A Distributed Computing Support (DisCoS) Environment

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Outline

- Background: The technology gap
- A framework for new technology
- New Approaches
  - Programming /Compiling Technology
  - Application Composition Technology
  - System Analysis Technology
- Summary

Presented externally at the *DSWA Workshop on HPC Requirements*
Feb 18-20, 1998

Distributed Computing Support (DisCoS)

"Empowering Applications to exploit Future Distributed Heterogeneous Computing Systems"

Enterprise/Scientific/Engineering Computing

Large, Complex, Heterogeneous Applications

Complex Distributed Adaptive Platforms

DisCoS

- Distributed compiler and programming model
- Application assembly technology
- Computing system analysis technology

➢ *Enabling applications to efficiently execute across distributed, heterogeneous platforms*

Defense Applications

Distributed Computing Support (DisCoS)

Other Runtime Services

Distributed Systems Management

Distributed Computing Platforms and Networks

Impact

Management enhanced with distributed applications

Example: Target Recognition
- Distributed execution
- Highly efficient execution
- Real time or faster than real time
- Improve accuracy of analysis

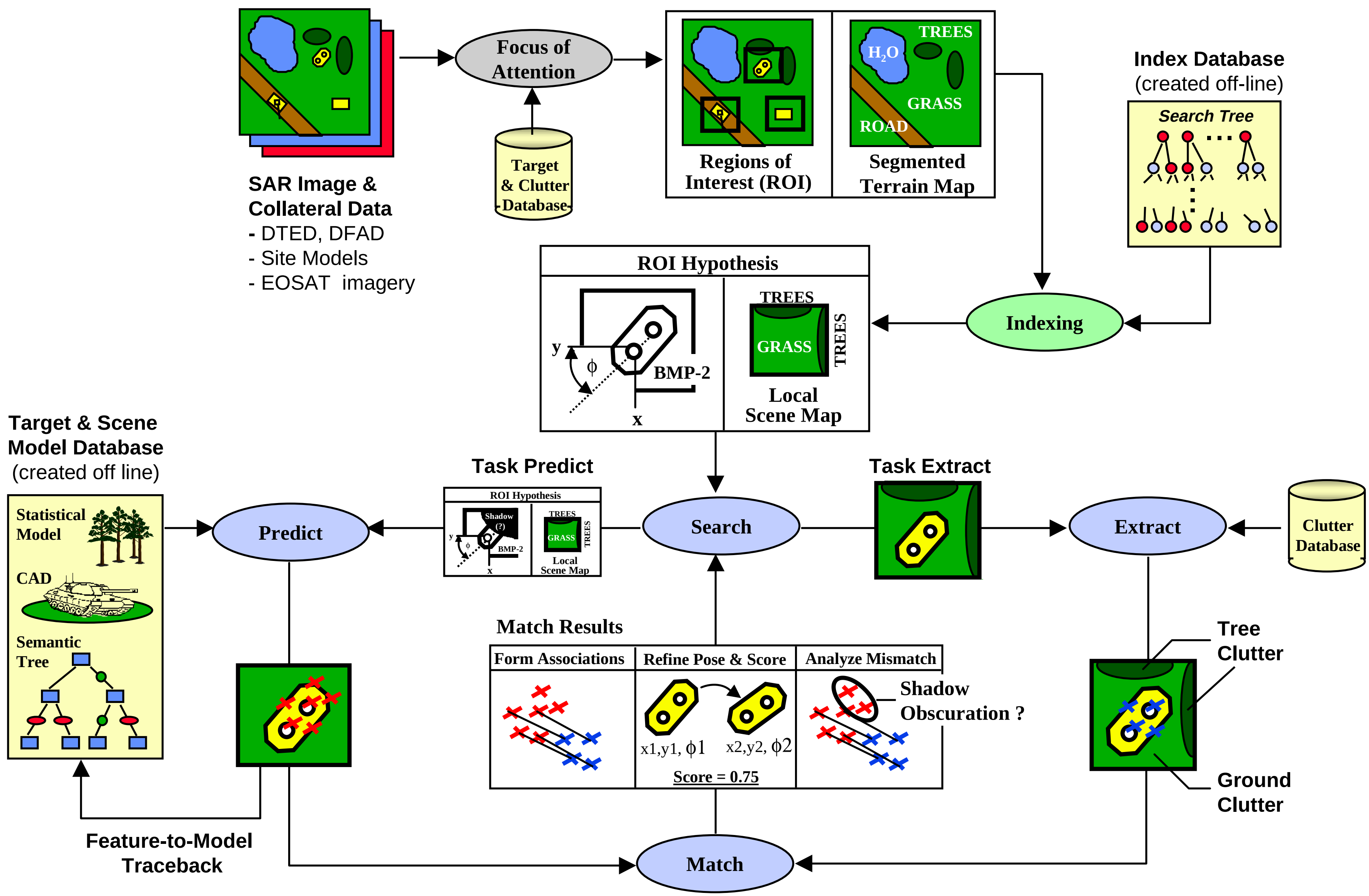
Improved process for application design, support and upgrade

Example: Pattern Recognition
- Reduce time to port applications: from months to ~hour
- Reduce cost to port applications: from $1M/port to $1K
- Enable rapid prototyping
- Reduce prototyping costs

Outline:
- Background: The technology gap
- Case example: DisCoS applied to MSTAR
- New approach
- Why now? Why the federal agencies?

