Milieu Approach for Software Development for the PCA Program

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Organization

- Goals
- Software Architecture
- Build Chain
- Metadata
- Dynamic Resource Management
- Software Components
- Prototype Results
- Future Work
- Conclusion

Goals of the Project

- Study and prototype a modeling language for streaming and threaded resources
- Study and prototype techniques for design space exploration in order to enable PCA scheduling
- Study and prototype techniques for system synthesis and generation
- Contribute findings to the MSI forum

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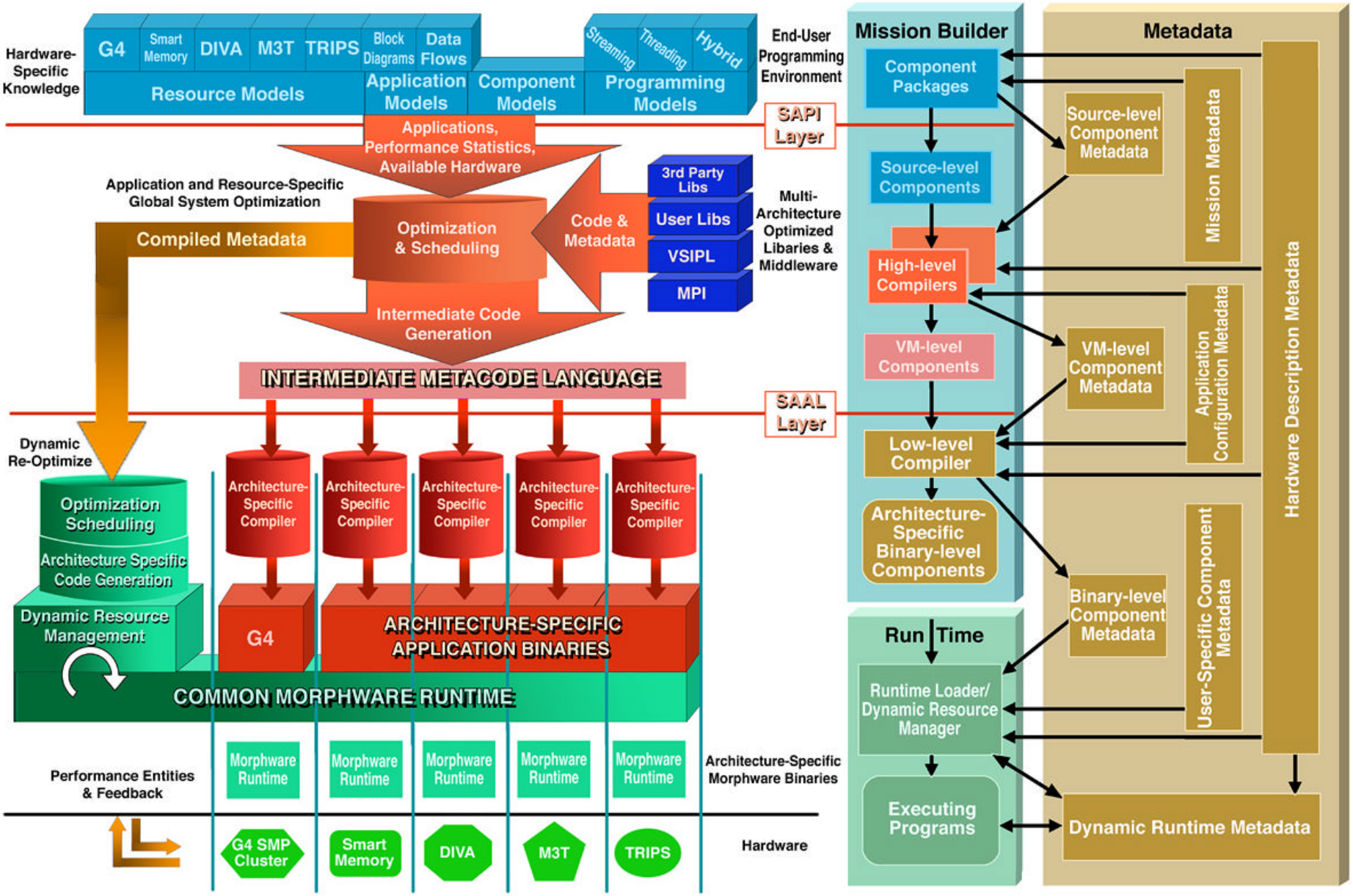
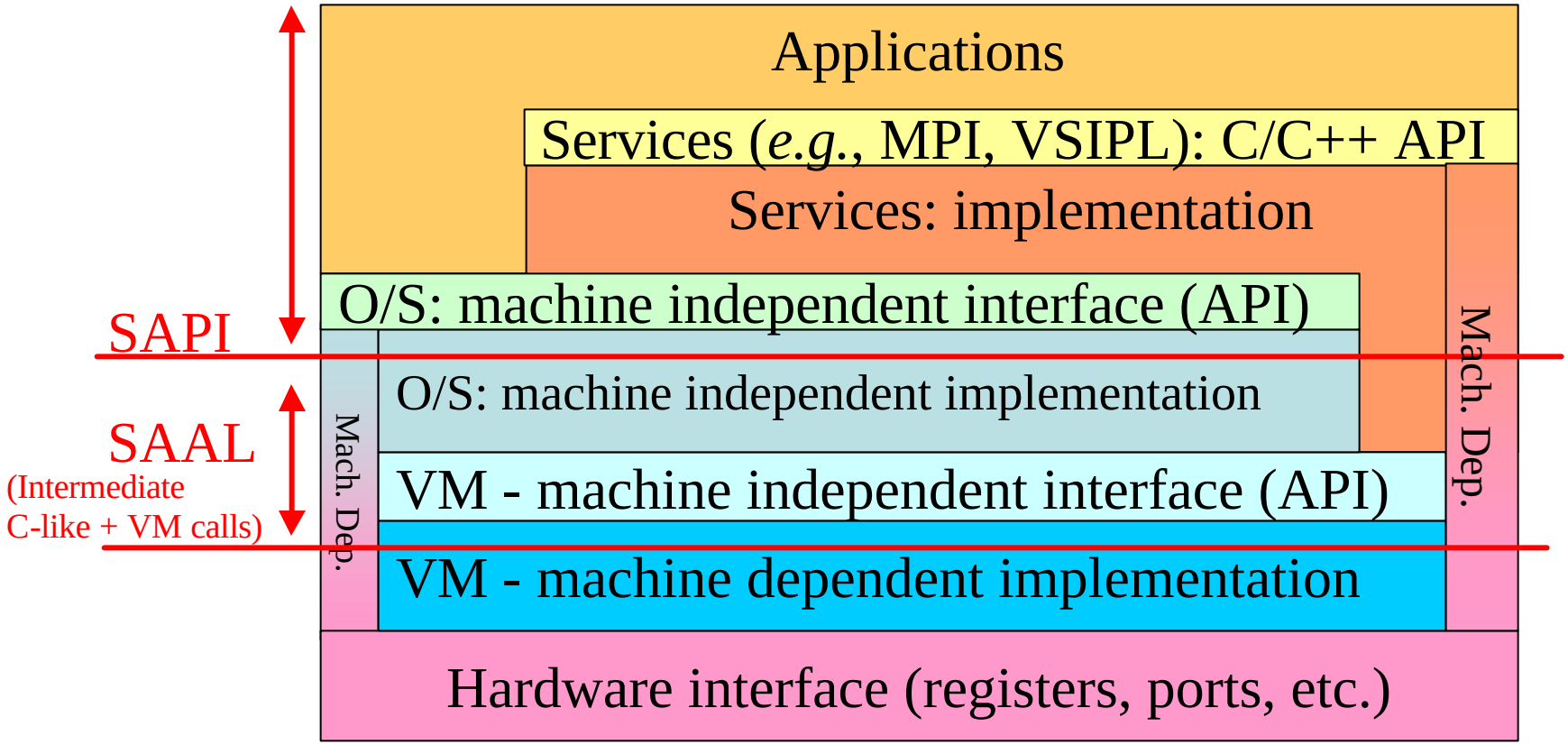
Integrated PCA Architecture↔Single Metadata System Mapping



