

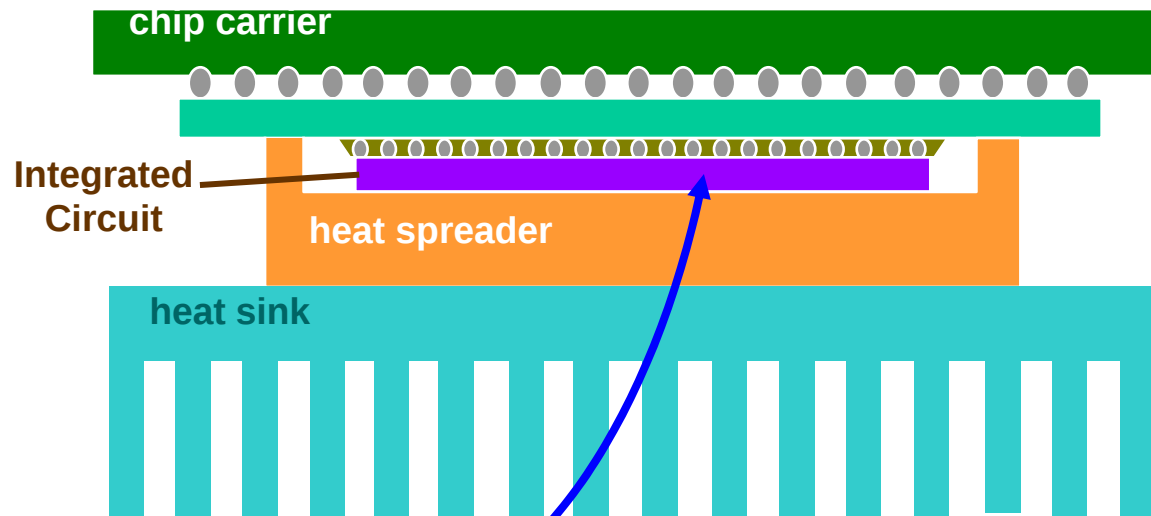
Opportunities in the Mechanical Parts of the System



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DARPA/MTO

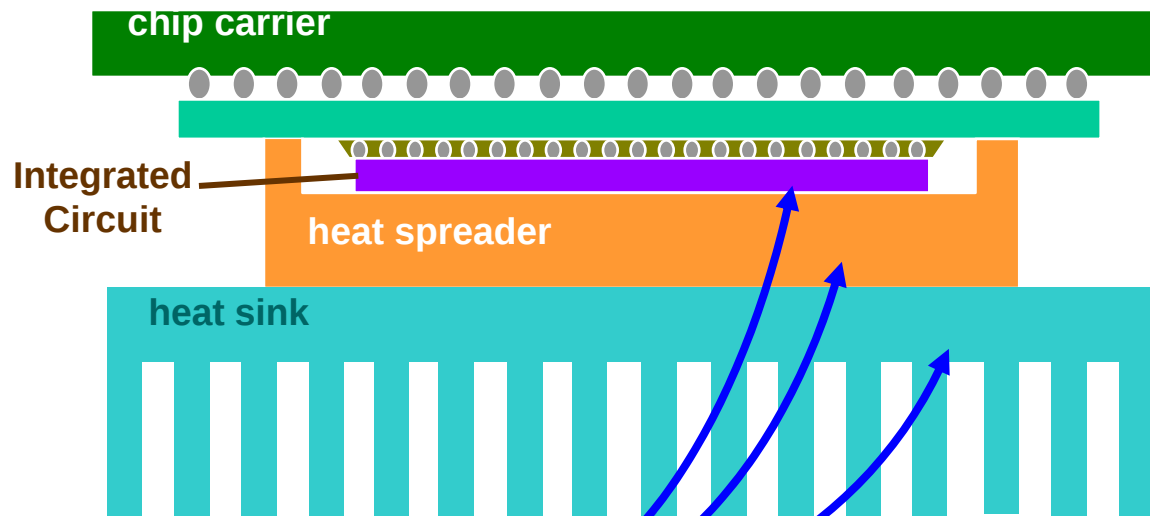
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Microelectronics Packaging Today