MSTAR

(Moving and Stationary Target Acquisition and Recognition)



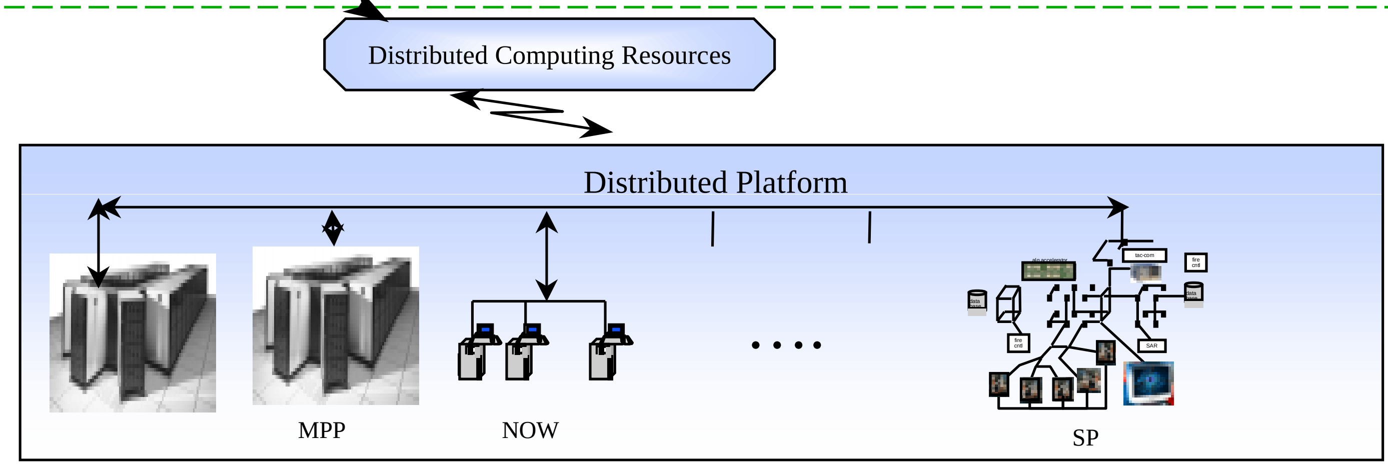
Technology Gap for Distributed Applications

