

# Trends in HPC and HPEC Convergence

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## Report Documentation Page

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# Thesis

- Over the last 10 years R&D investments have made *high performance embedded computing* for national security applications more like mainstream *high performance computing*
  
- Over the next 10 years R&D investments will make mainstream *high performance computing* for national security applications more like *high performance embedded computing*

# Thesis

- Over the last 10 years R&D investments have made *high performance embedded computing* for national security applications more like mainstream *high performance computing*
  - DARPA Touchstone
  - DARPA Embedded Systems
  - OSD High Performance Embedded Computing Software Initiative
- Over the next 10 years R&D investments will make mainstream *high performance computing* for national security applications more like *high performance embedded computing*
  - DARPA Adaptive Computing
  - DARPA Data Intensive Systems
  - DARPA Polymorphic Computing Architectures
  - DARPA High Productivity Computing Systems

# Thesis

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  - DARPA Touchstone
  - DARPA Embeddable Systems
  - **OSD High Performance Embedded Computing Software Initiative**
- Over the next 10 years R&D investments will make mainstream *high performance computing* for national security applications more like *high performance embedded computing*
  - DARPA Adaptive Computing
  - DARPA Data Intensive Systems
  - DARPA Polymorphic Computing Architectures
  - **DARPA High Productivity Computing Systems**



# HPEC Software Initiative

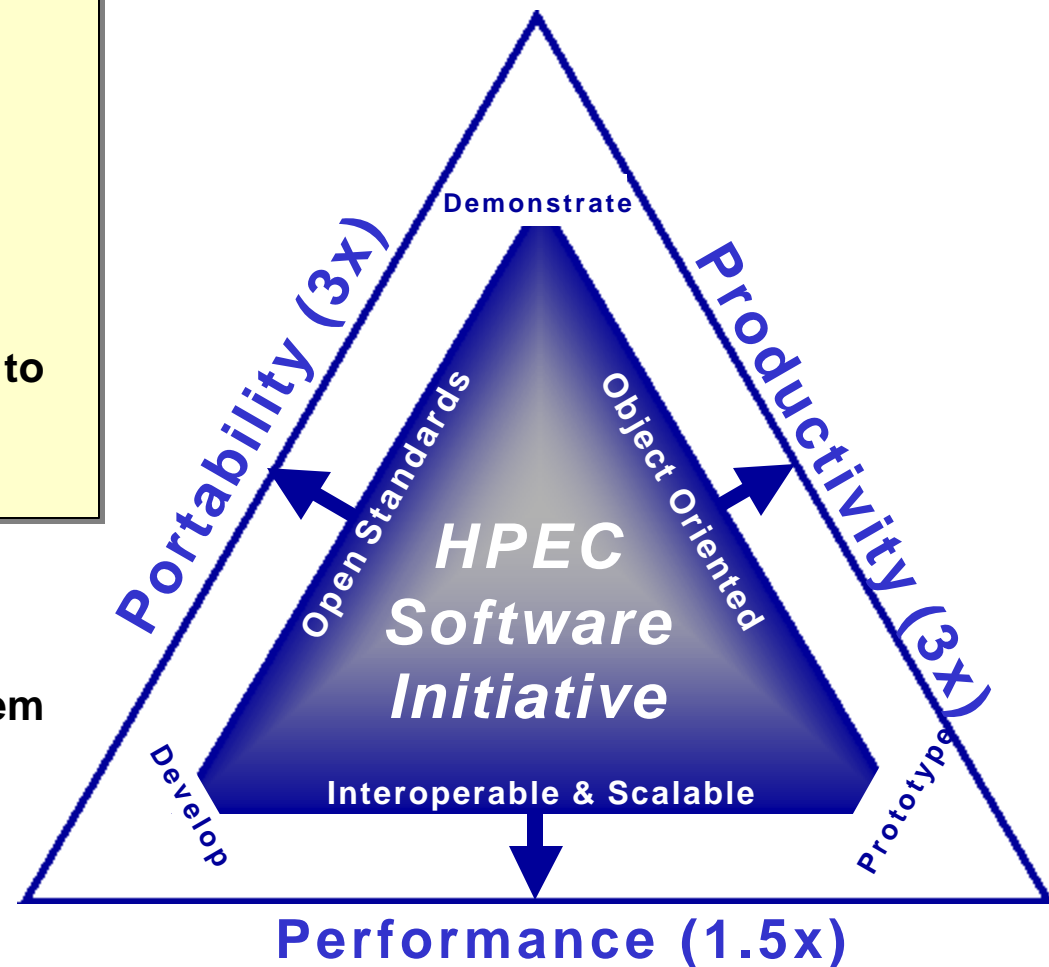
## Program Goals

- Develop and integrate software technologies for embedded parallel systems to address portability, productivity, and performance
- Engage acquisition community to promote technology insertion
- Deliver quantifiable benefits