SAPI, SAAL, VM (C/C++ Application)



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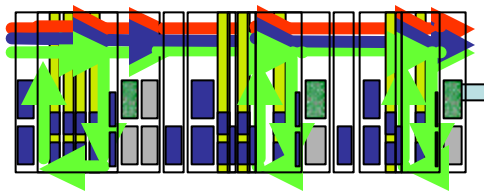
Current Technology Build Chain

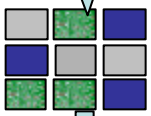


Component Model &
High-Level Metacode

Mission Compiler /
Metacode Processor

source code

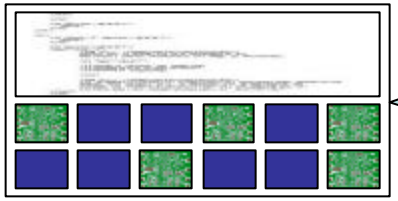
bound & unbound
metadata



Code Compiler

binary

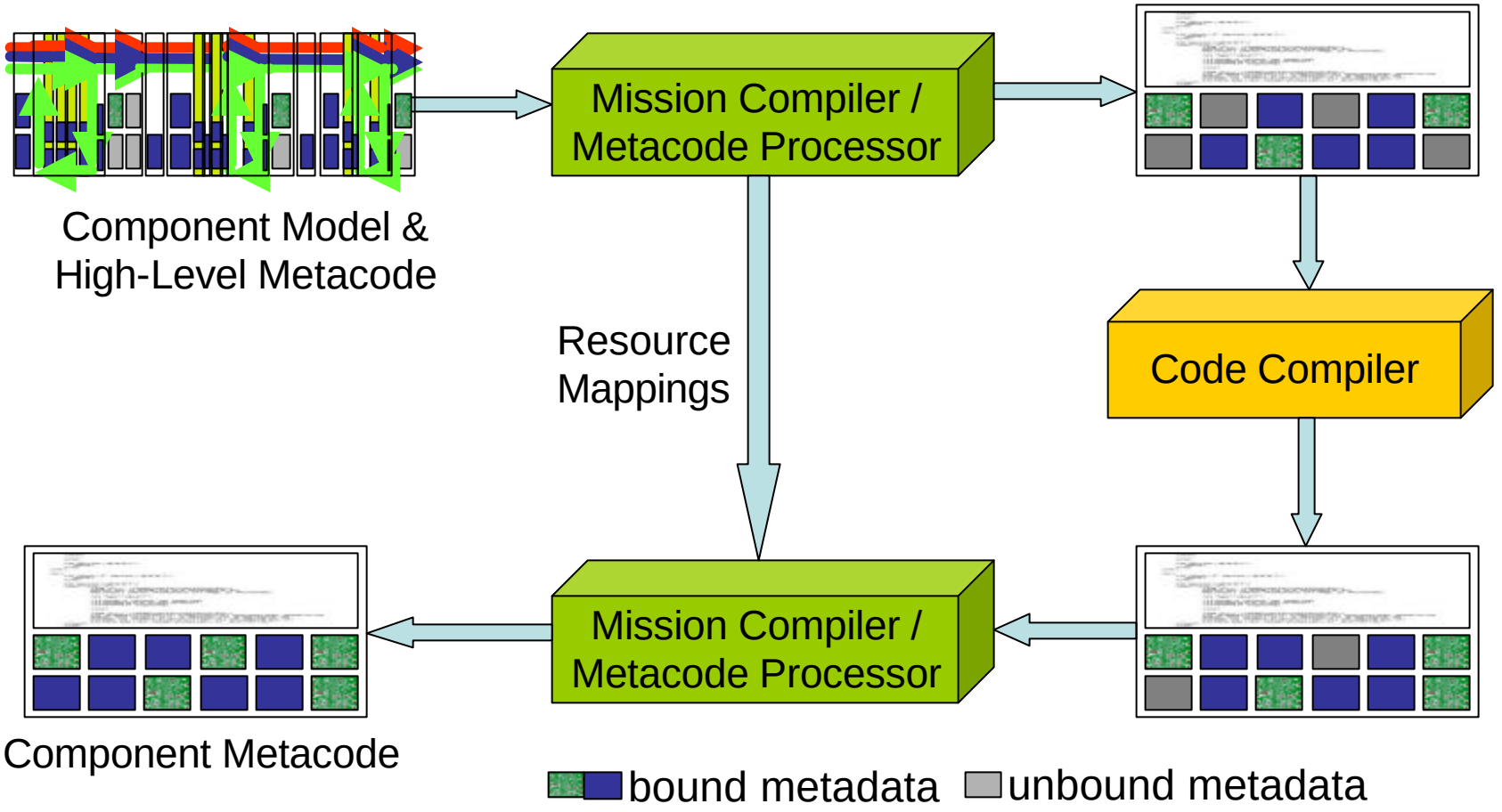
Mission Compiler /
Metacode Processor



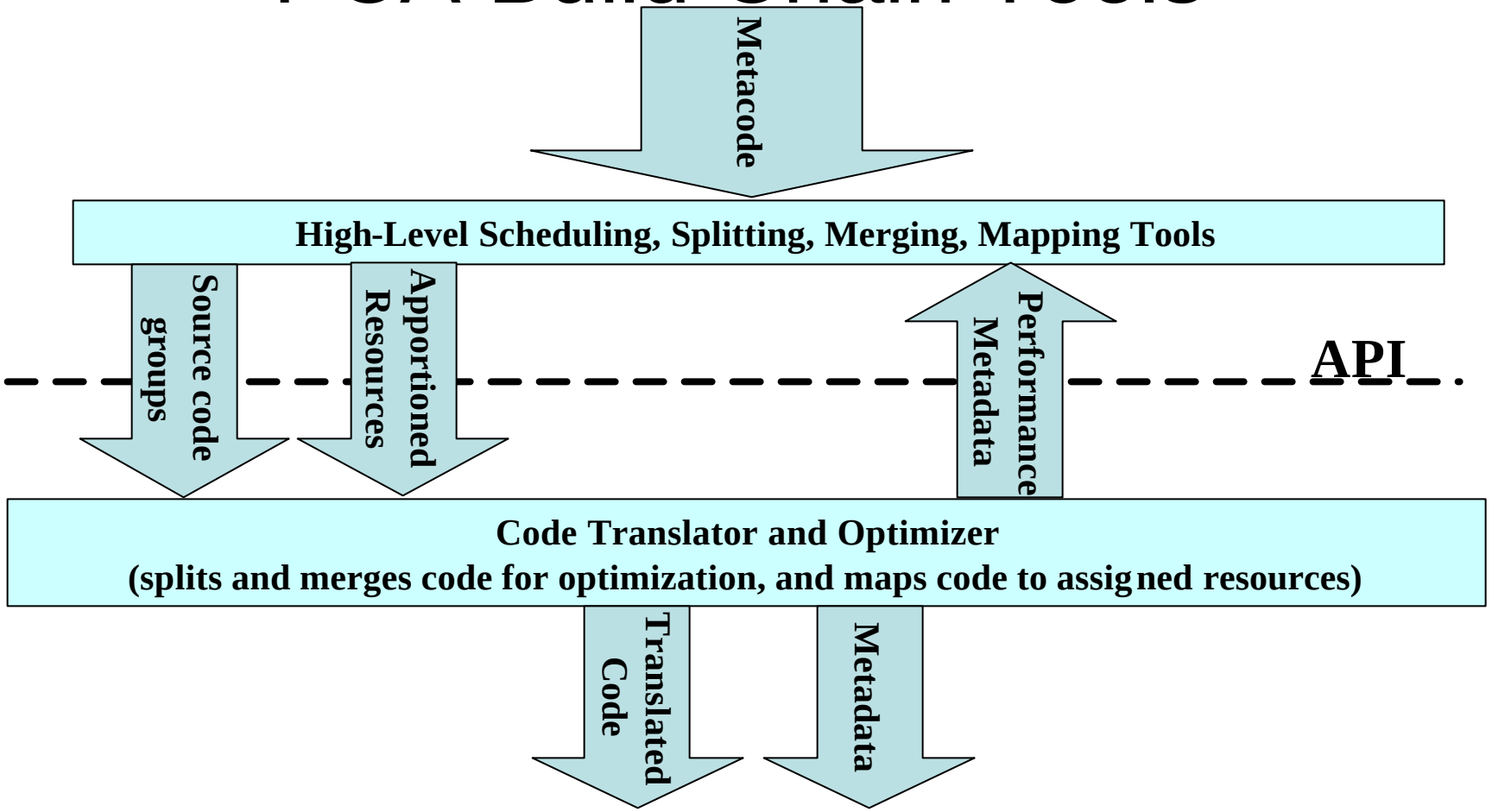
Component Metacode

bound metadata unbound metadata

1st Generation PCA Build Chain



Interaction of Compilers and PCA Build Chain Tools



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Metadata

- Describes functionality
  - Machine readable
  - Source code & language details
  - Interface and template parameters
- Known resource requirements
- Known performance capability
- Resource and Performance descriptors:
  - Static table
  - Database query
  - Parametric functions
  - Source code in high-level scripting language