Dynamic Analysis Situation

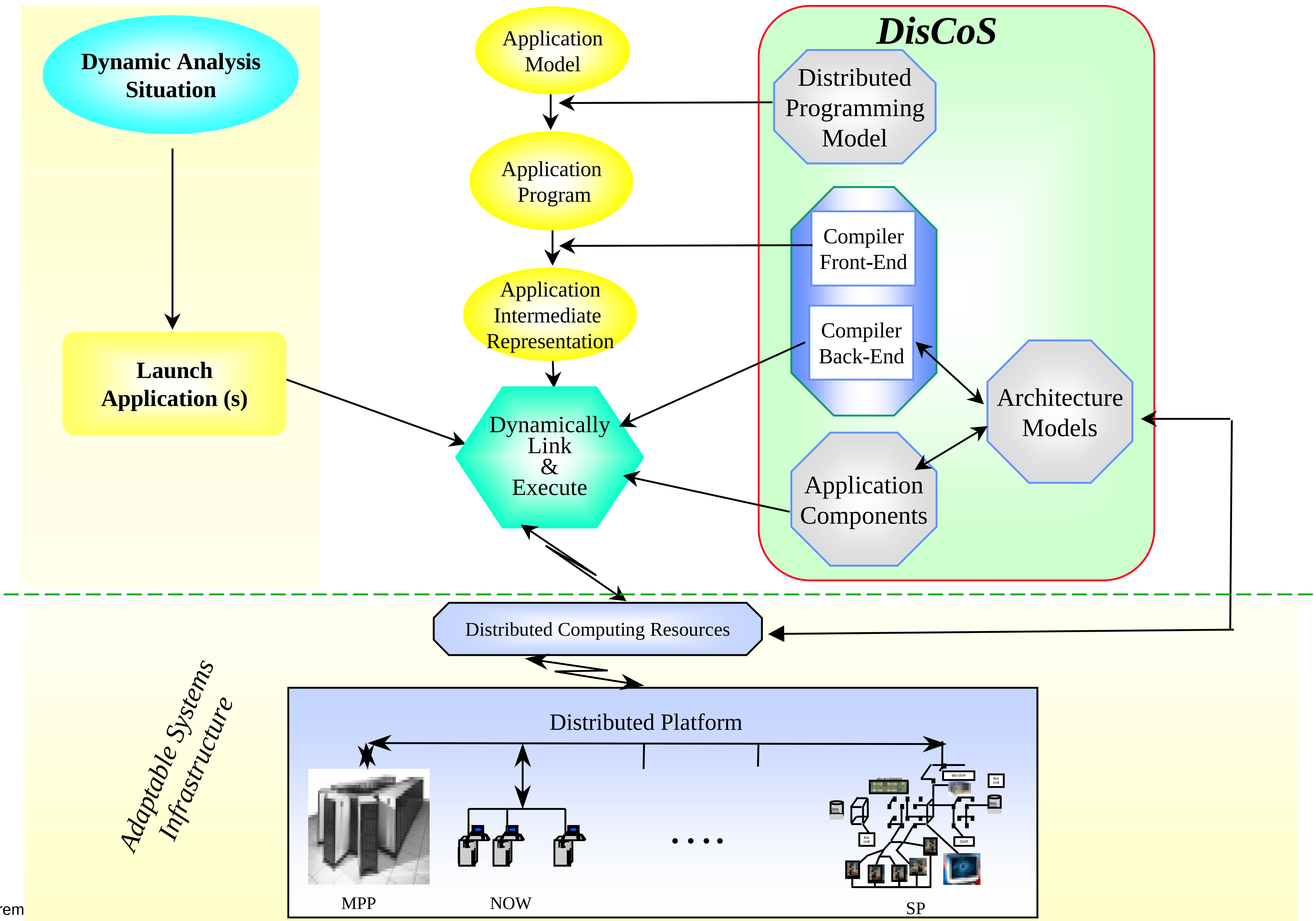
Launch Application(s)

Platform	Programming Model	Constraint
•Network of Workstations (NOW)	• Message passing • Static partition	• Inefficient load-balancing
•Symmetric Multiprocessor (SMP)	•Shared queue •Dynamic allocation of work	•Application "re-write" required
•Cluster of SMPs	•Message-passing across SMPs •Shared queue within SMP	• Application cannot be repartitioned dynamically when problem size or number of SMPs changes