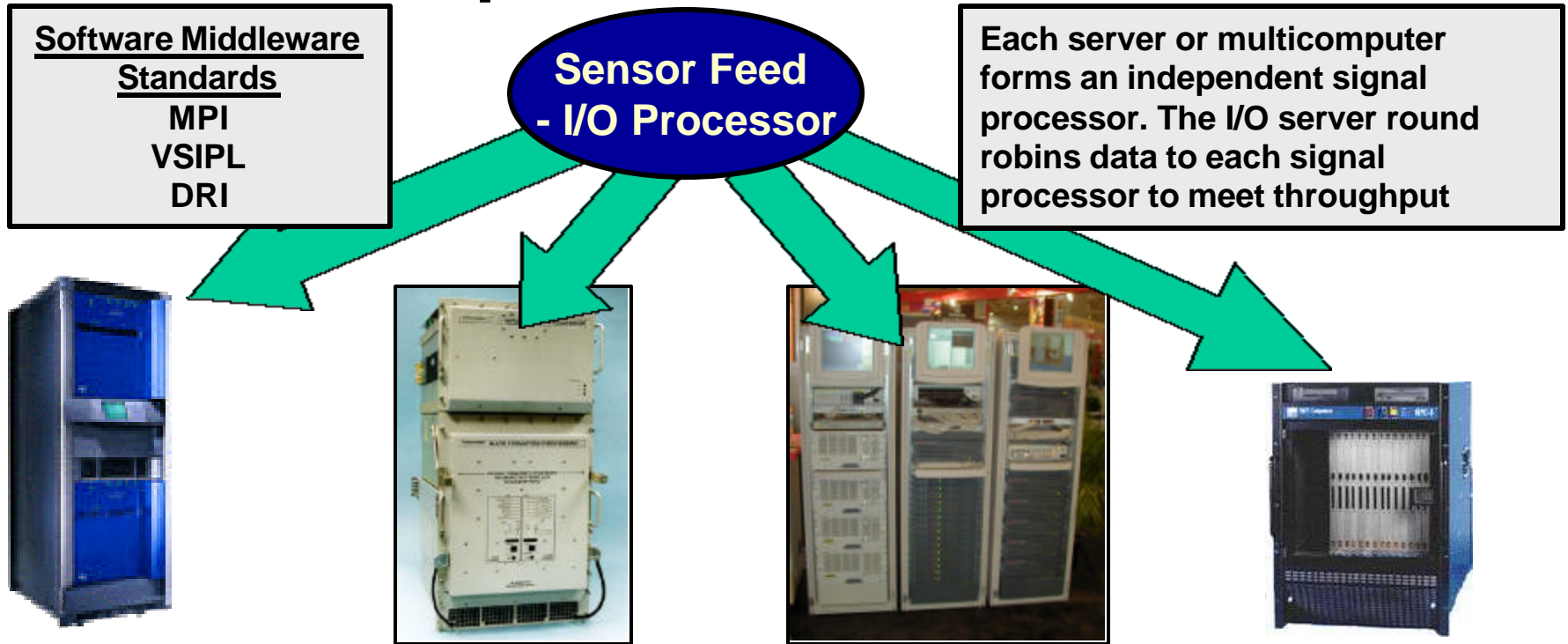
**Portability:** reduction in lines-of-code to change port/scale to new system

**Productivity:** reduction in overall lines-of-code

**Performance:** computation and communication benchmarks



# Common Imagery Processor Experiment Overview



**Shared Memory Servers**

**Distributed Memory Multicomputers**

Distributed memory CIP software would allow insertion of embedded multicomputer or commodity clusters as a signal processor in CIP system

# HPEC-SI Middleware

## Development

### **VSIPL++**

- MAPPING (data parallelism)
- Early binding (computations)
- Compatibility (backward/forward)
- Local Knowledge (accessing local data)
- Extensibility (adding new functions)
- Remote Procedure Calls (CORBA)
- C++ Compiler Support
- Test Suite
- Adoption Incentives (vendor, integrator)

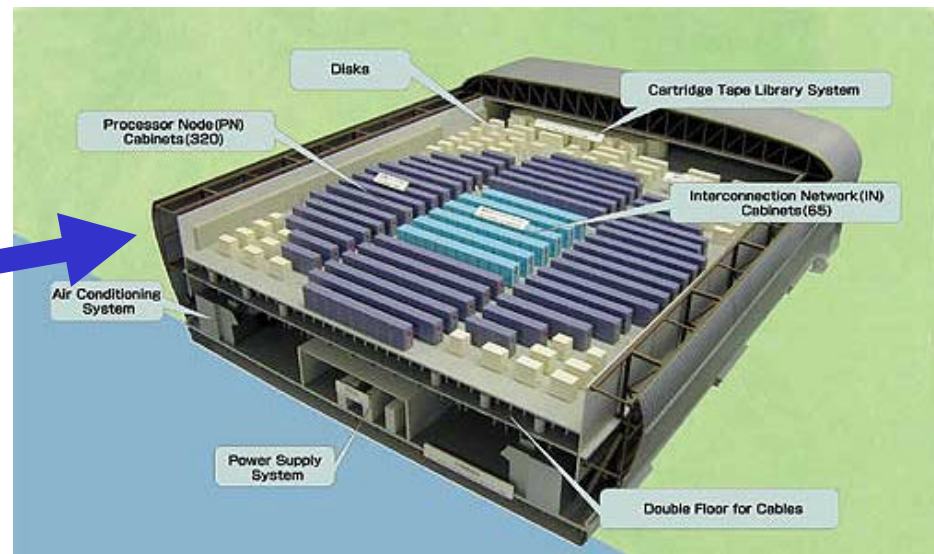
## Applied Research

### **Parallel VSIPL++**

- MAPPING (task/pipeline parallel)
- Reconfiguration (for fault tolerance)
- Threads
- Reliability/Availability
- Data Permutation (DRI functionality)
- Tools (profiles, timers, ...)
- Quality of Service