Determining Metadata

- Derive requirements and capabilities from analysis of source/machine code and hardware capability (Compilers can provide this service)
- Execute code on hardware to verify execution model
- Refine model for every hardware option
  - Analytical modeling will be complex
  - Simplifying assumptions may make model inaccurate
- Construct database of known values
  - Could be large
  - Will be accurate for known hardware configurations
  - Interpolate/extrapolate
- Construct a predictive model
  - Math functions
  - Perl scripts

XML Metacode

Library component

```
<component name="FIR">
  <optimizedsection
     cpu="G4"
     dtype="double”
     pmode=“threaded”>
    <source lang="C">
      -------
    </source>
  </optimizedsection>
  <optimizedsection
     cpu="G4"
     dtype="float”
      pmode=“streaming”>
     <source lang=“C”>
      -------
    </source>
  </optimizedsection>
</component>
```

Metacode Processor

```
<component
  name=“componentA”>
   <source lang=“C”
     pmode=“threaded”>
   ------------------
   ------------------
   ------------------
   </source>
</component>
```

User defined component

```
<component name="componentA">
  ....
  <constantdatadef
    type="float"
    label="pi">
     3.141593
  </constantdatadef>
  <variableassignment
    type="double"
    label="accum">
    <constantdataref label="pi"/>
    <callcomponent
       name="FIR"
       dtype="double"
       cpu="G4"/>
    <operation optype="multiply"/>
  </variableassignment>
</component>
```

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Dynamic Resource Management

- Needed to account for unknown events
  - Faults
  - All possible scenarios may be impossible to predict
  - May be prohibitive to generate static resource & component mappings for all scenarios
- Reduce search space by pre-selecting candidate components at build time

