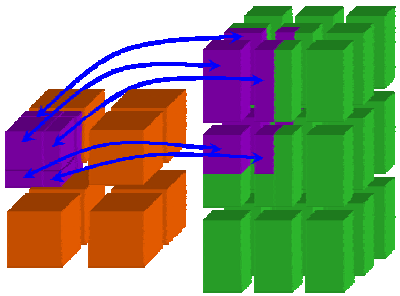
# MxN Data Redistribution
## for
# Coupling Disparate Parallel Components



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Interfaces in Parallel Multi-Physics Simulations (MS41)
SIAM PP04, Fisherman's Wharf
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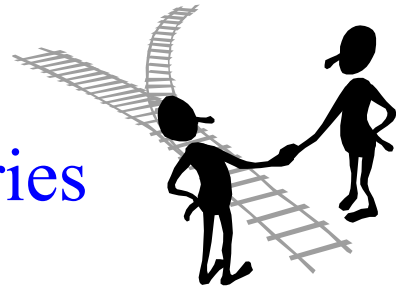
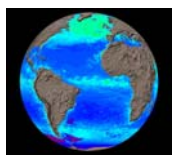
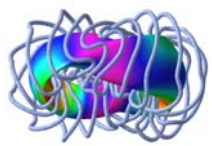
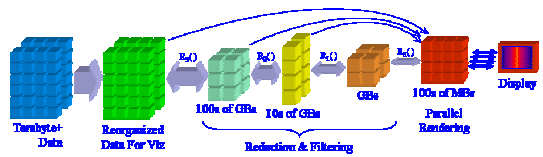
# Coupled Multi-Physics Simulations



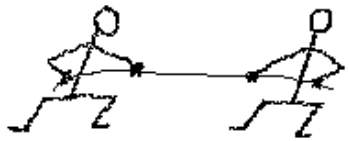
- Improved Fidelity from Live Coupling
  - ⇒ Dynamic Feedback versus Static Boundaries
  - ⇒ More Accurate Overall System Modeling
- Capitalize on Domain Expertise
  - ⇒ Combine "Best" Interdisciplinary Software
- Mechanism for Next-Generation Collaboration
- Applications of Coupling:
  - ⇒ Climate, Fusion, Biology, Numerical, Visualization

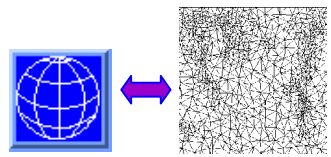



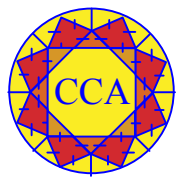
# What's the Catch?

- Independently Developed Models Use:
  - ⇒ Different Meshes and Time Scales
  - ⇒ Different Programming Models and Languages
  - ⇒ Different Data Structures and Decompositions