Integrated Circuit :

- 40+years of innovation in Materials, Designs, Architectures, Interfaces, Manufacturing...
- Mankind's Most Advanced Technological Achievement
- Beneficiary of many DARPA investments over the years



Thermal Management of ICs :

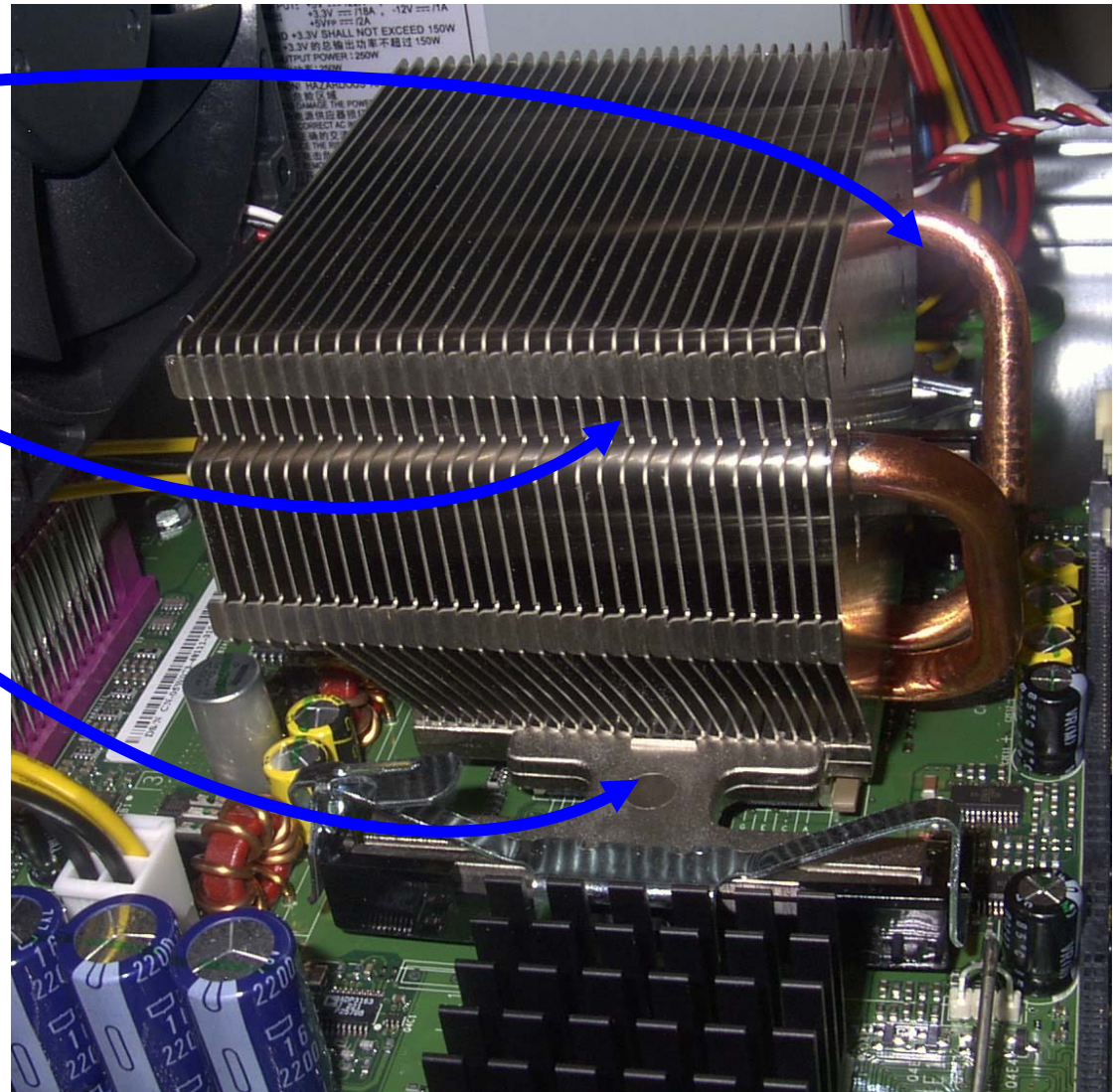
- Materials set includes Grease, Copper, Aluminum
- Relatively few insertions of modern technology
- Few investments by DARPA
- Size, Weight, Cost, Performance of Thermal Management Technology is becoming a significant factor in Systems