## From the Small to the Big



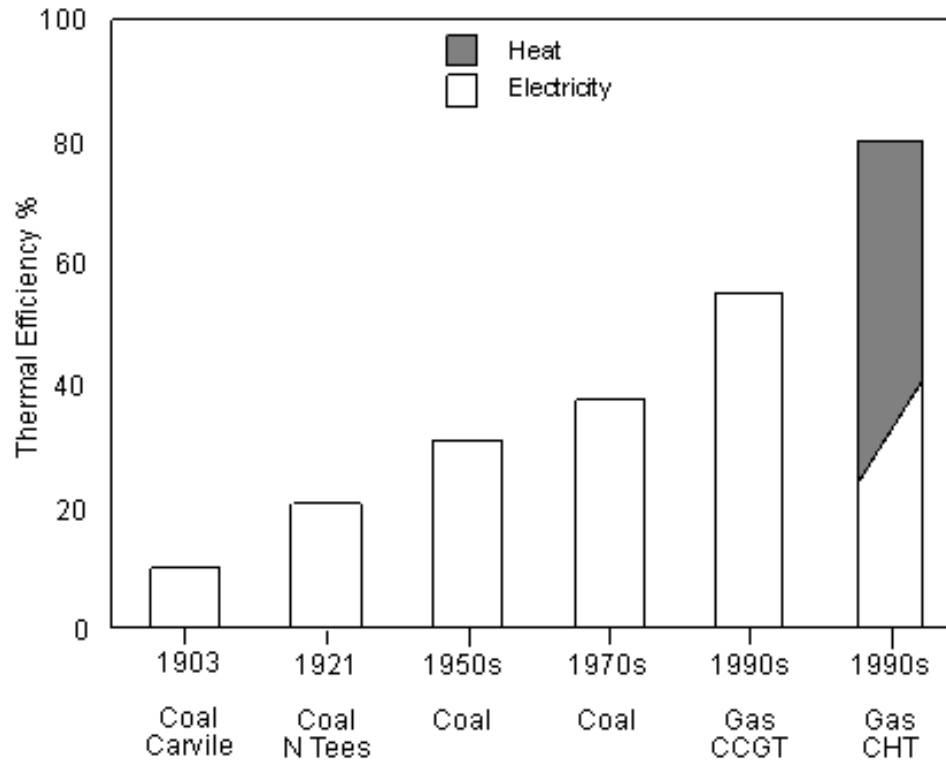
## Earth Simulator

Earth Simulator pictures from [www.es.jamstec.go.jp/esc/eng](http://www.es.jamstec.go.jp/esc/eng)  
JSTARS pictures courtesy of Northrop Grumman

# Efficiency: The Big Picture

Losses accumulate from the point of electricity generation, through distribution, and *finally during utilization by the end user*

## Efficiency of Electrical Power Generation



## One Ton of Coal Generated

Year	Energy
1891	150 kWh
1914	550 kWh
1920	630 kWh
1939	1566 kWh
2002	3000 kWh

Electricity distribution efficiency: 92%

ASCI Q: 24 - 30 Tflop/s (peak)  
 3 megawatts to run plus  
 2 megawatts to cool  
 (energy for 5000 homes)

## Computing efficiency

Gflop/s

Percent peak

Gflop/s/Watt

...

MITRE

[www.electricity.org.uk/uk\\_inds/environ/env\\_19.html](http://www.electricity.org.uk/uk_inds/environ/env_19.html)  
[www.parcon.uci.edu/paper/energy.htm](http://www.parcon.uci.edu/paper/energy.htm)



# High Productivity Computing Systems

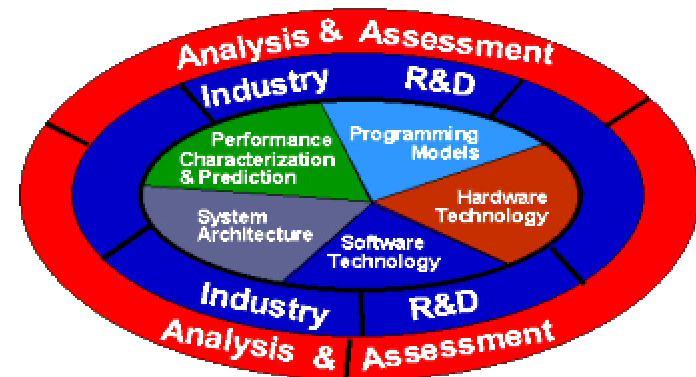


## Goals:

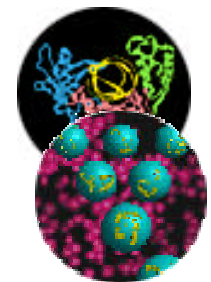
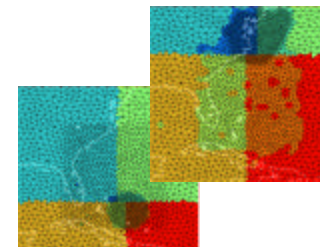
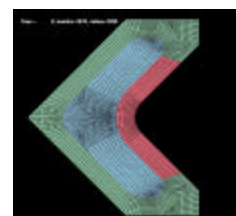
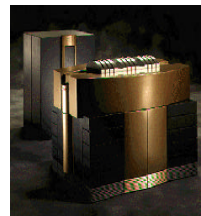
- Provide a new generation of economically viable high productivity computing systems for the national security and industrial user community (2007 – 2010)

## Impact:

- **Performance** (efficiency): critical national security applications by a factor of 10X to 40X
- **Productivity** (time-to-solution)
- **Portability** (transparency): insulate research and operational application software from system
- **Robustness** (reliability): apply all known techniques to **protect against outside attacks**, hardware faults, & programming errors