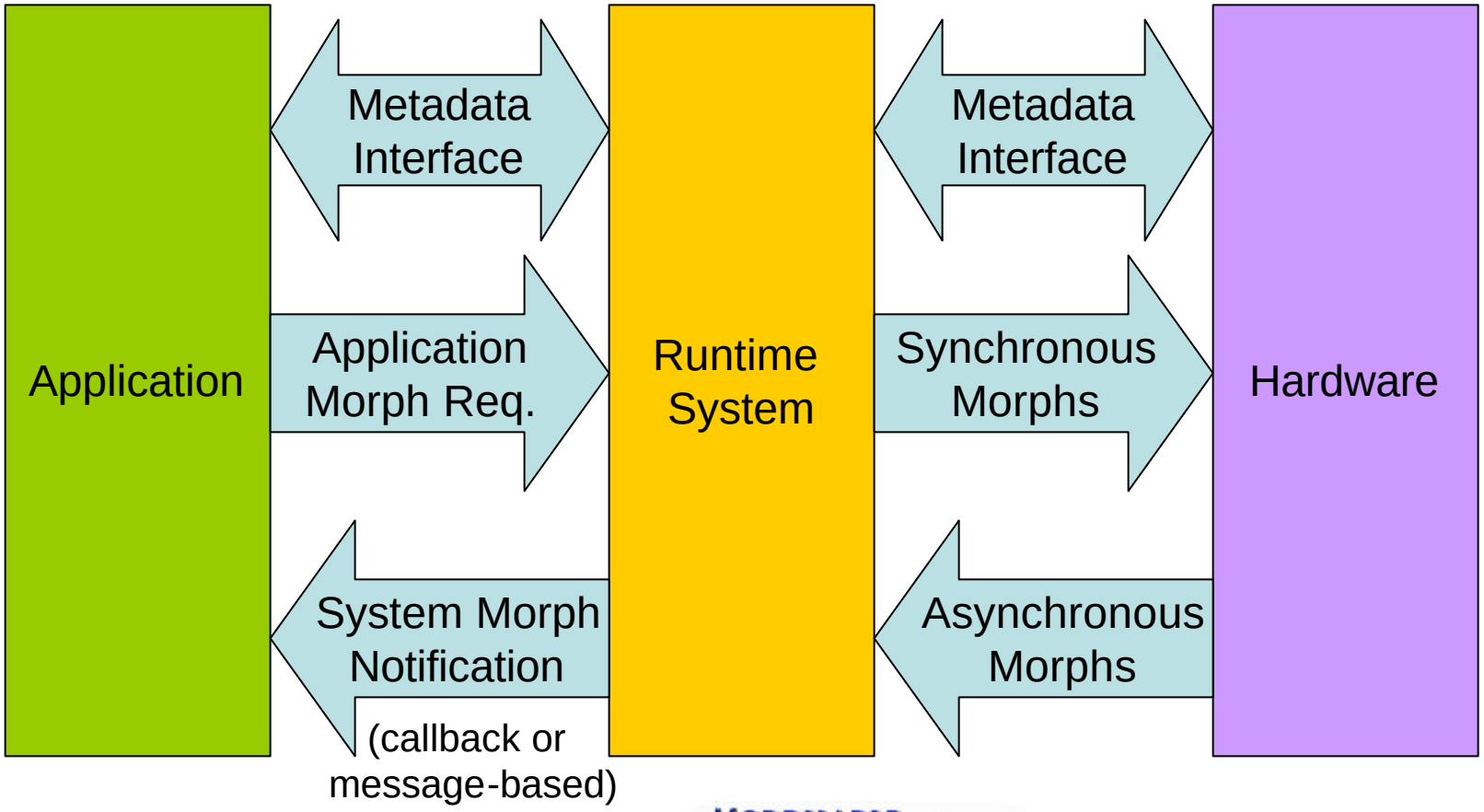
Application Initiated Morphs

- Application requests resource reconfiguration within allocated resources
  - May be compiler generated
  - May be explicitly coded
- Application explicitly requests new mode (components) within allocated resources
- Application explicitly requests additional resources or releases resources
- Application explicitly requests new mode (components) requiring different resources

System Initiated Morphs

- System modifies allocated resources transparently (without affecting applications' components)
- System moves application components to execute on a different set of equivalent resources
- System modifies resources allocated to components of an application
- System modifies components and resources allocated to an application

Application/System Morph Notification and Metadata Interface



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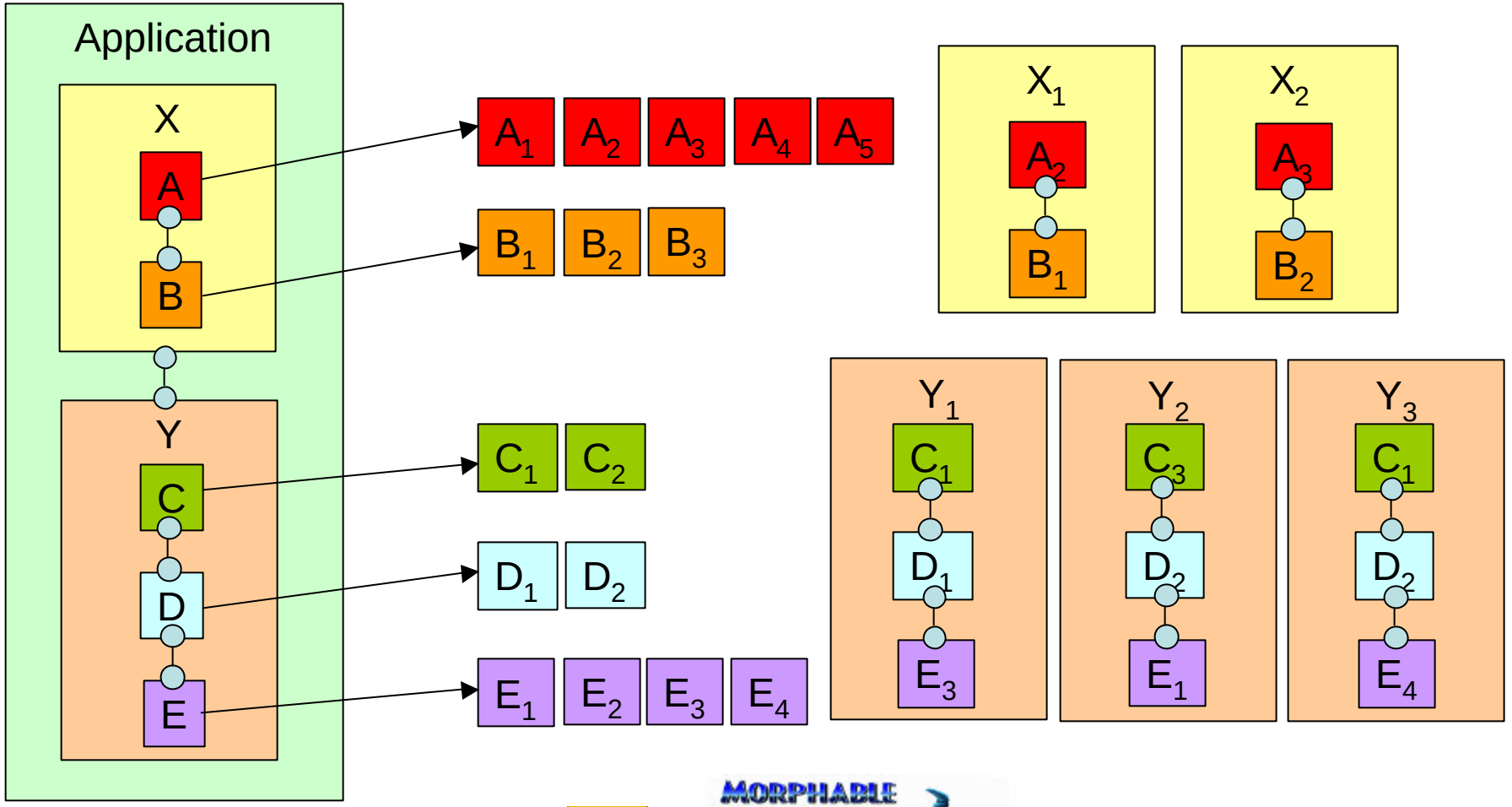
Component Concepts