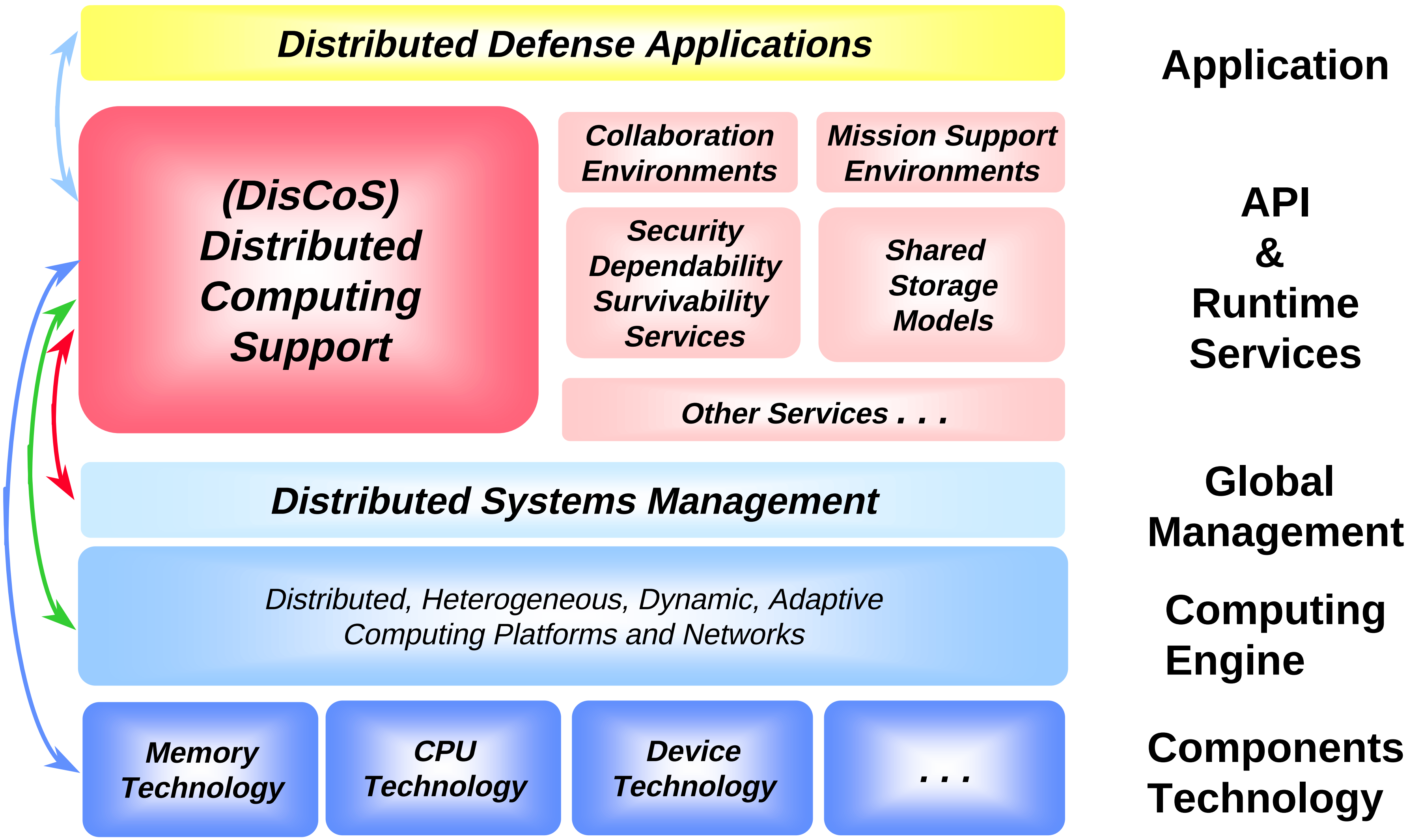
Adaptable Systems Infrastructure



The Solution: DisCoS Technology



Distributed Systems Software/Hardware Architectural Framework



Technical Approach

<u>The Goal</u> of this research is to create a System for Applications' *development and runtime* support, comprised of:

- programming models and compilers which enable applications to dynamically map to the reconfigurable system infrastructure;
- software tools for dynamic selection of application components;
- analysis tools to enable delivering quality of service

<u>The Impact</u>: DisCoS will enable applications to:

exploit the changing features of the underlying distributed reconfigurable heterogeneous platforms, and satisfy dynamic demands

<u>Techlogy Areas</u>:

- ***Application Programming System (APS)*:**
  distributed programming models and compilers
- ***Application Composition System (ACS)*:**
  dynamic selection of distributed application components
- ***Application Analysis System (AAS)*:**
  technology for performance engineered distributed applications
- ***Validation, Integration and Demonstration*:**
  validation, integration and demonstration of the technology

Technical Areas

- **Application Programming System** (distributed programming models and compilers)
  - distributed programming models for complex, distributed hardware platforms with complex memory structure and be adaptable to changes in the underlying platforms
  - interfaces that allow applications to specify performance related parameters to enable applications to achieve quality of service
  - compilers that interface with models of the underlying distributed hardware and software platforms to allow retargeting and optimizing application mappings on such complex systems

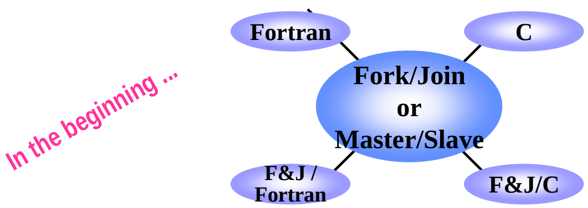
- **Application Composition System** (dynamic selection of distributed application components)
  - technology for building knowledge-based systems allowing automatic selection of solution methods allowing applications to adapt to changes in the underlying platforms or to changes in the application problem
  - application interfaces and methods for problem specification and extracting content information, standards of interfaces, data representation and data exchange, and standard high-level and low-level libraries
  - interfaces to debugging tools and performance models

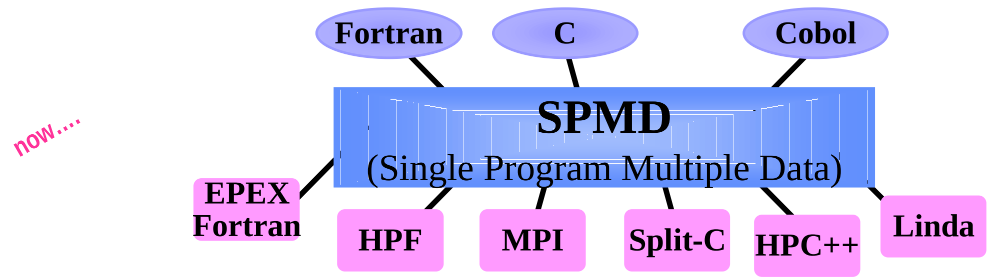
- **Application Analysis System** (technology for performance engineered distributed applications)
  - modeling languages and models for application and system description
  - multi-resolution levels of data abstraction for interoperability of performance models of different levels of abstraction
  - methods and tools for measurement and instrumentation