Heat Pipes woven through base and fins to provide efficient heat transport to full area

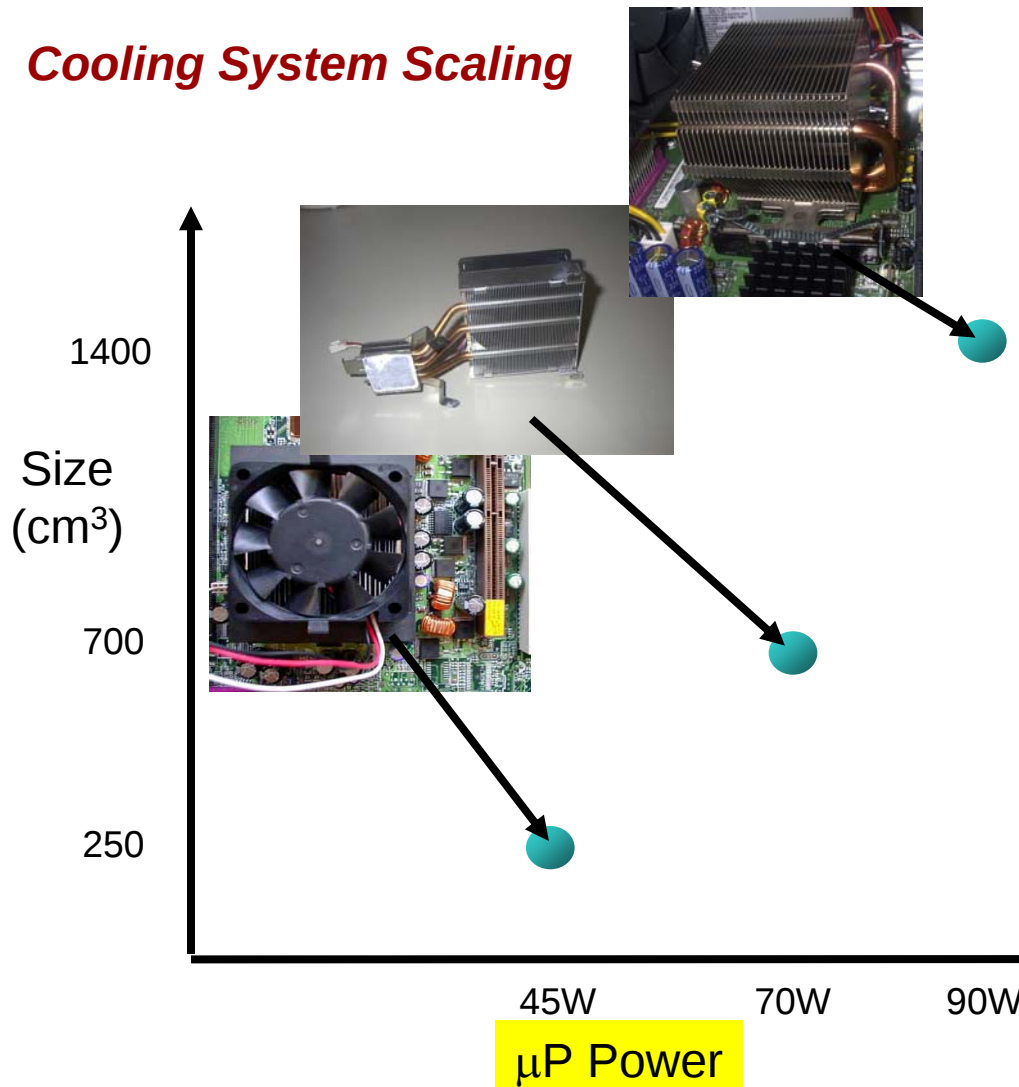
4"x4"x3", 400 gm heatsink for thermal management of 90W Intel Microprocessor