HPCS Program Focus Areas



## Applications:

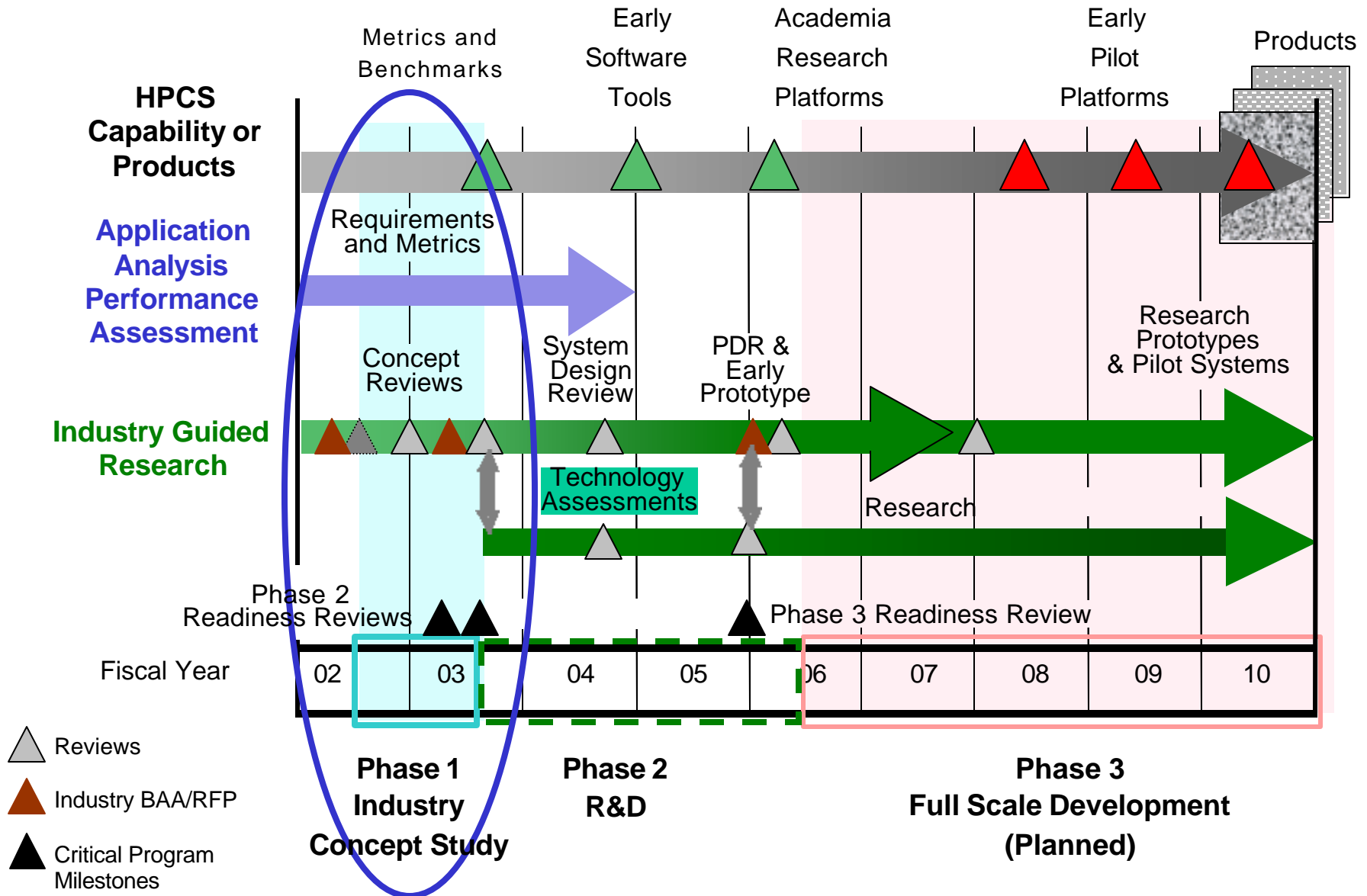
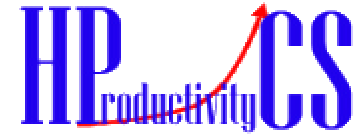
- Intelligence/surveillance, reconnaissance, cryptanalysis, weapons analysis, airborne contaminant modeling and biotechnology