    (initial efforts for this technology are supported under the as a result of the DARPA BAA 97-12, issued by F. Darema)

- **Validation, Integration and Demonstrations** (validation, integration and demo of the technology)
  - validation of key technologies developed under each of the tasks above
  - identify integrator to integrate the technologies developed above
  - demonstration of the ability of these technologies for design and runtime support of key applications executing under dynamically changing conditions (examples: Target/Pattern Recognition)

Application Programming System
Challenges and Approaches



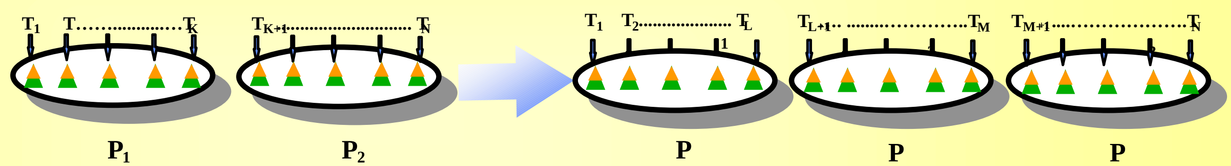


The present models poorly serve applications that:

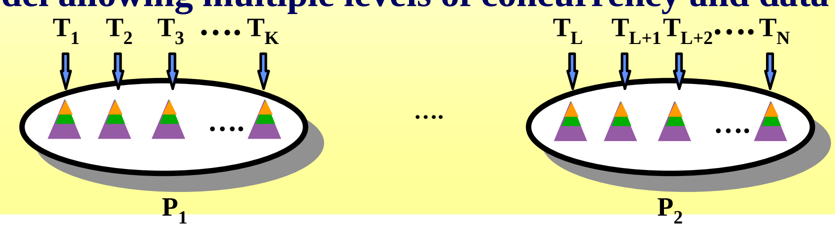
- **Require dynamic task scheduling and resource allocation**
  - **Tree-based algorithms (database searches)**
  - **DD applications, e.g. weather simulations using adaptive-mesh refinement**
- **Need task independence in the presence of multiple levels of memory hierarchy**
- **Must run on distributed heterogeneous platforms**

DisCoS will overcome the limitations with a new model and compiler technology:

- **Extend SPMD, compiler directives, negotiation with Operating System**
  - **Dynamically chunk the queue (ROI example)**



- **Develop a hybrid model combining features of existing models**
- **Create a new model allowing multiple levels of concurrency and data distribution**



Application Composition System
Challenges and Approaches

Present approaches for application software reuse and composition:

- Libraries of application kernels
- Libraries for specific models of memory hierarchy
- Problem Solving Environments enable “wiring together” specific application