Spring-Loaded Clamps for constant pressure on back of die, and minimize torque on interconnect

Size, weight, performance, reliability of thermal management can dominate DOD systems.



Cooling System Scaling



Scaling driven by :

- Increases in power density
- Thermal transport through grease
- Wicking/transport in heat pipes
- Fin thermal conduction
- Convective Heat transfer to air

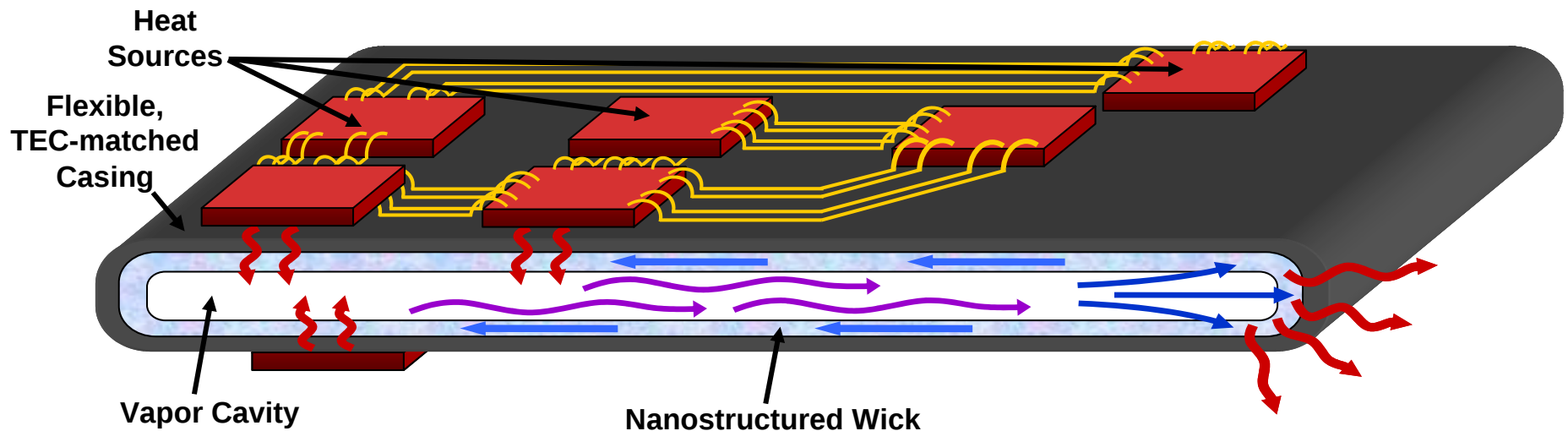
Recent industry transition to multicore is a “surrender” to this thermal barrier.

DOD systems suffer from same scaling. Cooling of computers, radar arrays, optics, instruments, engines - all limited by 50 year-old cooling technology.

It is time to bring high-technology, modern materials, nano-engineered interfaces, and adaptive structures to this problem. Possible benefits throughout DOD.

