NSA Overview

NAS/CSTB Study

The Future of Supercomputing

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Signals Intelligence

Mission Management Challenges

Targeting, Access, Selection & Filtering, Signal Processing (Text, Speech, Graphics, Video, Data), Analysis, Information Management and Dissemination, Security

Testing the Limits of Computation

Cryptanalysis

Natural Language Processing & Analysis

Data Management

Meeting the Needs of Federal Policy Makers in National Security, Homeland Security and Economic Security Matters but First in Support of the Nation's Warfighters

NSA's HEC Strategy

- ***Leverage HEC Vendors; Acquisitions, R&D***
- ***Develop Strategic Partnerships***
- ***Maintain Critical In-House Technical Mass***
- ***Fund Leading Edge Technology Research***
- ***Support Internal SPD Efforts***
- ***Keep Strong Linkages Among R&D, Acquisition, User Communities***
- ***Emphasize Usability & Programmability***
- ***Keep a 0 – 20 Year Perspective; Never Give Up!***

NSA's HEC R&D Program

HEC Architectures and Systems

High Speed Switches and Interconnects

Superconducting Electronics

Thermal Management

Programming Environments

Quantum Information Sciences

Vendor Partnerships

High Performance Interconnects

- ***Vendor-neutral Packet Router/Switch Interconnecting SMPs, MPPs***
- ***High Speed/High Bandwidth I/O – 3 Gbs***
- ***Memory-Processor Optical Interconnect***
- ***Partnership with ASCI PathForward Program***

Superconducting Electronics

- ***Superconducting Crossbar***
  - ***Proof of concept of 128x128 superconducting crossbar matrix***
  - ***Demonstrated serial data rate of 10Gbs per port***
- ***Superconducting Processor***
  - ***Prototyped superconducting microprocessor FLUX-1 with 6700+ logic gates; 25 ghz => 60 ghz***
- ***Subnanosecond Memory***
  - ***Fabrication and test of subnanosecond memory hardware***

The Pervasive Architectural Issue

*Type T Systems**

Commodity Components, Sub-systems

Performance: Degrades with Scaling

Server Architectures (SMP)

4-128 Processors/Node

Relatively High Latency

Distributed Memories (Shared in Node)

Memory BW: Poorer

Programming Model: Usually MPI

Programmability: Harder

Vendors: IBM, HP, Sun, SGI

*Type C Systems**

Highly Customized

Performance: Better Sustained

Various Architectures (MPP, PVP…)

8-128 Processors/Node

Accelerators: Vector, Multithreading Registers, Special Functions

Distributed, Shared Memories

Memory BW: Better

Programming Model: SSI; Shmem, MPI

Programmability: Easier

Vendors: NEC, Fujitsu, Cray

*Burton Smith, CAS2001

CRAY X1

CRAY X1

- ***Multi-year Joint Development Effort in Scalable Vector Architecture with NSA/DDRE and Cray Inc.***
- ***Technology Transfer - NSA Developed Technology***
  - ***e.g., Spray Cooling, MCM, UPC***
- ***Aug-Sept '02: Beta models delivered***
- ***Production Systems Shipped 31 Dec '02; 1000 Processor 4 Cabinet System in '03***
- ***Broad User Participation in X1 Program Reviews***
- ***Exceptional Congressional Funding-Follow on Systems in '02, '03***
  - ***X1e Scalable to 50TF***
  - ***Black Widow***

X1 Programmer's View

- **Traditional shared memory vector application**
  - OpenMP, Pthreads
  - 4 MSPs (50 GFLOPS)
  - Single node memory (16-32 GB)
  - Very high memory bandwidth
- **Distributed memory applications**
  - MPI, shmem(), UPC, Co-array Fortran with Single System Image
  - Same kinds of optimizations as on microprocessor-based machines
    - work and data decomposition
    - cache blocking (higher BW in cache, MSP improves short VL)
  - But less worry about communication/computation ratio, memory stride and bandwidth
    - multiple GB/s network bandwidth between nodes
    - scatter/gather and large-stride support