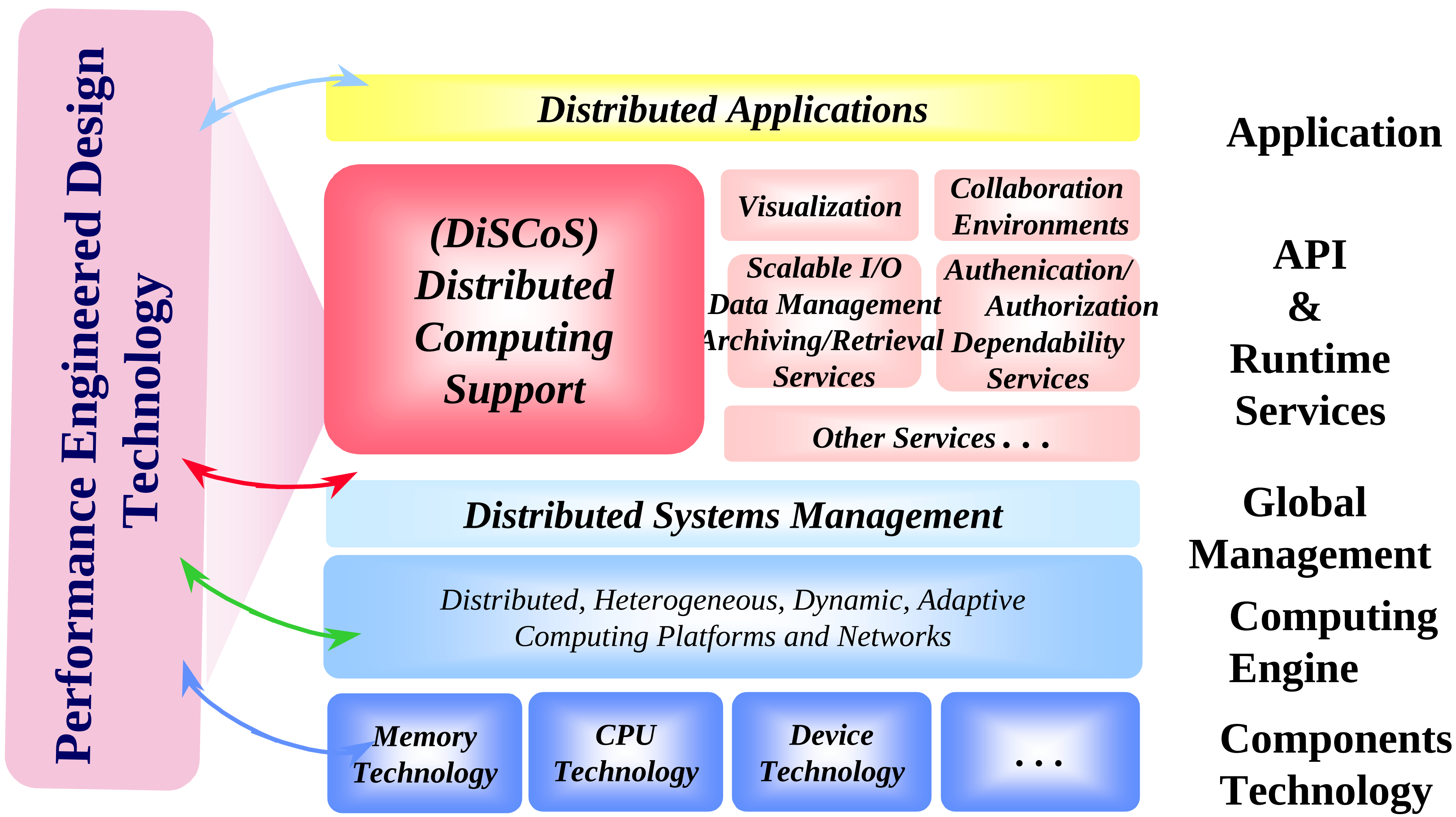
Problems not addressed by existing technology:

- Find and select compatible software components to build applications for heterogeneous platforms
- Bridge different data models used by components
- Build applications by dynamically composing independently-developed components

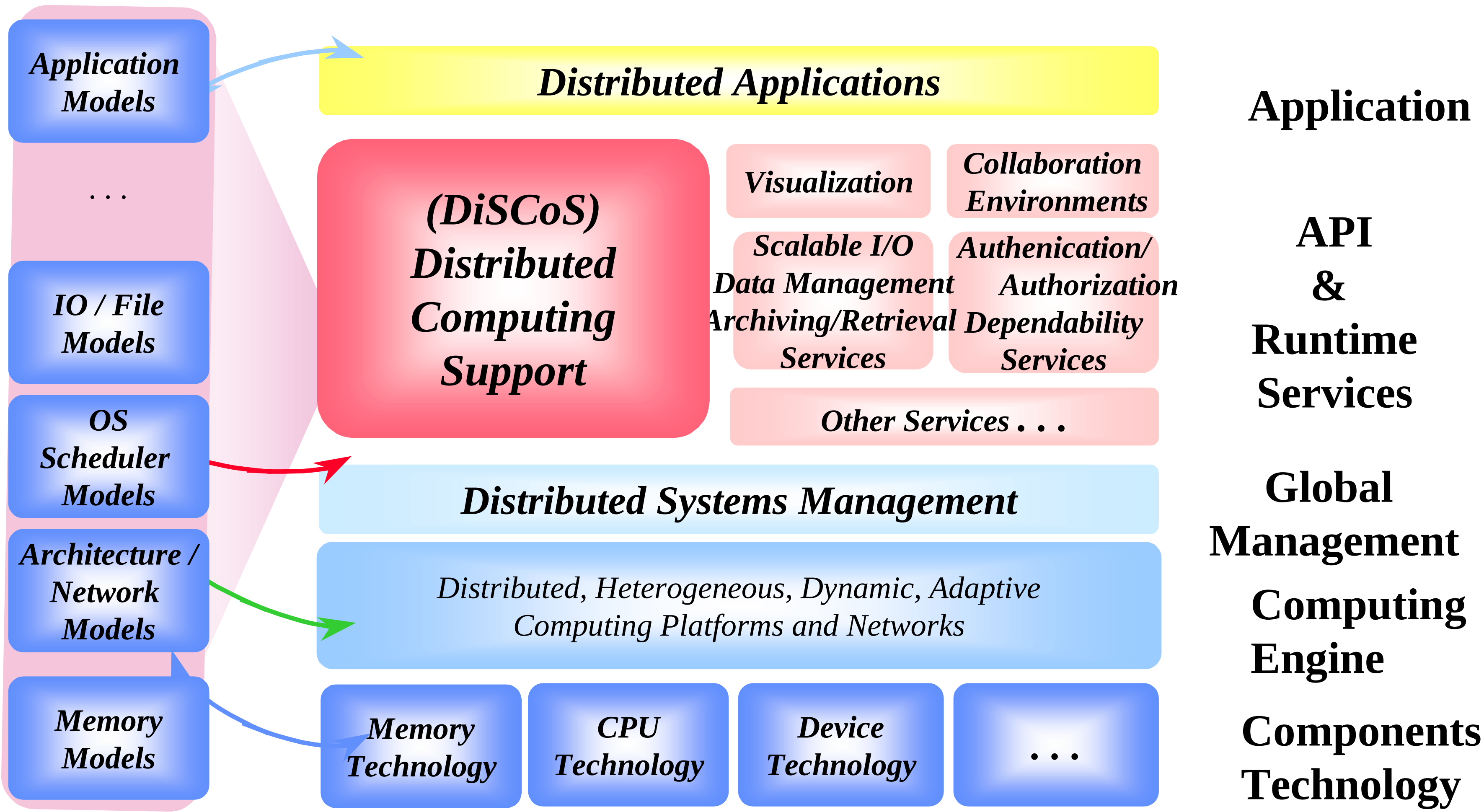
New technology:
“user interface + libraries + knowledge-base “