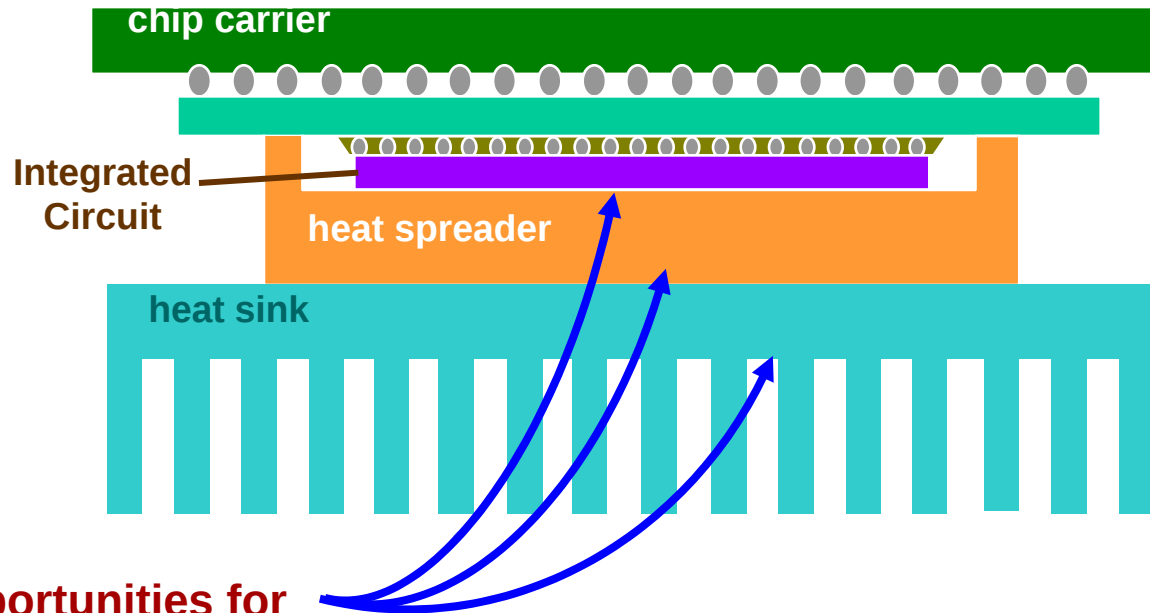
Example Opportunity

Technology Vision : A new 2-D, thin, lightweight MCM substrate incorporating fluids, and nanostructured materials to achieve vastly superior thermal conduction & possessing all mechanical properties necessary for hard-mounting ICs.



- Extreme lateral thermal conduction, 100X above current MCM substrates, capable of up to 1000X above Diamond
- Large 2-D area, <1 mm thick
- Nanostructured wick for enhanced heat transfer and fluid transport
- Structural, flexible, thin, & light-weight materials that match the TEC of Si, GaAs, or GaN
- 2-phase heat transfer to eliminate load-driven thermal non-uniformity across substrate

Other Opportunities?



Other Opportunities for Enhanced Thermal Management ?

- Optimized Micro/Nano Composites for Thermal Interfaces
- Package-Integrated Pumped Fluid Cooling Technologies
- Engineered Surfaces for Enhanced Heat Transfer (Solid→ Liquid, Liquid→Air)

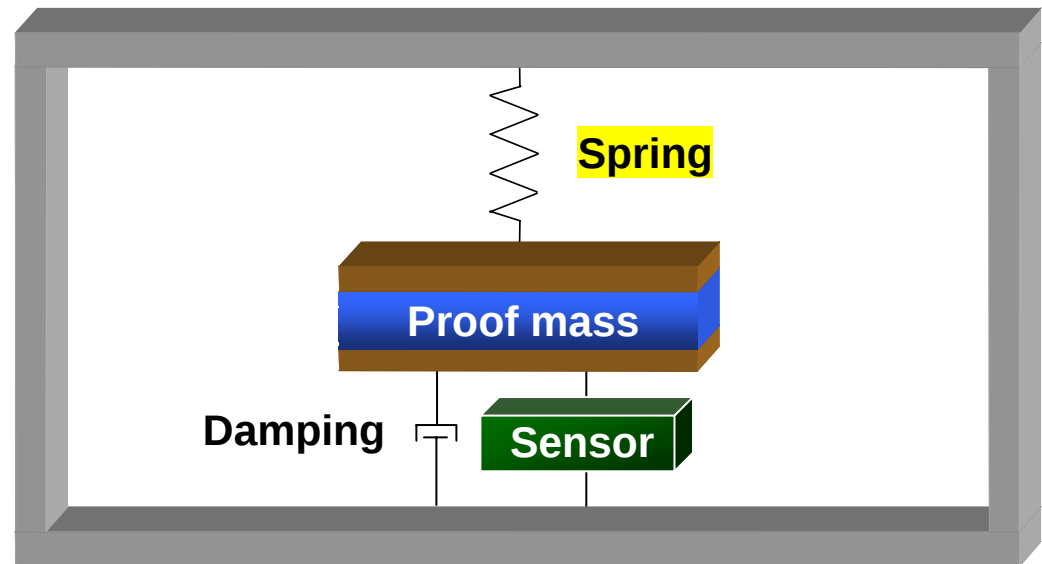
There are opportunities for significant performance enhancements throughout thermal systems.