Background

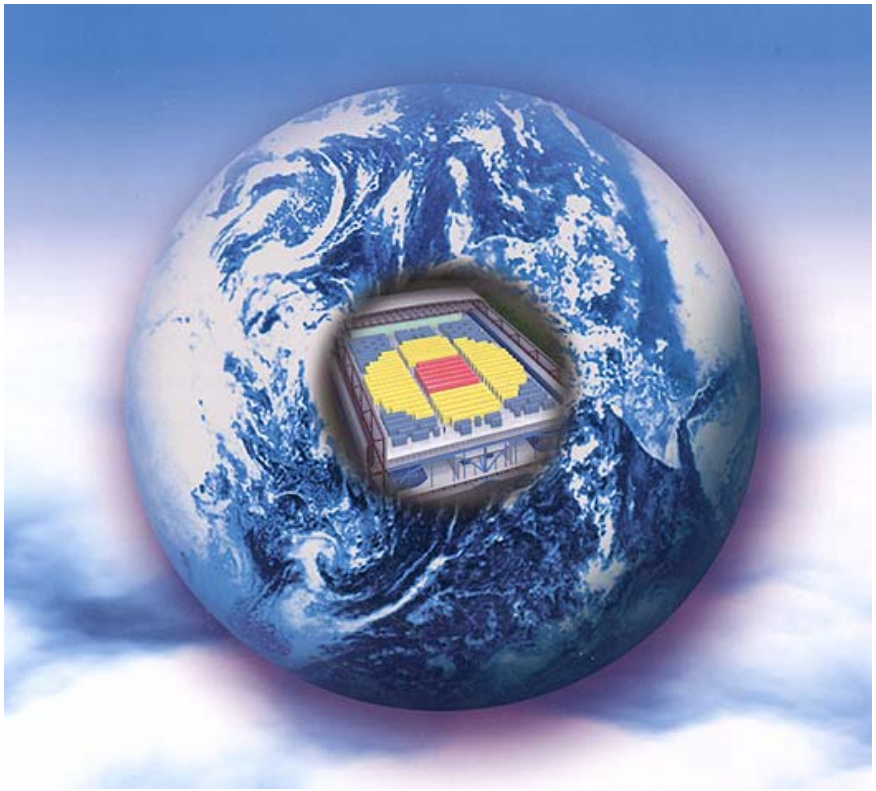
- ***Two Recent Studies Worth Citing:***
  - ***Congressional (HAC) Task to Develop an Integrated Long-range HEC R&D Plan for National Security Community***
  - ***Federal-wide NSTC Task Force to Study HEC R&D, Capabilities, Acquisitions***

Background to HAC Task

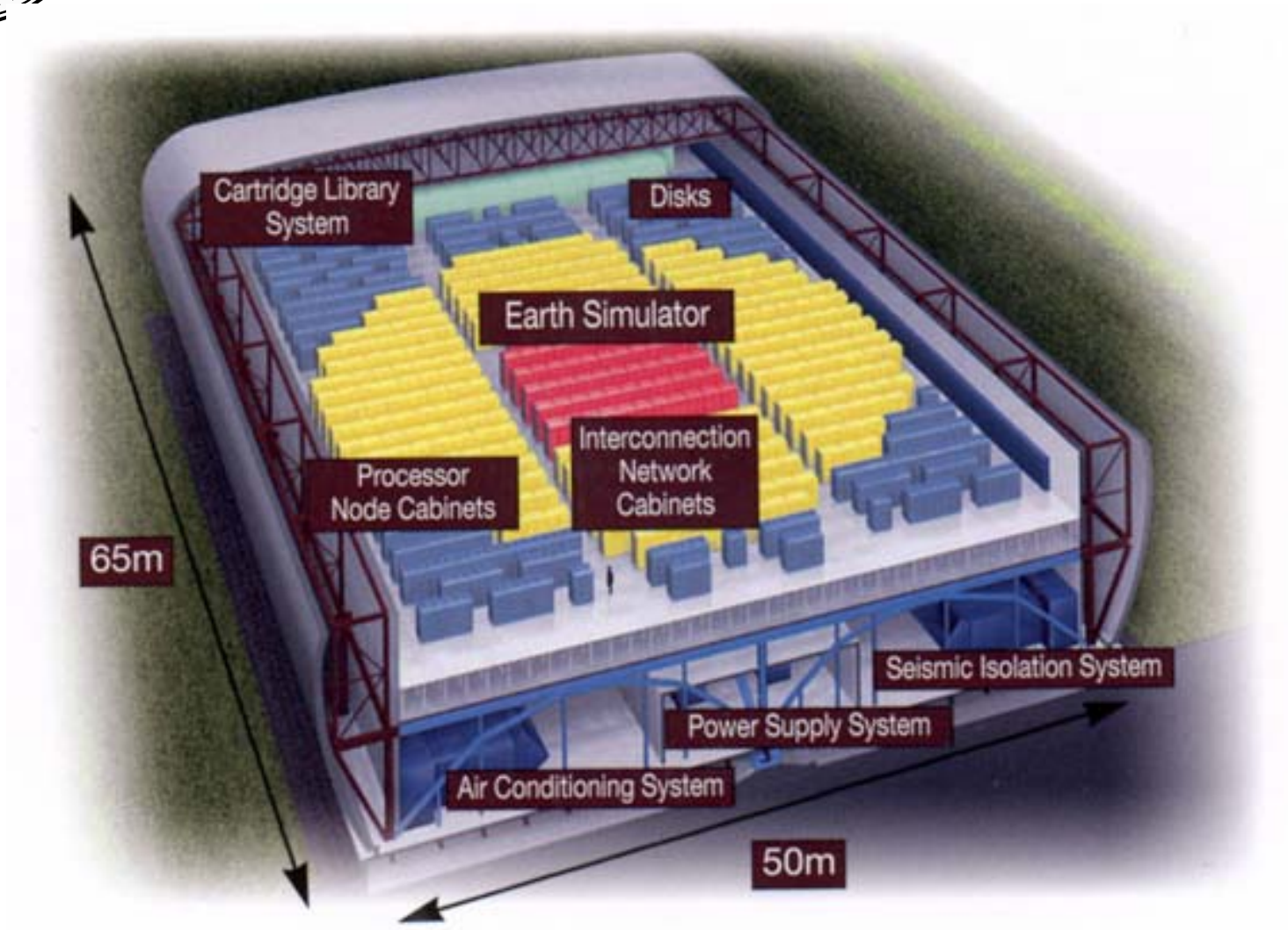
- ***Cray-NEC Agreement***
- ***Elimination of Tariffs***
- ***Intensive Discussions with DoD Principals on National Security Implications***
- ***Fragility of High End Leadership for US; Japanese Earth Sciences Machine***