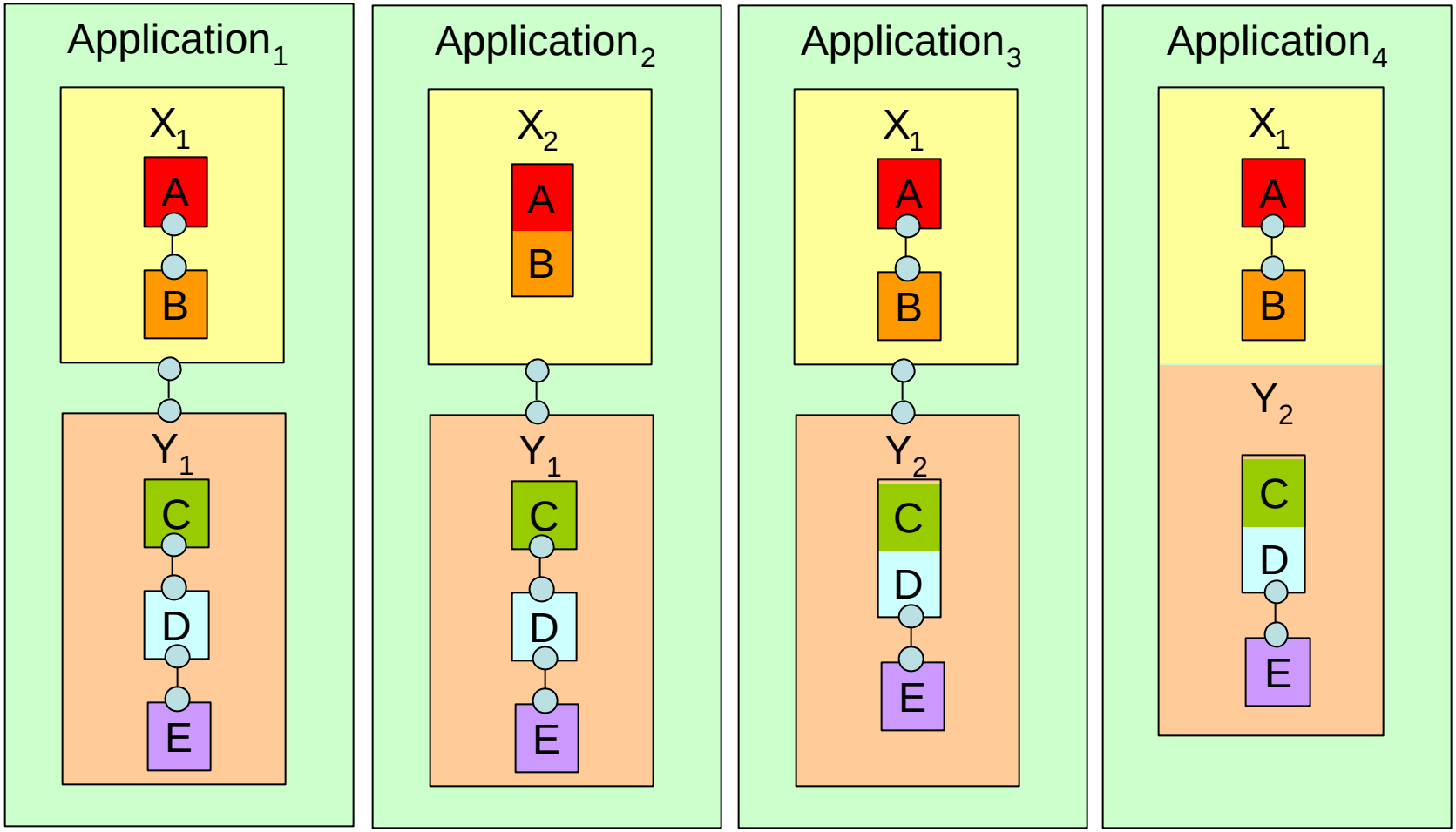
- PCA components are hierarchical
- Design and implementation alternatives are explicitly represented in the hierarchy at any level
- A compound component may encapsulate concurrency between lower-level components
- PCA Application is a component composed from a collection of components, component clustering specifications, abstract VM specifications, and component-VM element mappings
- PCA Mission is composed of PCA Applications, VM instantiation, component to physical VM element mappings, mode-change rules, and mission constraints that govern application behaviors

Component Options



MORPHABLE MILIEU

Component Boundaries



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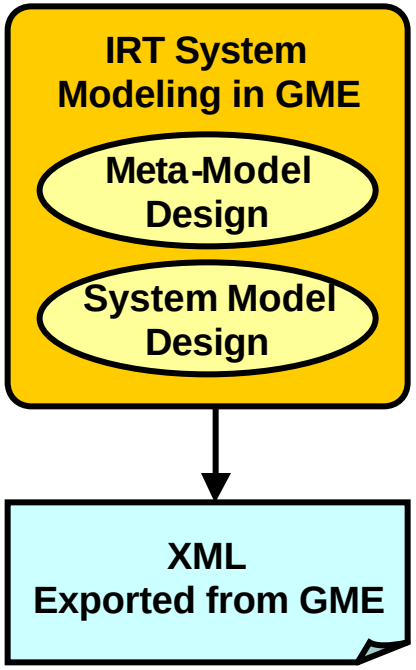
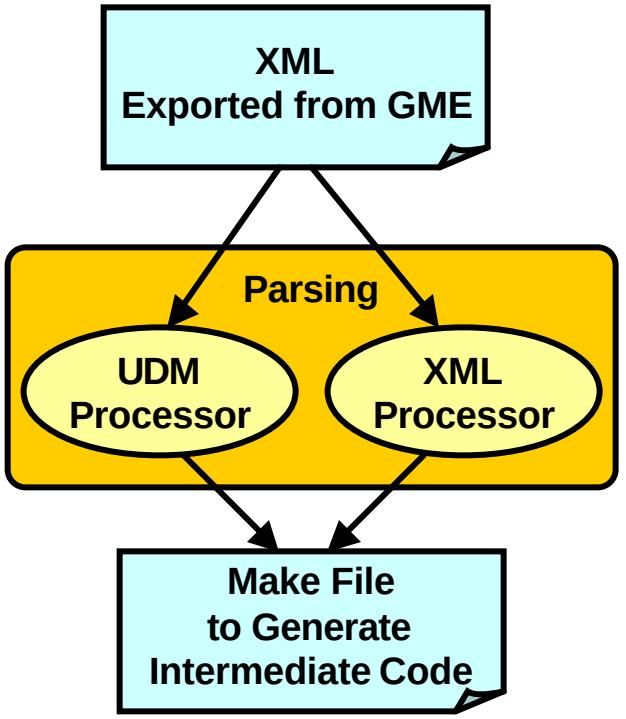
Step 1: Application Modeling