Typical Inertial Instrument :

- Fixed Mass
- Fixed Suspension

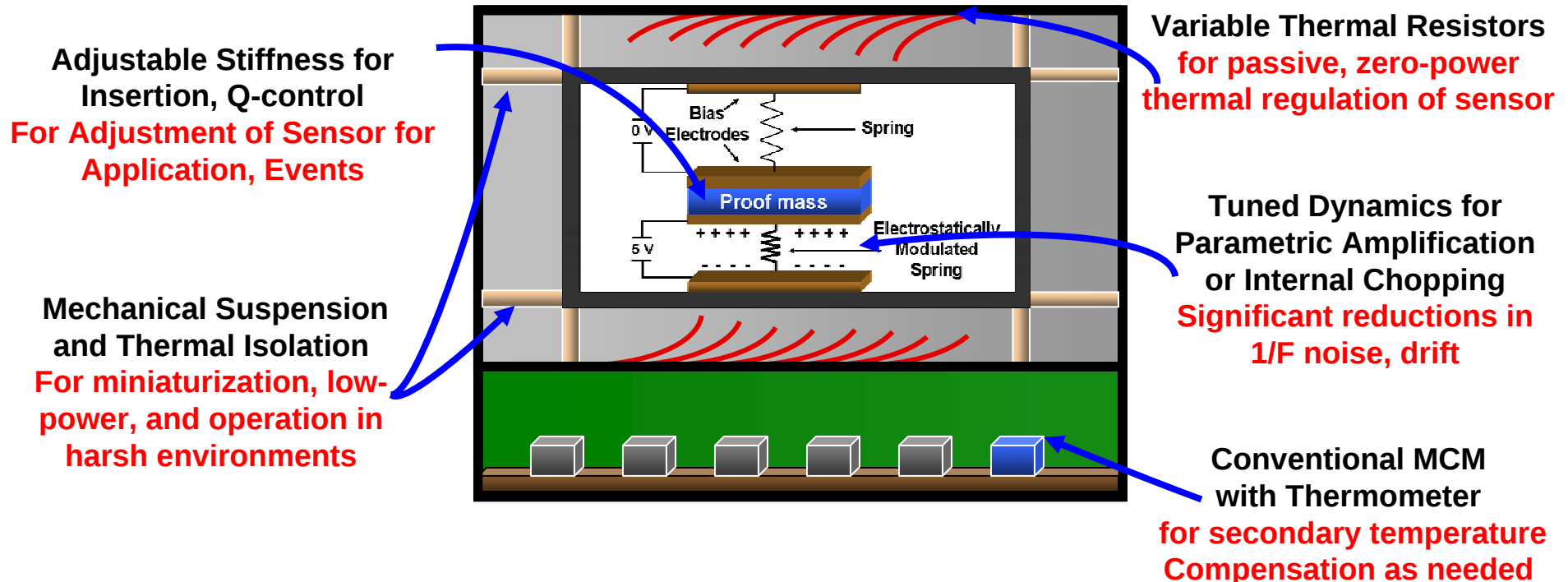
Performance enhancements achieved through:

- Improvements in sensor
- Accurate temperature compensation
- Expensive packaging



Present Technologies for State of Art Inertial Navigation :

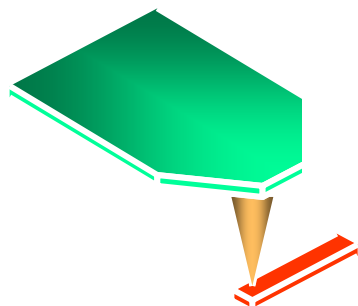
- Mechanical Instruments with Electronics in Package and Temperature Control of System -> fragile, large, high-power, expensive
- All important parameters are static quantities, sensitivity modulation not used
- Advanced nonlinear dynamics, parametric amplification, not used in these systems



Opportunities for Improvement through Variable Mechanics :

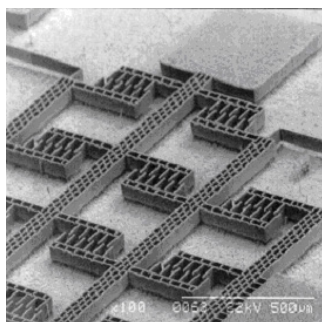
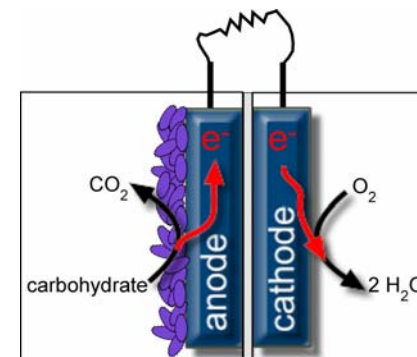
- Utilize nonlinear dynamics to tune performance, amplify, and operate in variable scenario
- Utilize MEMS for device, package, thermal management, dynamic management
- Deliver complete instruments with enhanced performance and smaller size, weight, power,...

Other Areas of Interest



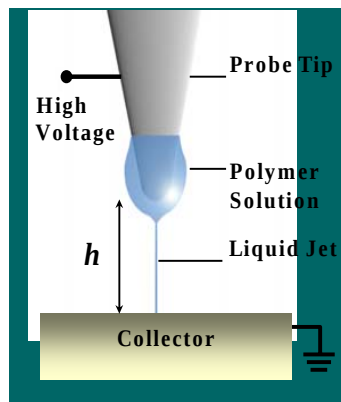
Tip-Based Nanofabrication
Fields, Fluxes, Gradients
 that can only exist if
 confined to nm-scale

**Hand-Held Energy
 Generation**
Convert Cellulose,
other available
biomaterials into
fuel for energy
generation



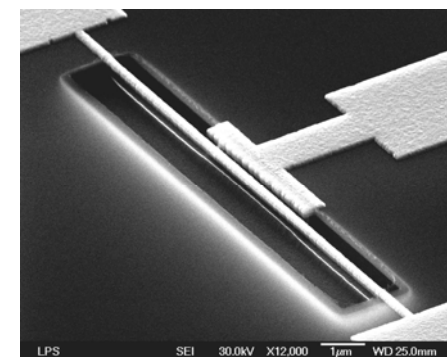
Metal Microstructures
Leverage unique
qualities of metals
(Titanium, Stainless) for
harsh-environment
sensing

Neutron Detection
MicroDroplet Chambers
and geiger counters for
miniature detectors



Electrospun Polymer Fibers
High-strength nm-scale
fibers with aligned
molecules and nano-
composite additives

**Quantum Mechanical
 Detection**
Phonon confinement
and energy
manipulation for
sensing, processing





Mechanical Opportunities



Summary

- There are performance-enhancement opportunities on the mechanical side of many systems
- 20+ years of research on MEMS, Nanofabrication, and engineered materials provides many interesting possibilities for impact on thermal and mechanical interfaces
- These situations are ideal opportunities
- Other interests emerging through discussions with labs and users