**Fill the Critical Technology and Capability Gap**

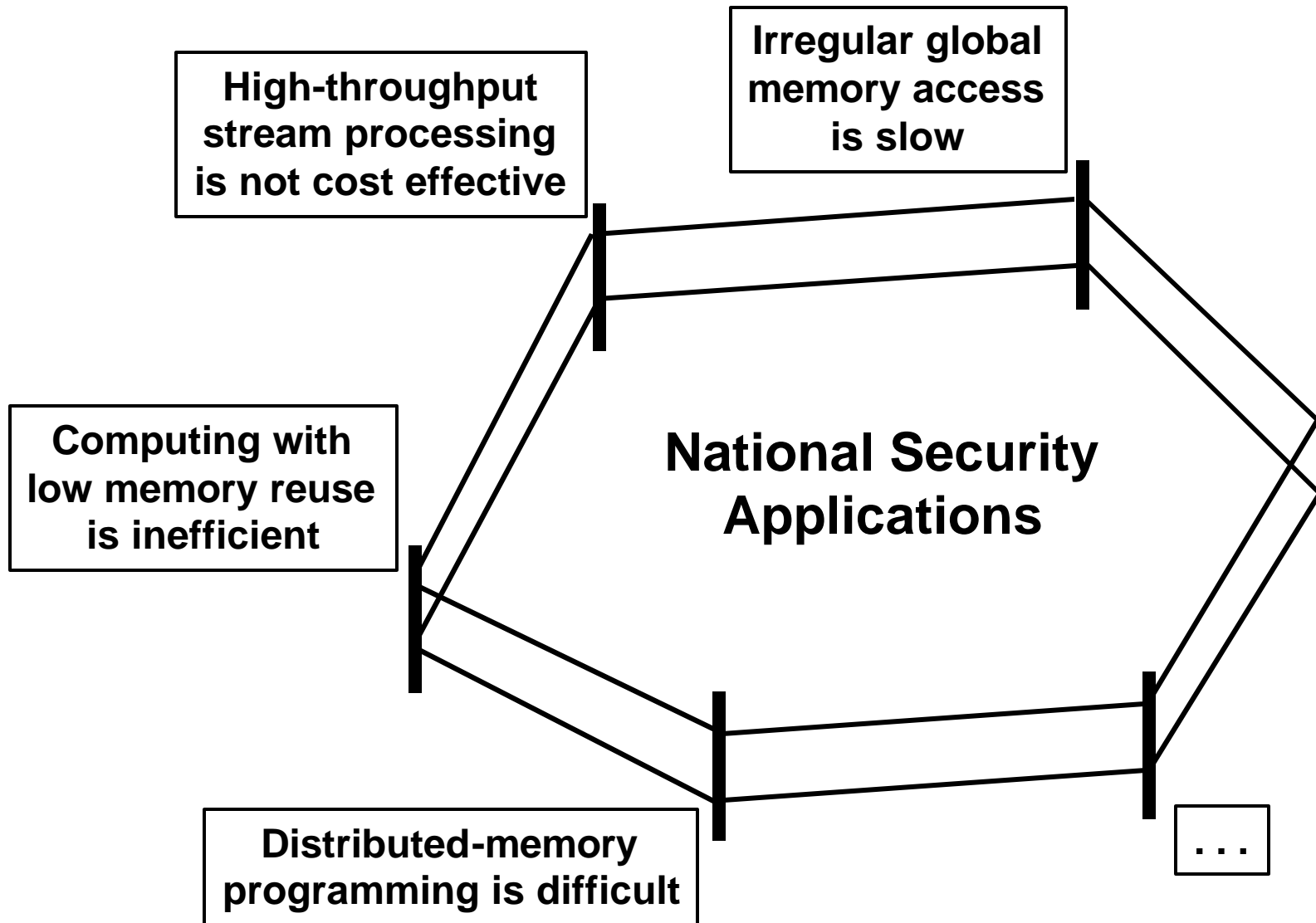
**Today (late 80's HPC technology).....to.....Future (Quantum/Bio Computing)**