- System design using GME2000
  - Graphical modeling tool
  - Graphically design component hierarchy
- Define design alternatives
- Specify metadata for each component
- Export model using XML format



Step 2: Model Processing

- Parse the XML representation of the model
- Traverse model component hierarchy and retrieve metadata specification of each component
- Dynamically generate makefiles for intermediate code generation and compilation



Step 3: Intermediate Code

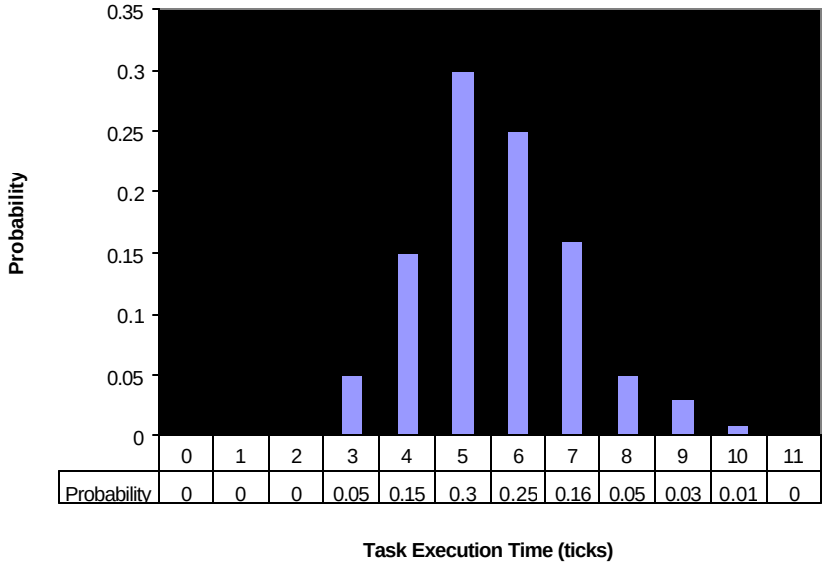
- "High-level Compiler"
- Generate the intermediate code for IRT system
- Matlab is end-user programming environment
- C is the intermediate environment
- Translate IRT source from Matlab to C

Step 4: Binaries

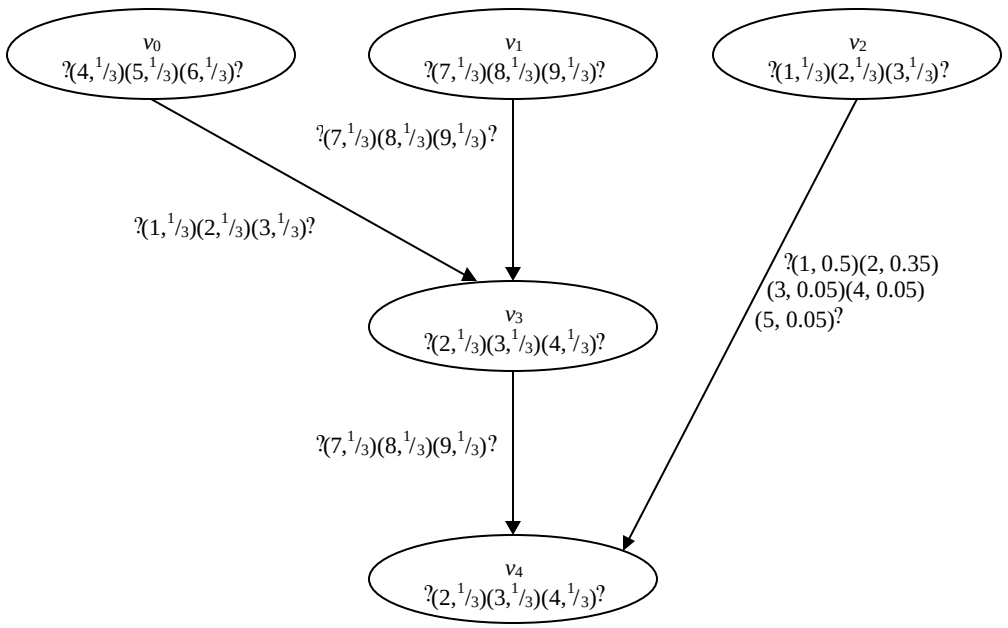
- “Low-level Compiler”
- Compile the intermediate code (C code)
- Generate architecture-specific executable binaries
- Metadata is expected to be interpreted and generated for resource management at this level