- Straightforward extensions of existing technology:
  - **Develop knowledge-based systems of components for specific defense applications**
  - **Populate the knowledge data-base of components for specific platforms**
- Medium Risk Research Agenda
  - **Develop efficient data exchange mechanisms between different data representations**
  - **Use data-mining to extract performance knowledge of specific application components**
  - **Develop general interface mechanisms for selecting suitable components**
- High Risk Research Agenda:
  - **Automatic generation of application beginning from high-level specifications (e.g. text, equations)**

Distributed Systems Software/Hardware Architectural Framework



Distributed Systems Software/Hardware Architectural Framework



Application Analysis System Challenges and Approaches

Present methods and tools for performance analysis

- Modeling (queuing and analytical models)
- Simulation tools
  - architecture, network, cache, and I/O simulators
  - trace-driven, execution-driven simulations
- Performance data generation and collection
  - software assists (user directives, libraries)
  - hardware monitors
- On-line analysis and post analysis; Visualization

Problems with present technology

- Existing performance methods and tools study isolated system components
- Interaction of design features across different system layers not well understood
- No means to exploit design information at one level for another level (compiler-architecture for optimization of data mapping, or task scheduling)
- Dynamically-changing heterogeneous systems are even harder to analyze
- Current technology cannot be used to predict performance of future systems and allow reduction of prototyping effort