Japan's Earth Simulator

- US450M govt project
- 40 Tflop/s system
- Operational in 2002
- World's largest general purpose system
- driven by climate and earthquake simulation requirements
- built by NEC
- 640 CMOS 8 Processor vector nodes

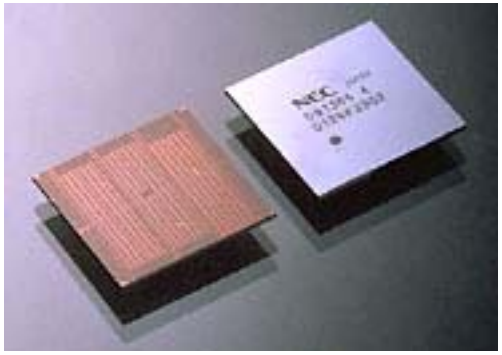


Earth Simulator Building



NEC SX-6

Peak performance is 8 Gflop/s
per single-chip processor,
64 Gflop/s per node, and 8 Tflop/s
for the largest configuration.
Shared memory of up to 64 gigabytes per node,
memory bandwidth of up to 256 GB/sec/node,
I/O bandwidth of 6.4 GB/sec/node.



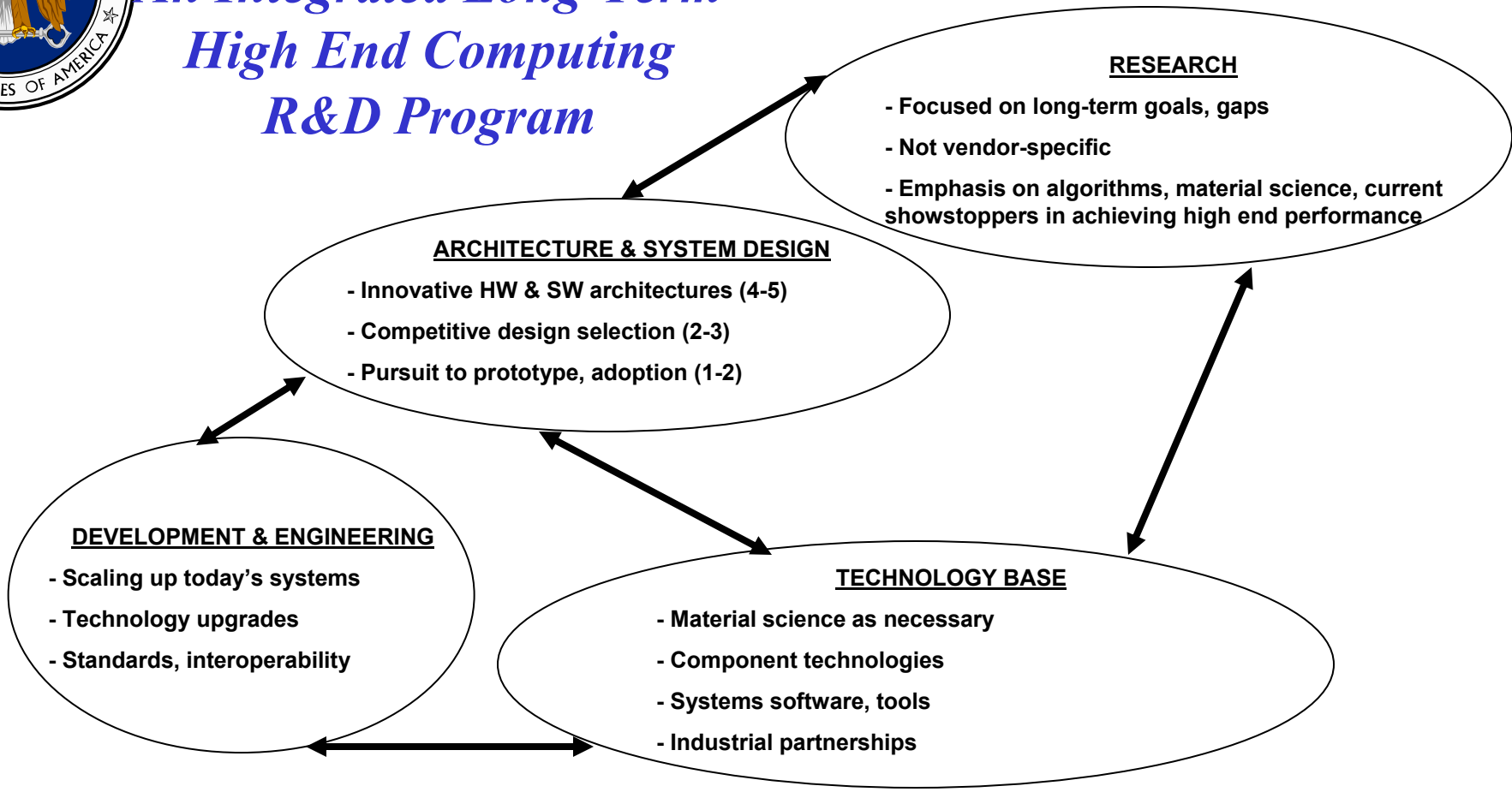
HAC Task on HEC R&D Program

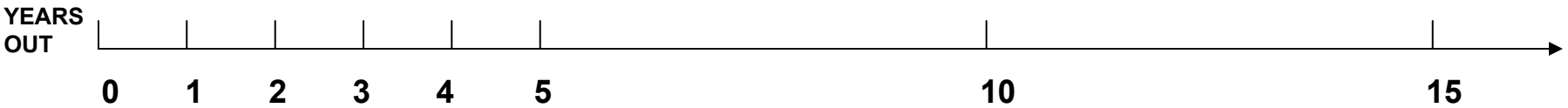
- ***Multi-agency Study Resulted in Development and Acquisition Plan for HEC R&D Program***
- ***Participants:***
  - ***Executive panel: NSA, DUSD S&T, DoE***
  - ***Agencies conducting R&D in HEC for national security applications: NSA, DARPA, NNSA, NASA***
  - ***National Security users of HEC: NSA, NNSA, NASA, DoD High Performance Computing Modernization Program, ASD C3I, Naval Oceanographic (Fleet Numerical), NIMA, NRO, military high end computing laboratories***
- ***Status: Study in DoD for Coordination, Funding***

Do We Really Want World Leadership?

- *'92 - Joint DARPA/NSA Proposal – PBD gave $350M/yr to DARPA for HPC Program*
- *'95/96 – DoD IPT; Recommended National Security HEC R&D Program, $300-500M/yr*
- *'99 – PITAC Recommended R&D Program with PetaFlop Goal*
- *'99/00 – HEC WG Response; Joint Program Proposal; Exceptional Funding*
- *'02 – Congressional Task; Long-Term Integrated HEC Program*

An Integrated Long-Term High End Computing R&D Program





IHEC Features

- Joint Program Office; DDRE Oversight
- Consolidate Existing DARPA, DOE/NNSA and NSA R&D Programs
  - Applied Research Component
  - Advanced Development (HPCS) Component
  - Engineering & Prototype Development Component
- Center(s) of Excellence

HEC Needs for National Security

- ***Comprehensive Aerospace Vehicle Design***
- ***Operational Weather/Ocean Forecasting***
- ***Stealthy Ship Design***
- ***Nuclear Weapons Stockpile Stewardship***
- ***Army Future Combat Systems***
- ***Electromagnetic Weapons Development***
- ***Intelligence Support***
  - ***Imagery & Geospatial Intelligence***
  - ***Signals Intelligence***
  - ***Threat Weapons Systems Characterization***