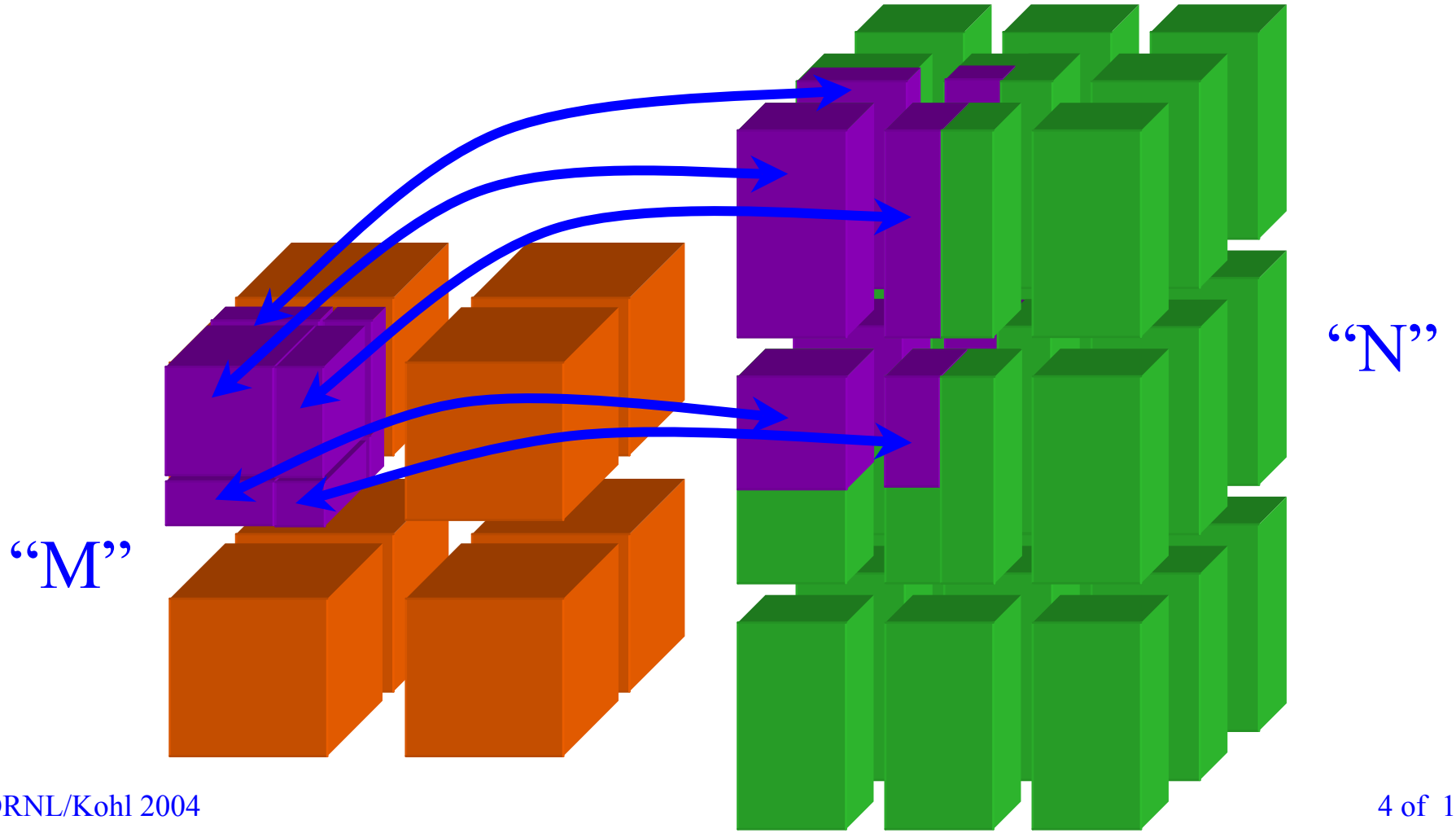


- Coupling Therefore Requires:
  - ⇒ Spatial and Temporal Interpolation
  - ⇒ Language Interoperability & Component Tools
  - ⇒ Parallel Data Exchange and Redistribution
    - Synchronization, Communication Schedules