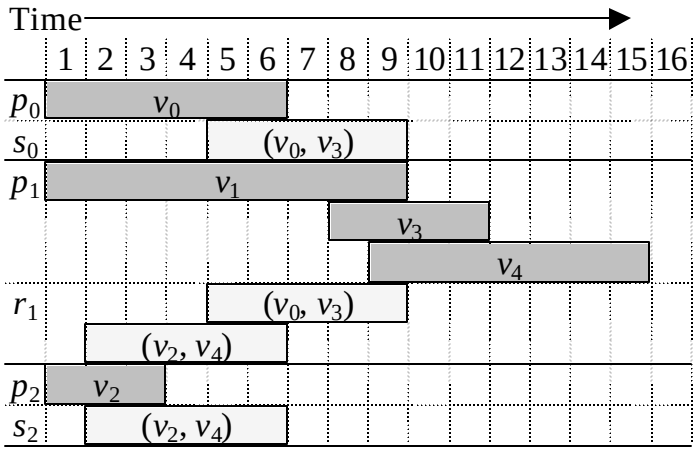
Scheduling Problem

- Non-preemptive schedules for parallel soft real-time applications represented as DAGs
- Metadata specifies execution time probability distributions of tasks (computation and communication)
- Metadata specifies task precedence



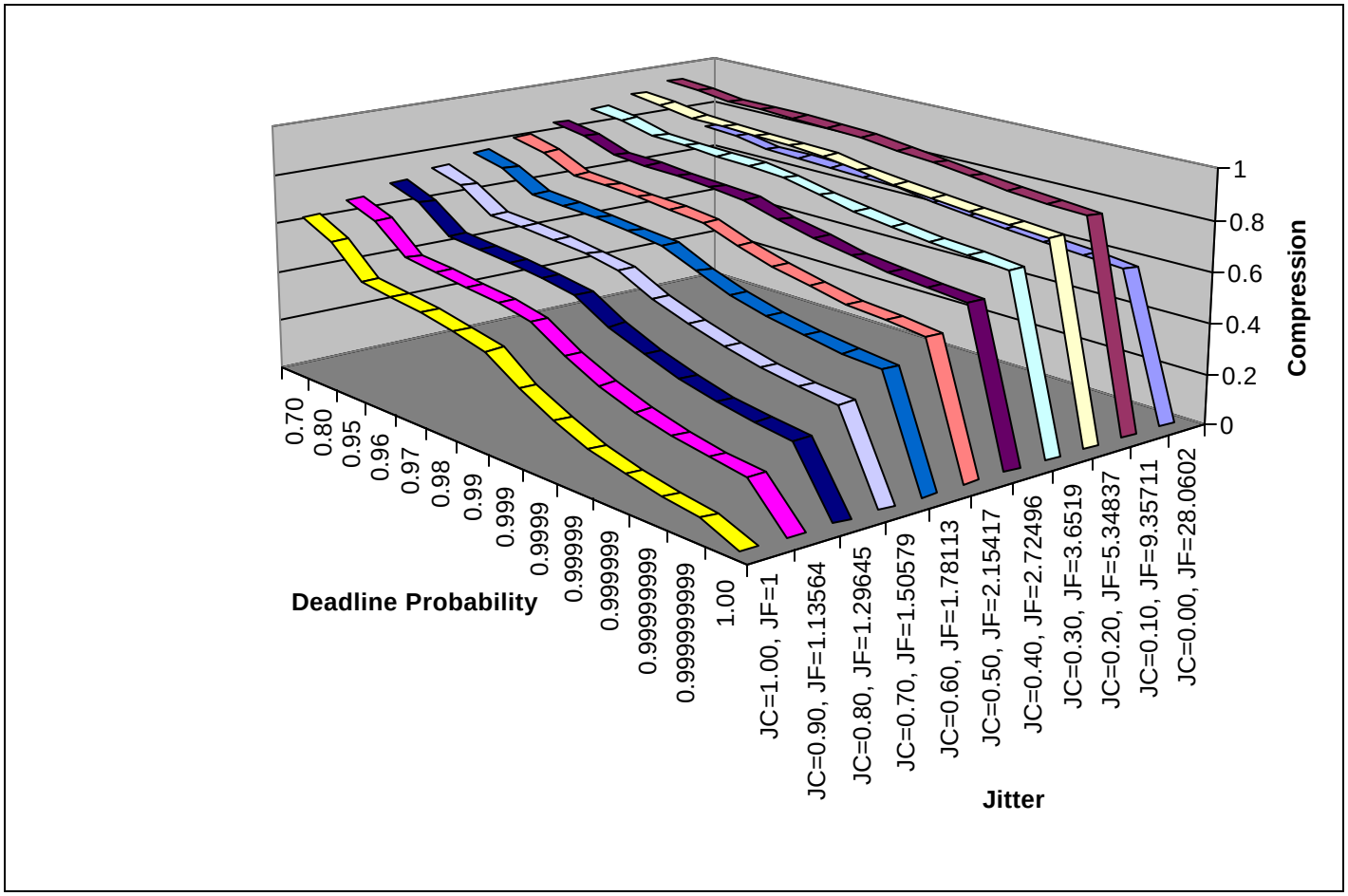
Schedules





p_n: processor n
s_n: outgoing communication link at processor n
r_n: incoming communication link at processor n

Scheduling Options



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Future Work - I

- Extend build chain demonstration for a parallel application using MPI on a cluster of dual Xeons with Linux
  - GME2000 metamodel
  - Multiple component implementations with parametric/predictive metadata
  - Metacode parsing and processing
  - Code generation, compilation, and linking
  - Application initiated software morphs
  - Fault handling

Future Work -II

- Continue to contribute to the MSI forum
  - Metamodeling specification
  - Metadata specification
  - APIs
    - MPI
    - VSIPL
  - Compiler and build chain tool interaction
  - VM specifications

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Conclusion

- Conceptual architecture for PCA software
- Developed prototype build chain tools
  - Matlab
  - C++, MPI, VSIPL
- Working with the MSI forum to specify
  - Software interfaces
  - Metadata elements and organization
  - Component organization
  - Tool interactions