# HPCS Program Phases 1-3

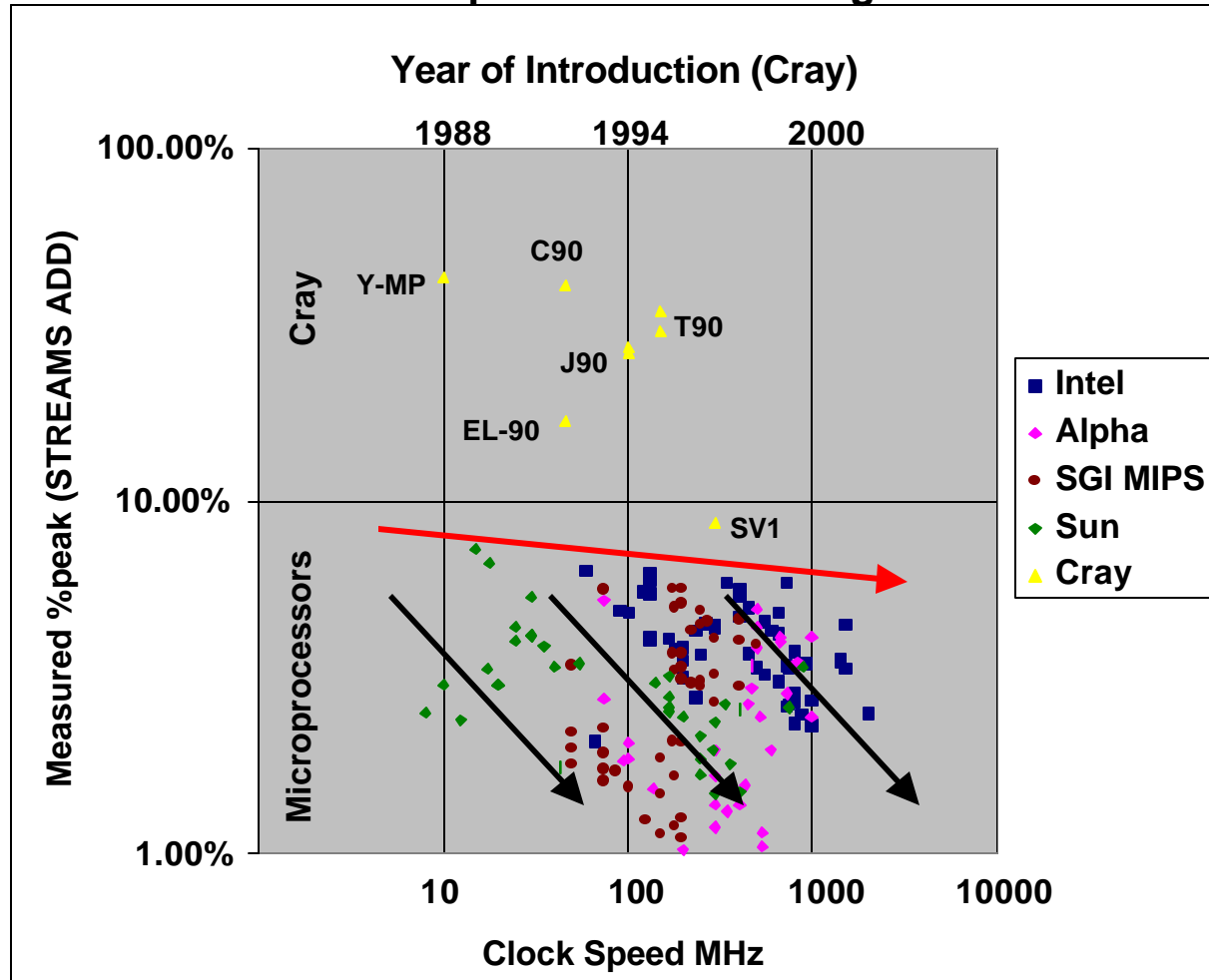


# Bounding the HPCS Challenges



# Why applications with limited memory reuse perform inefficiently today

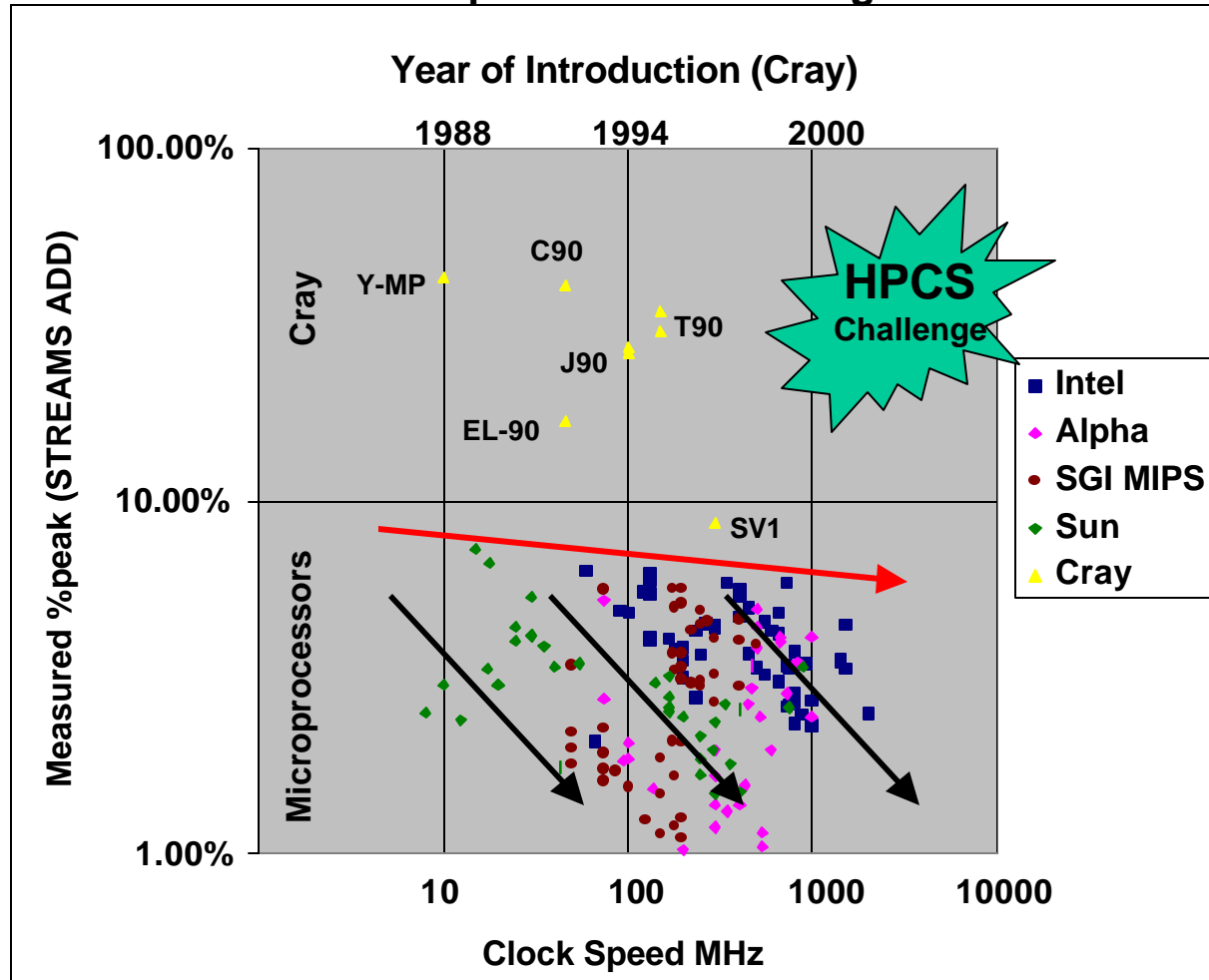
STREAMS ADD: Computes  $A + B$  for long vectors  $A$  and  $B$



- New microprocessor generations “reset” performance to around 6% of peak
- Performance degrades to 1% - 3% of peak as clock speed increases