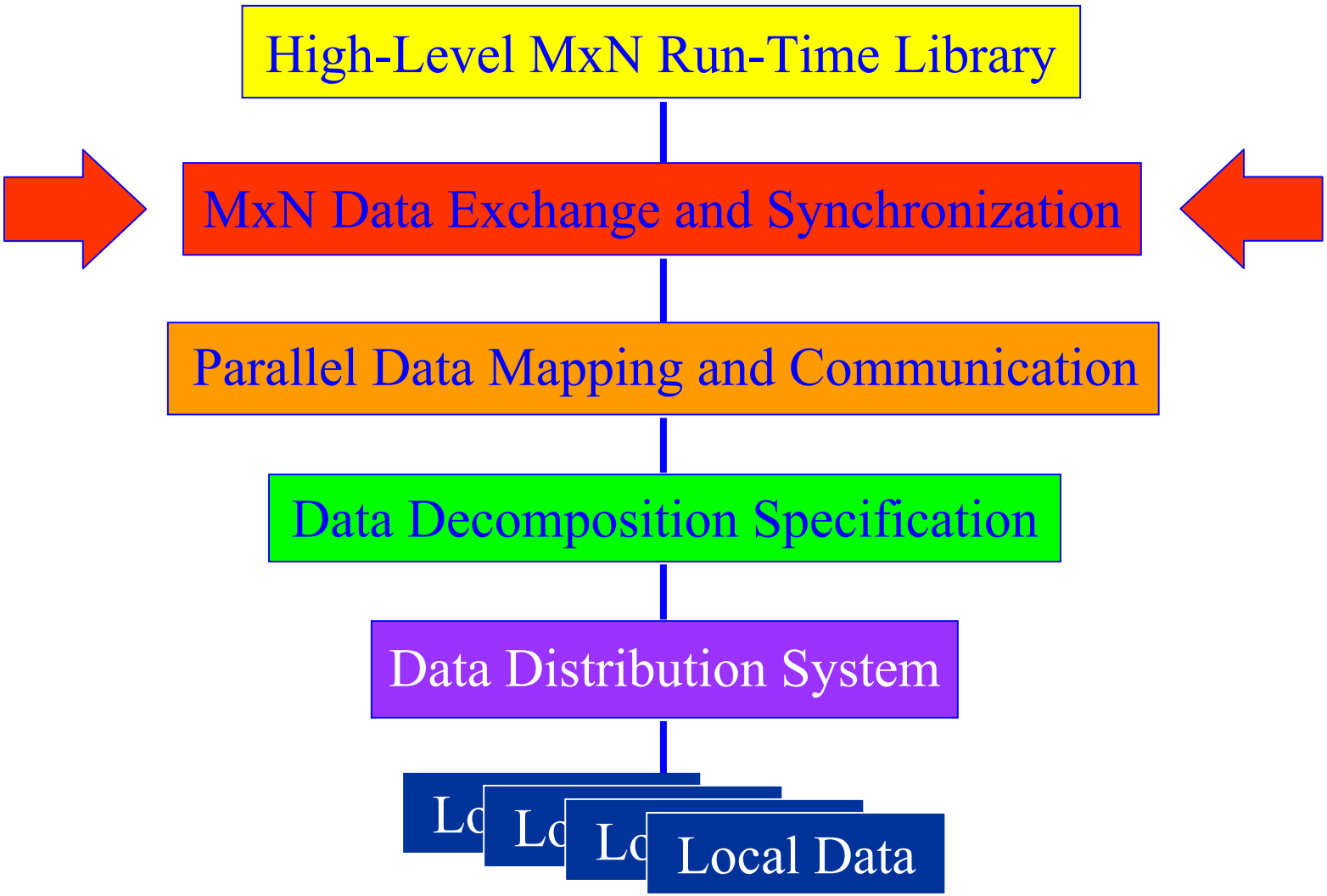




# The "Basic" Problem: MxN Parallel Data Exchange



# MxN Layered Structure




# The Common Component Architecture (CCA)

- Component-Based Software Engineering

  ⇒ Manage Complexity of Scientific Simulation Software

- Successful in Business ~ Corba, DCOM, EJB

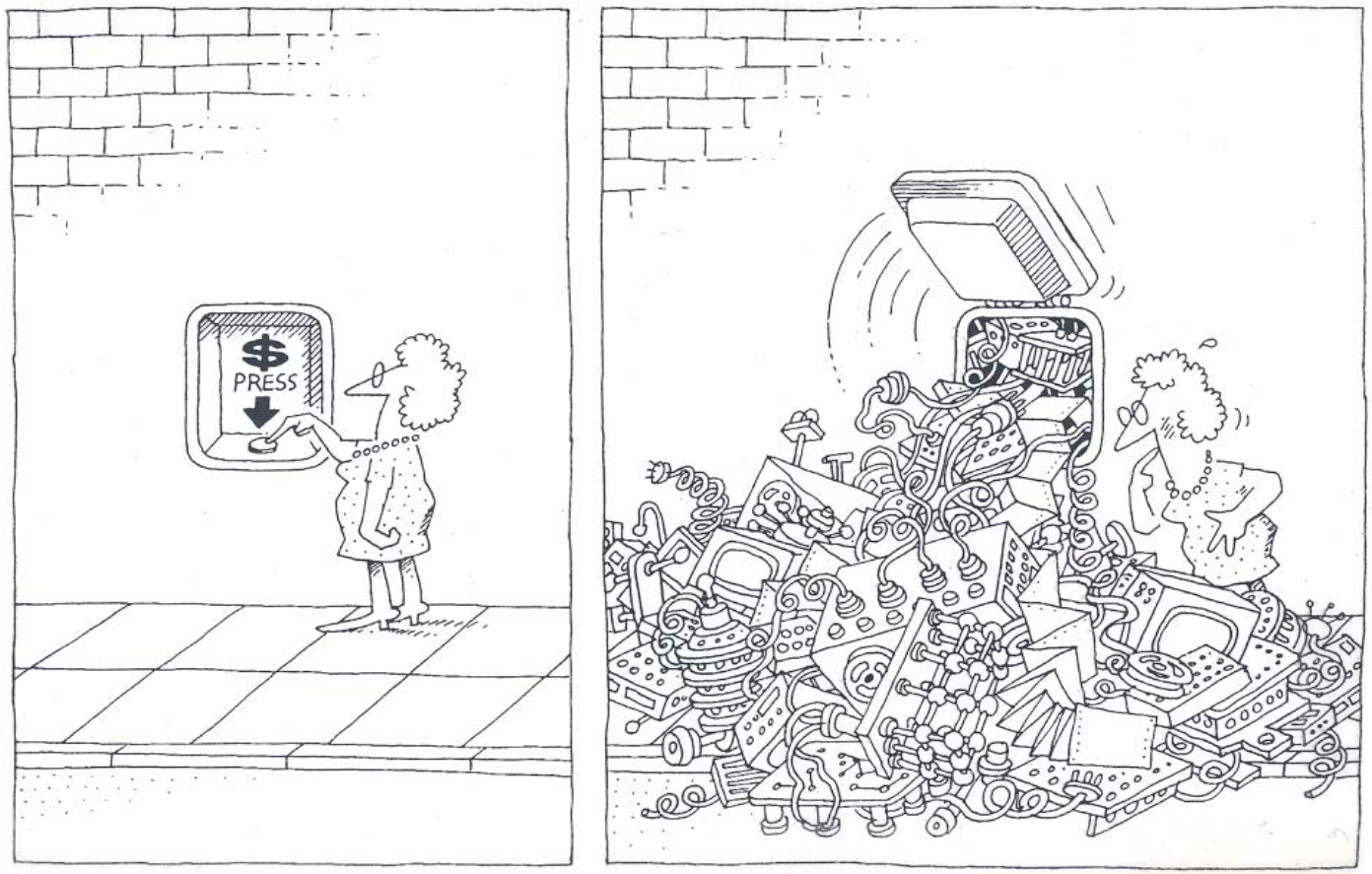
  ⇒ Add Performance, Languages, Science Data Models, and MxN Parallel Data Redistribution!

- National Forum (Open) / DOE SciDAC Center




http://www.cca-forum.org/

# Why Components?



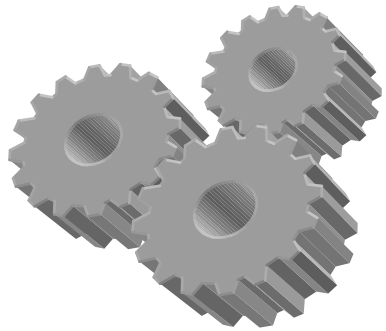

The task of the software development team is to engineer the illusion of simplicity *[Booch]*.

# Why Components?

- Well-Defined Abstract Interfaces
  - ⇒ No "Cheating" Allowed…
    - Hides Implementation Details (Separated Name Spaces)
    - Combine Multiple Implementations in Same Code
  - ⇒ Note: Cost of Standardization Efforts…
- Eases Code Re-use, Enables Swapping
  - ⇒ Simple Wrappers, Bridge Language Gaps
  - ⇒ "Port" Abstraction Enables Intelligent Proxies…

The task of the software development team is to engineer the illusion of simplicity *[Booch]*.

