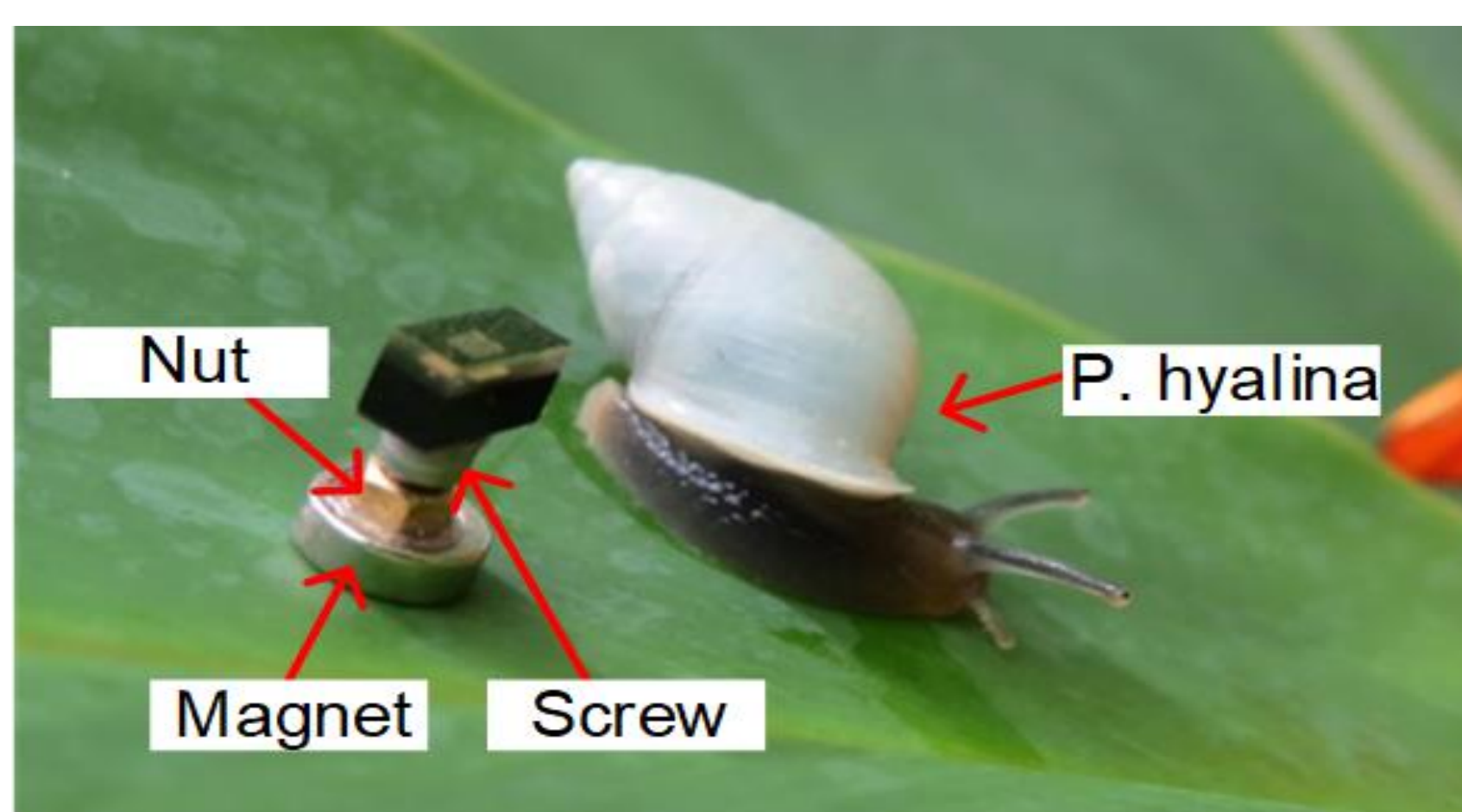## Available Power Budget

Scaled Version

1mm² Li Thin-film (0.2mm³)

Alkaline AA (9800mm³)

20mm Li Coin (1280mm³)

Power Budget (W) vs Desired Lifetime (sec.)