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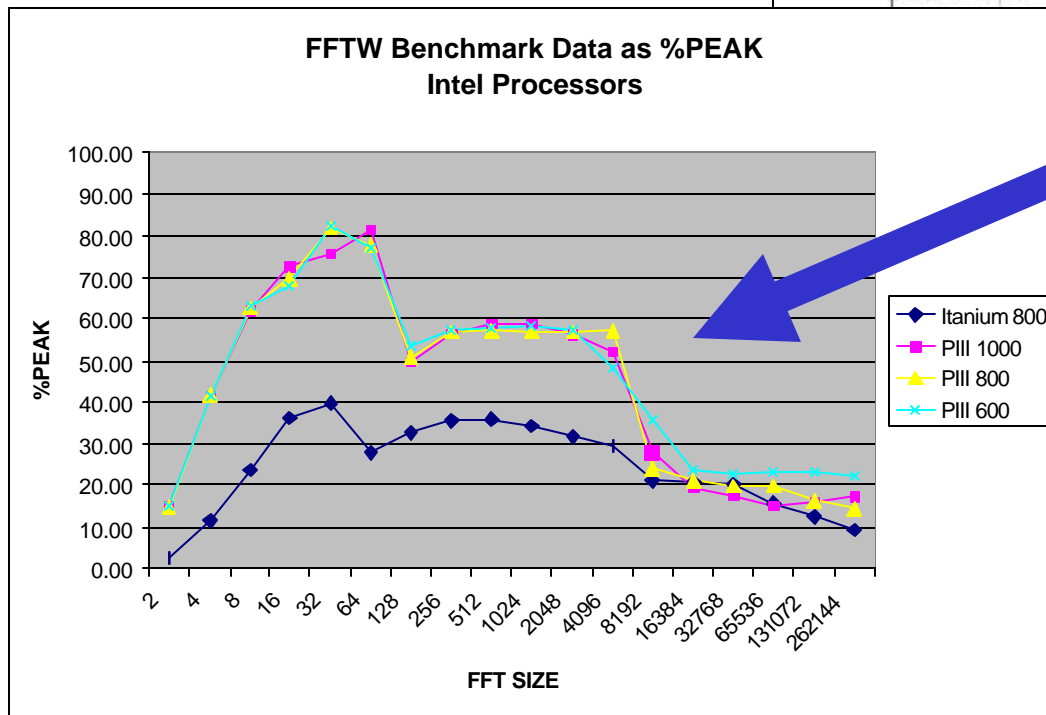
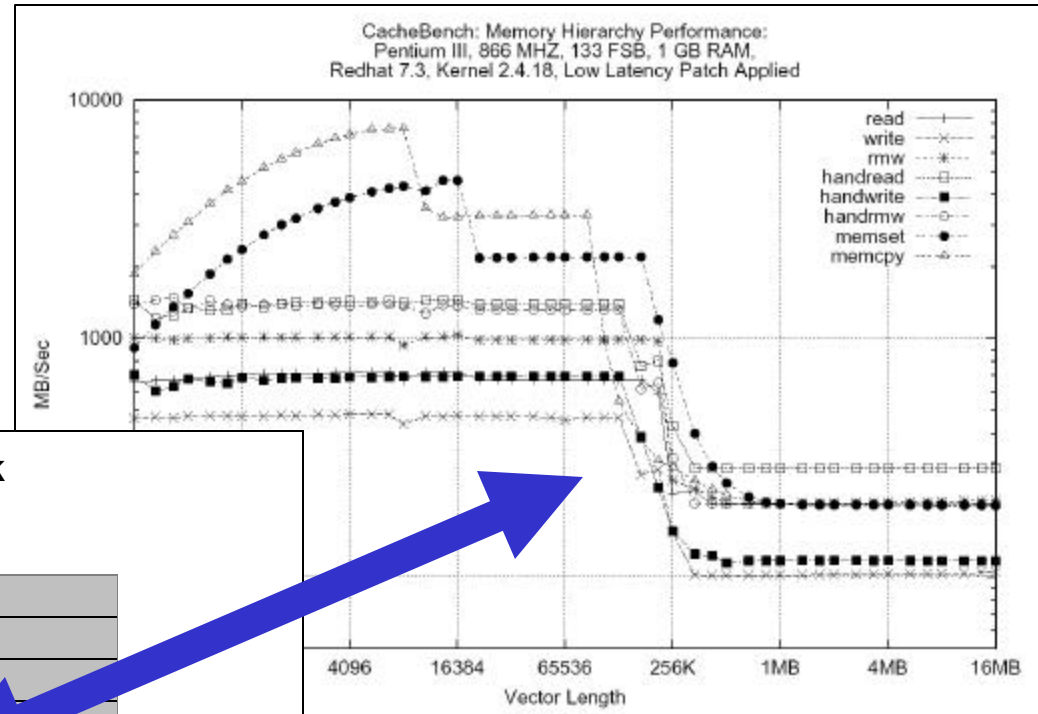


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# Long FFTs are Inefficient

## CacheBench

Direct correlation between memory bandwidth from various levels of the memory hierarchy and the performance of real applications