HAC Task – Users Needs

Comprehensive Aerospace Vehicle Design

Modeling and Simulation

F18, F22, F35,V22
Hypersonic Vehicles
Hypersonic Weapons
Mach 4-8

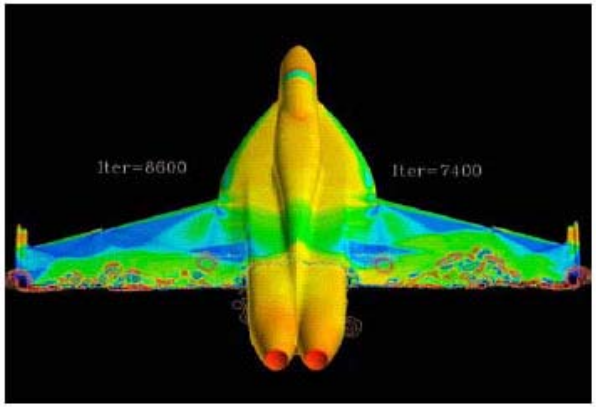


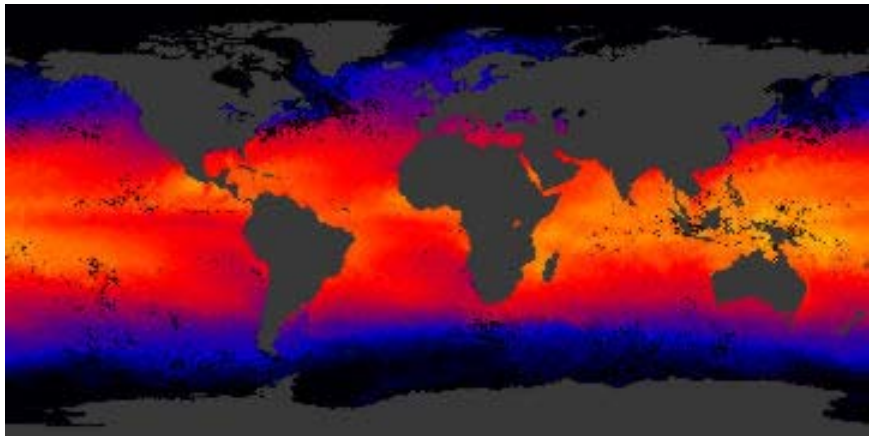
Figure 4: Prediction of unsteady shock oscillation on the F/A-18E using DES.

External Airflow	*Materials*
Propulsor Performance	*Signature*

FNMOC

Operational Weather/Ocean Forecasting

Global, Regional, Tactical Atmospheric, Oceanographic, Wave, Ice, Tropical Cyclone



Pressing Need: 4D Coupled Air-Sea-Land Models; <9km Resolution for 0-14 Days and <1km Urban Areas