- Alkaline AA
- 20mm Li Coin
- 1mm² Li Thin-film

minute, hour, day, month, year, decade, century

Design Challenges for IoT²

Small Battery Size

Difficult Battery Replacement

No Discrete Component

→ Low Power Circuit Design & Energy Harvester

→ On-Chip Designs for Replacement

The World's Smallest Computers

WORLD'S SMALLEST COMPUTER

Computer History Museum

Ecological Applications

Nut
P. hyalina
Magnet
Screw

[Bick, Commun. Biol. '21]

Ecapsulation
2.6mm
Stacked IC Layers
8.4mm
8.4mm
Attached on monarch
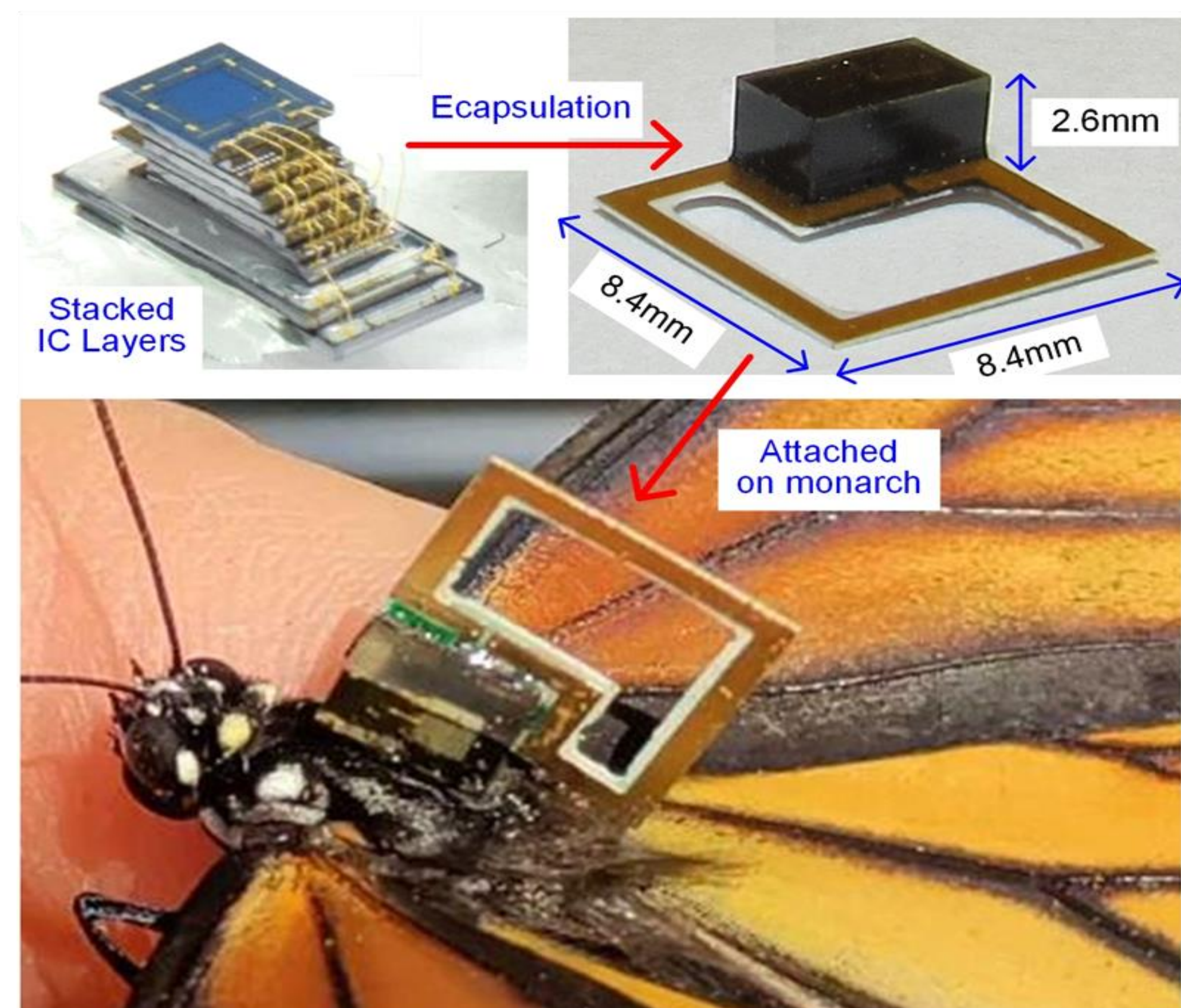
[Lee, MobiCom. '21] **Best Paper Award**