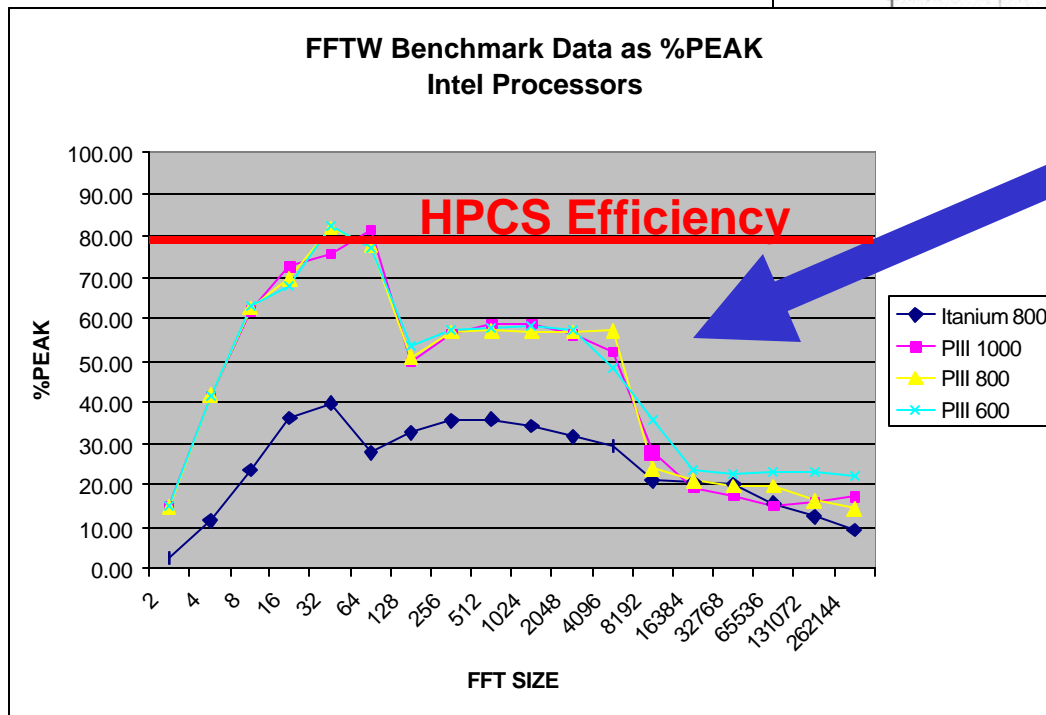
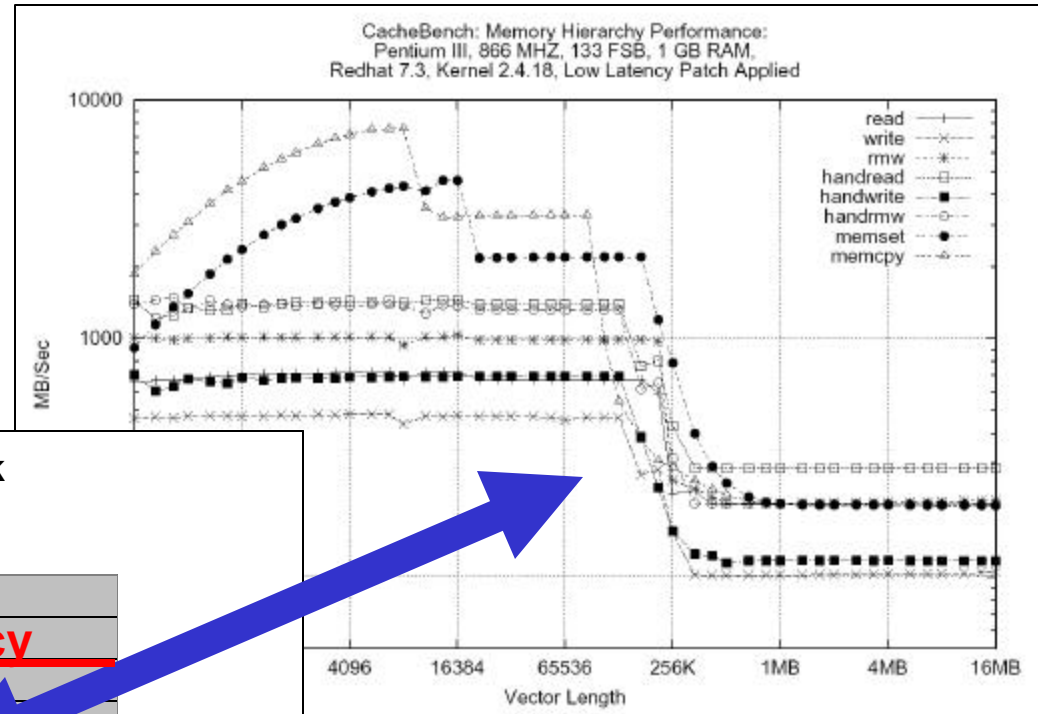


For the CacheBench benchmark see [icl.cs.utk.edu/projects/llcbench/cachebench.html](http://icl.cs.utk.edu/projects/llcbench/cachebench.html) (Phil Mucci)  
For FFTW software see [www.fftw.org](http://www.fftw.org) (Matteo Frigo & Steven G. Johnson)

# Long FFTs are Inefficient

## CacheBench

Direct correlation between memory bandwidth from various levels of the memory hierarchy and the performance of real applications



**HPCS Challenge**  
Cost effective signal processing in software for high throughput streaming applications

For the CacheBench benchmark see [icl.cs.utk.edu/projects/llcbench/cachebench.html](http://icl.cs.utk.edu/projects/llcbench/cachebench.html) (Phil Mucci)  
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# Value Proposition: Metrics

## Producer

- Sells computers
- Sells support
- Profit
- Market share
- Stockholder's equity
- Reputation
- Peak rates
- Customer satisfaction
- Deliver solutions
- Novel technology
- . . .

## Consumer

- Has national security mission
- Needs a computer to process data or calculate answers
- In time--time to solution
- Fits (size, weight, power)
- Easy to program--idea to sol'n
- Affordable--life-cycle, facilities and support costs
- Efficient--sustained rates
- Reliable
- Evolvable
- . . .

# Thesis

- Over the last 10 years R&D investments have made *high performance embedded computing* for national security applications more like mainstream *high performance computing*
  - Looking for good HPEC-SI demonstrations
- Over the next 10 years R&D investments will make mainstream *high performance computing* for national security applications more like *high performance embedded computing*
  - Looking for good HPCS challenge problems

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