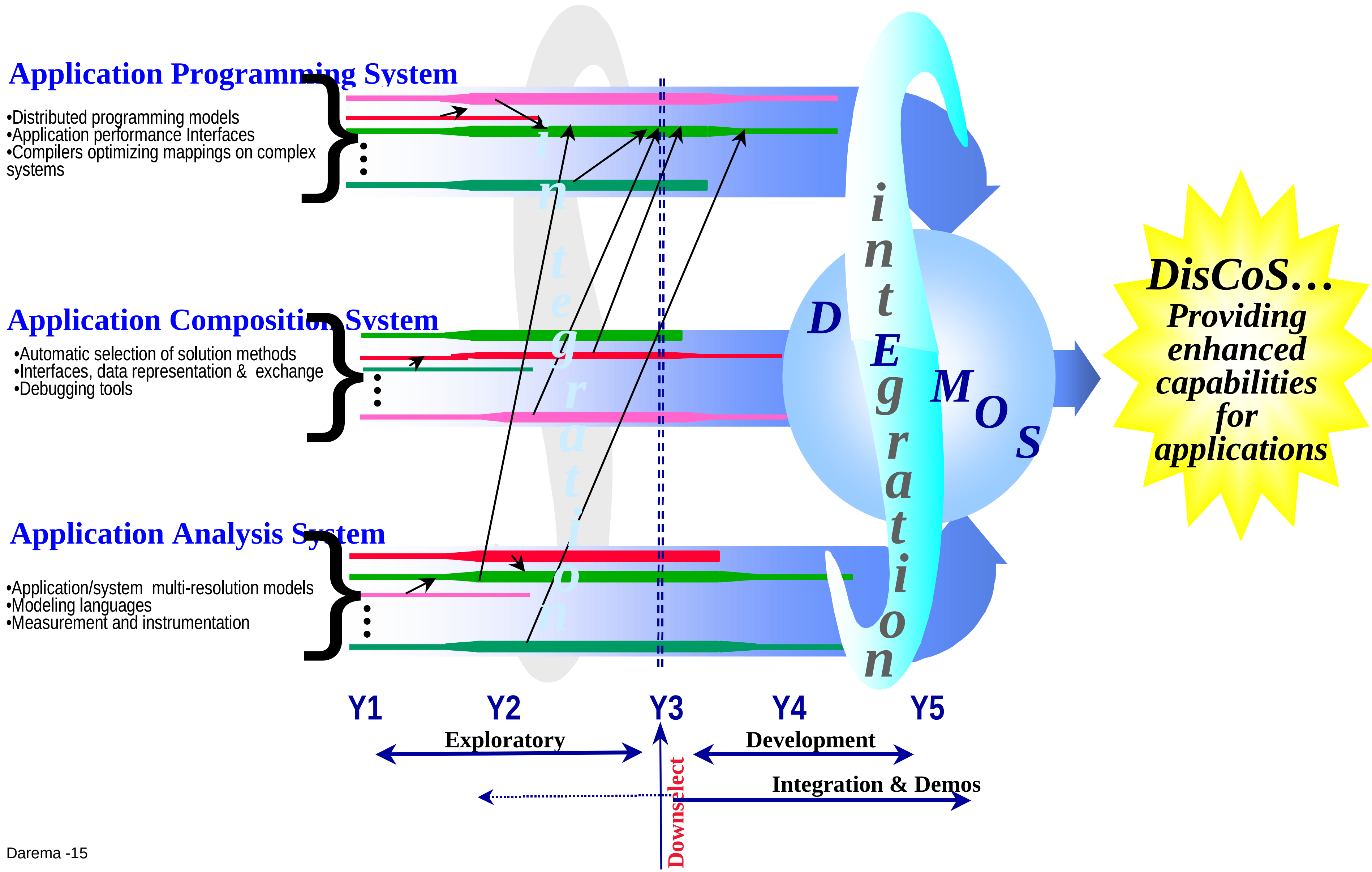
DisCoS approach for performance analysis:

- Low Risk Research Agenda:
  - **Enable optimizations via application directives to the compiler**
  - **Develop simple parametric models of the application and underlying platform**
- Mid-Risk Research Agenda:
  - **Use parametric application models with system software and hardware models for optimizing task scheduling and partitioning by the compiler**
- High Risk Research Agenda:
  - **Develop performance frameworks with multi-resolution, integrable models across all levels of the system hierarchy, for more accurate compiler optimizations and mapping, and with capability to predict performance of the computing system, as a whole and across levels**

Validation, Integration and Demos
Technical Approach

- Select defense applications; candidates: Large industrial applications
- Identify modules in these applications for validation of DisCoS components, like programming models, compiler techniques
  - Use these modules for demo-ing compiler capability to map these modules across platforms.
  - Test compiler ability to use resource information and architecture models
- Integrate the DisCoS components into the DisCoS system
- Demo use of DisCoS on development and runtime support of these application modules on distributed, heterogeneous platforms

DisCoS Roadmap



Role of the Federal Agencies

- The development of this technology will need intiative from the Federal Agencies
- Effort analogous to one that pushed the frontiers for parallel and scalable computing
- Build on cross-agency co-ordination
- Hard to do given the shrinking budgets and mission oriented programs
- … but...

Why Not Industry

- Desktop is the driver for commercial software, and industry focuses on producing flexible software for the low-end
- "Commercial/Enterprise Computing" also poses requirements for more flexible and adaptable, reconfigurable interoperating systems and applications

..... BUT.....

- Industry focused on the short term returns, rather than investing on research for the enabling technology
- Moreover, industry addresses the problem by providing **services** for:
  - application porting
  - application integration

  .... and making LOTS of $s!!!

  <u>Services</u> is the <u>fastest growing</u> component of <u>computer vendors</u>' business

- Industry however has history of adapting and productizing research technology which has demonstrated success

DisCoS Benefits to Future Computing

The Future Computing Environment:

- **Need for time-sensitive results**
- **Large applications, not computationally uniform**
- **Applications spanning multiple machines, dynamic resource needs**
- **Hierarchical distributed architecture computing platforms**
- **Resources with time varying availability**

The DisCoS system:

- **Creates ability for complex defense applications to be distributed, adaptable to reconfigurable platforms, and achieve quality of service**
- **Decreases time to rebuild distributed applications by two orders of magnitude (from months to ~hours)**
- **Reduces prototyping time and cost of large distributed applications (from many months to days, and from many $Ms to few $Ks)**
- **Preserves application investment over time and as hardware platforms change**