Planning, Exercise, Engagement Support – All Services

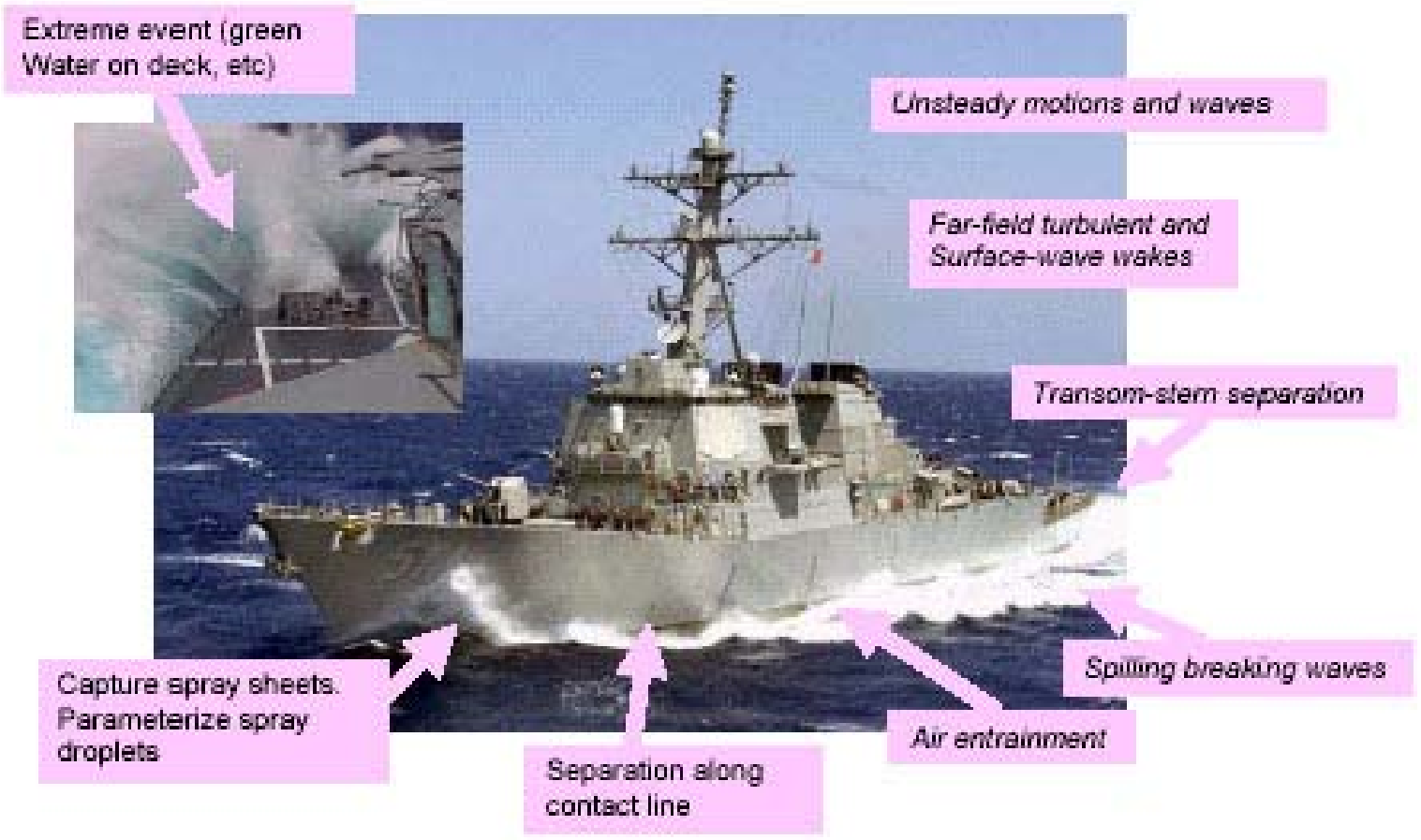
STRATCOM, Joint Forces Command

MDA, DTRA, LLNL for WMD

Backup to NWS

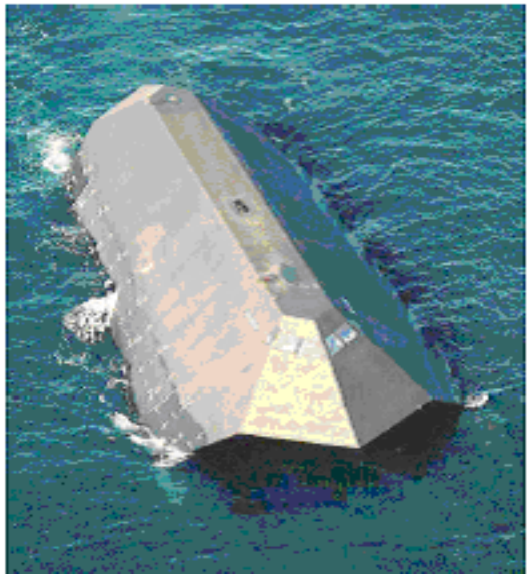
Stealthy Ship Design

Modern Surface Combatant



Stealthy Ship Design

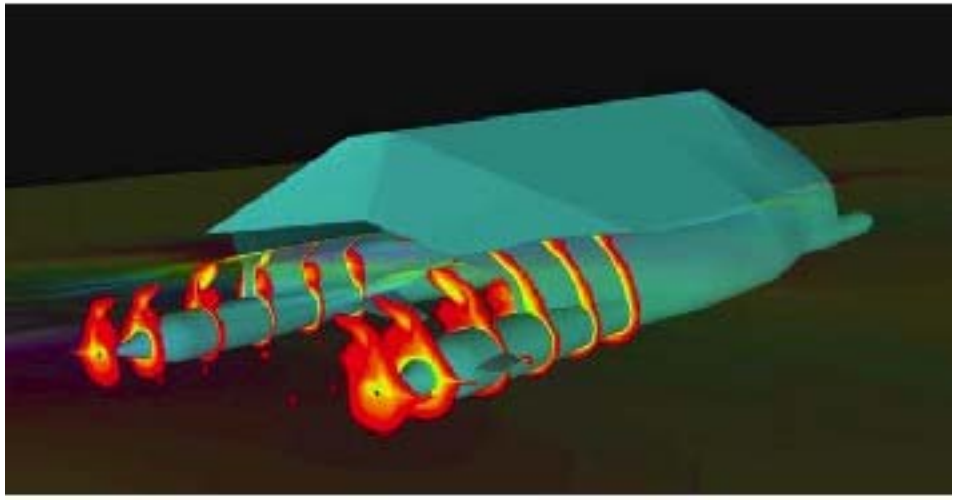
DD-X Land-attack Surface Combatant



Task is Signature Mitigation Submarine Levels of Stealth

Faster Running Models 20-30X for Design Tradeoffs

6 DOF CFD "In Seaways" Models Simulating Turbulent Wakes, Steep Breaking Waves, Entrainment of Air, Generation of Spray



Nuclear Weapons Stockpile Stewardship

Develop/Validate High Quality Computational Physics

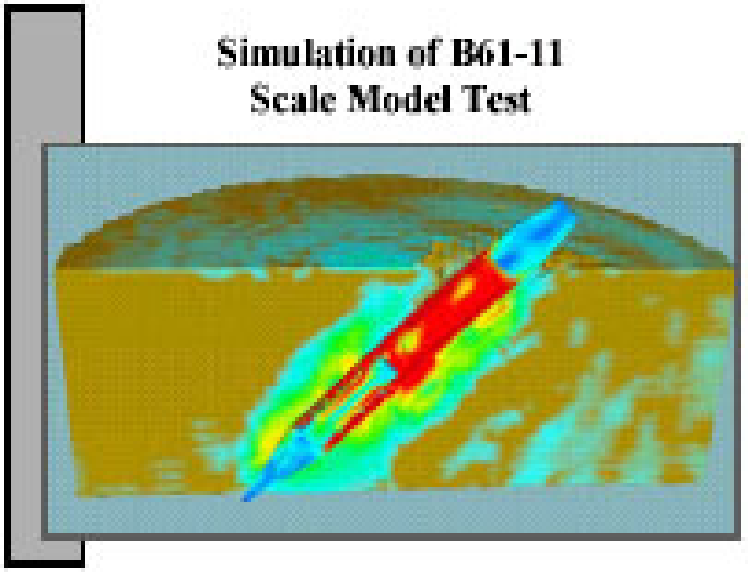
Modeling & Simulation in Support of Stockpile Certification

Finite Element Models

Mechanical, Thermal, Shock Hydrodynamics, Crash Dynamics

Exceptional Requirements

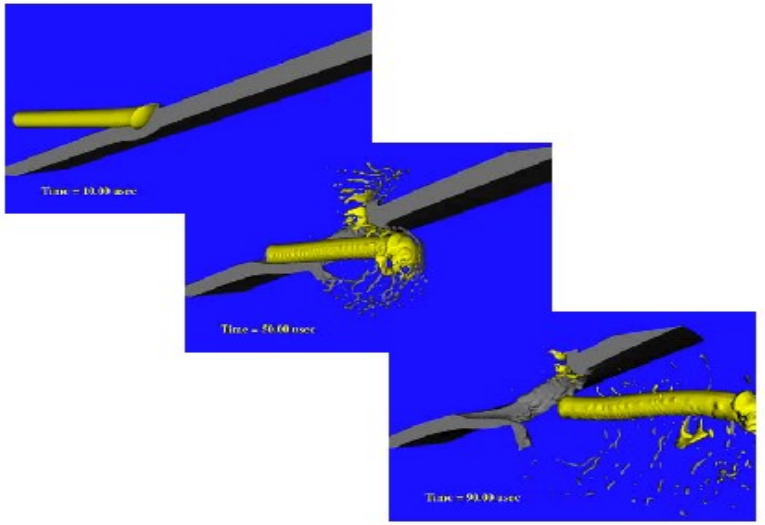
2PF, 200TB Memory, 14 PB Storage, I/O: 1-2 Hour Dumps



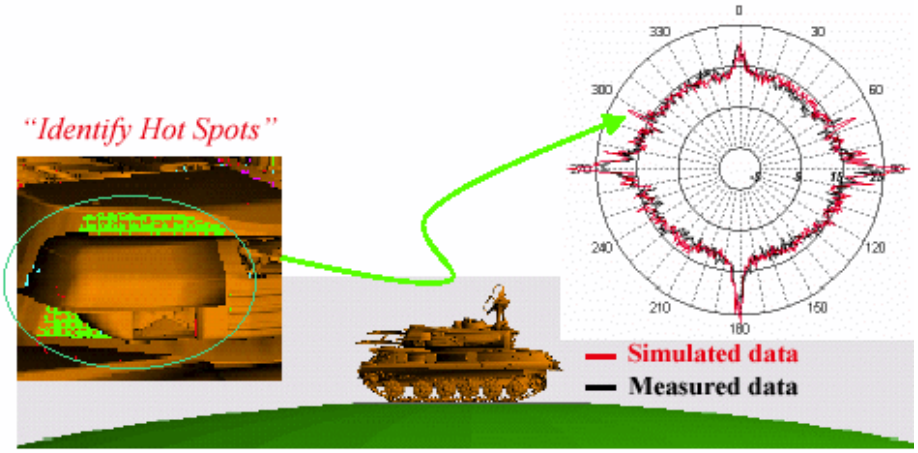
Army Future Combat Systems

Lethality & Survivability

Kinetic Energy Penetrators
Multifunction Warheads Kinetic Energy Missiles



Modeling Complex Projectile-Target Interactions



Modeling Radar Cross Section in the Presence of the Ground Plane

Passive, Reactive Armor
Advanced Hybrid Materials
Low Observables (IR, Accoustics)

Modeling & Simulation is Absolutely Key to New Capabilities

Electromagnetic Weapons Development

Airborne Laser for NMD

Chemical Lasers – Boost Phase Weapon

Modeling Laser Power & Gain (Optics)

Modeling Strength, Distribution, Spatial Spectrum of Stratospheric Turbulence

Staggering Computational Challenges:

Limited Observational Data
Operational M&S Support

A Critical Layer in U.S. Ballistic Missile Defense

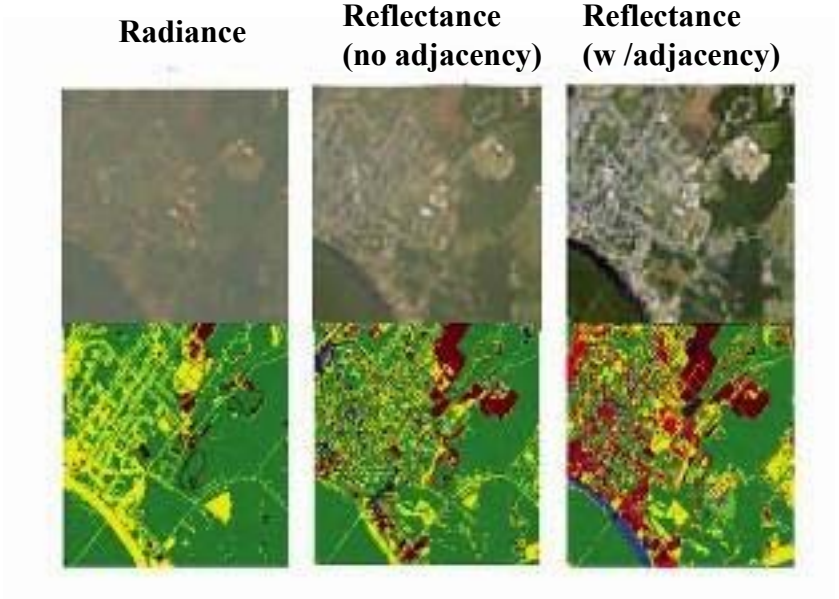
Intelligence

Imagery & Geospatial Intelligence

Multi-Sensors: EO, IR, SAR, Multispectral, Hyperspectral, Motion Video, GIS

Processing Challenges

Real-time, Huge Data Sets, Selection, Filtering, Conformal Integration



Support to Battlefield Management, Reconnaissance, Mission Planning, Tactical Situational Awareness, Targeting, BDA, and Technical Intelligence

Intelligence

Threat Weapons Systems Characterization

Critical to

National Warning System

Developing U.S. Weapon Response to Threat Systems

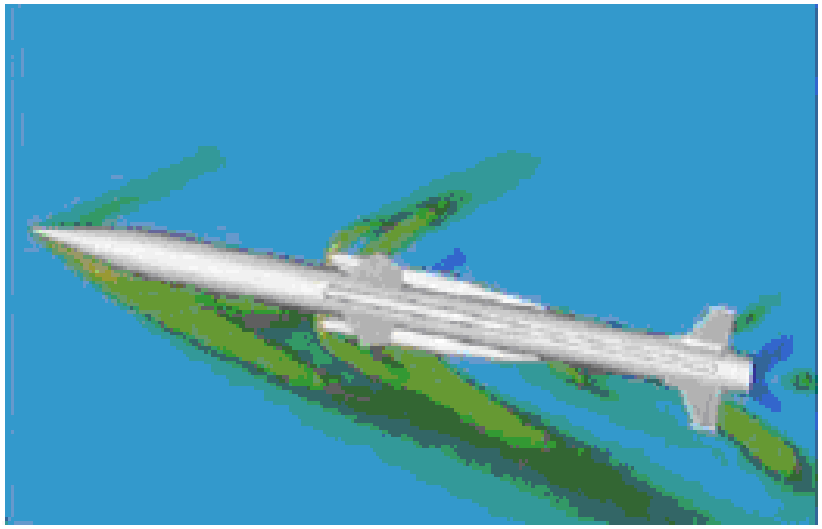
Battlefield Surveillance

National Missile Defense

Accurate Signatures

Missile Performance

Complete Flight Trajectories



Modeling & Simulation Critical, Access to Threats Seldom Available, Wind Tunnel, Signature and Field Measurements Prohibitive

HEC Improvements Needed

- ***Sustained Performance 4X-100X***
- ***Interconnects (Processor, Memory, Board, Node)***
- ***Larger, Global Shared Memories***
- ***Scalable I/O***
- ***Scalable, Balanced Architectures***
- ***Processor Designs***
- ***Improved Cooling***
- ***Reduction in Power & Size***
- ***Systems Software***
- ***Programming Paradigms***
- ***Ease of Use (Tools, Tools, Tools)***
- ***Time to Solution***

Summary

- ***Capacity & Capability Issues Often Enmeshed***
- ***It's Data and Computation, Dummy!***
- ***System Cost is an Important Factor***
- ***Increasing Concern on Industry Server Focus***
- ***TF Bar has been Raised (NEC, Fujitsu, Cray)***
- ***Sea Change in M&S; Past Physical Dimension***
- ***Technology Futures a Major Concern***
- ***Nat'l Security Sector HEC at Substantial Risk***
- ***National Security R&D Program Essential***

Lessons for HEC Managers

We Deserve What We Get, if We…..

- ***Live with Market-driven Architecture & Technologies***
- ***Fail to Understand our User's Needs, Problems, Applications***
- ***Accept Unbalanced Systems as State-of-the-Art***
- ***Don't Really Understand Vendor Machines - Strengths, Weaknesses***
- ***Can't Parse "Price", "Price/Performance" and "Performance"***
- ***Take Research & Development for Granted***
- ***Do not Seek Opportunities for Collaborations***
- ***Fail to Fight for HEC Budgets; R&D <u>and</u> Procurement***

Topics for Further Discussion

- ***State of the Industry***
- ***Foreign Competition***
- ***Industrial Market***
- ***IHEC Program***
- ***Technology Futures***
- ***Users Needs***