# MxN Interface



## Parallel Data Exchange Operations

"Easy" Stuff

⇒ Describe and "Register" Data/Decompositions

⇒ Map Data Elements ~ "Communication Schedules"

⇒ Build Synchronized MxN "Connections"

⇒ Initiate Data Transfers Asynchronously: "dataReady()"

## Generalizes Existing Tools:

⇒ CUMULVS, PAWS, Meta-Chaos

CUMULVS

PAWS Parallel Application Work Space

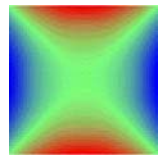
CHAOS

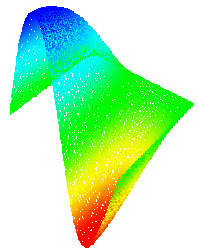
## Several interface evolutions (ongoing…)

⇒ Reconciling appropriate level of detail & flexibility

# MxN "Explicit" Component Solution

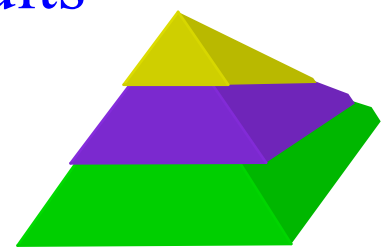
- Port-based direct invocation of MxN methods
  - ⇒ Most general solution, but…
  - ⇒ More challenging to the end-user scientist.
    - "Assembly language" level interface…
    - Preliminary platform for experimentation
- Several implementations have evolved…
  - ⇒ Using generalized DistArrayDescriptor
  - ⇒ Basic inter-framework capabilities
  - ⇒ Visualization, Coupling





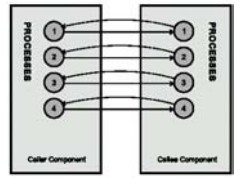
# Future Work ~ "Implicit" Solutions

- Need simpler, high-level interfaces
  - ⇒ For the non-expert… even automated handling
- Targeting built-in framework services
  - ⇒ Capture method invocations via port indirection
  - ⇒ Implicitly apply MxN functions to reconcile parallel data arguments & returned results
- Increases framework complexity
  - ⇒ Use pluggable service registration!
  - ⇒ Requires additional method specifications…

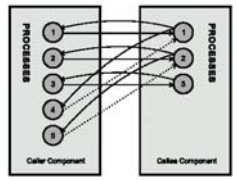


# Parallel Remote Method Invocation (PRMI)

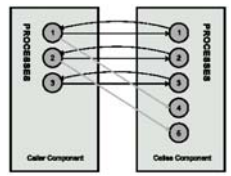
- Next step beyond "simple" data exchange…
  - ⇒ Method itself has parallel context
  - ⇒ Specification of semantics and policies is key!



- Preliminary PRMI progress:
  - ⇒ PAWS prototype and early policy identification
    - Invocation scheduling, marshalling arguments & results
  - ⇒ 2nd SCIRun prototype explores method specification
    - SIDL extensions for "independent" and "collective" methods
    - With sub-grouping, generalizes PRMI invocation semantics

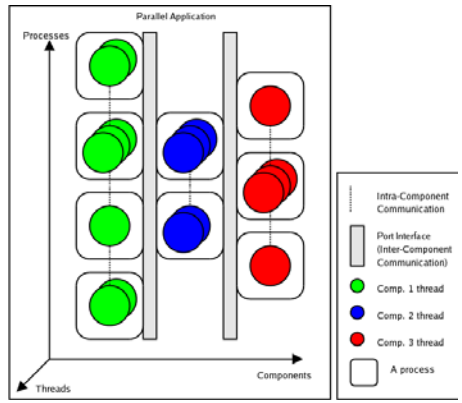


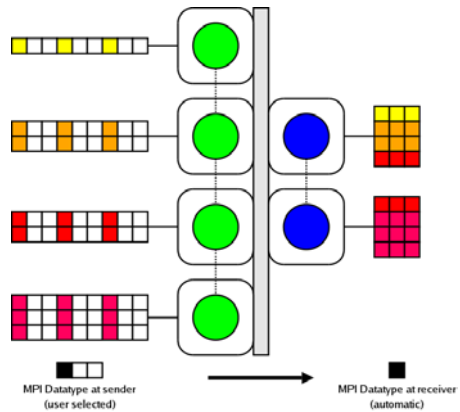
- Still much research ahead…
  - ⇒ Transport mechanisms (SOAP, etc)
  - ⇒ Parallel data argument & results meta-data specification…



# Distributed MxN Data Scenarios

- Incompatible with Parallel MxN
  - ⇒ No co-location components
  - ⇒ Different connection semantics
- Distributed-Parallel Framework
  - ⇒ Experimental ~ "DCA" (Indiana)
  - ⇒ Process Participation & Synch
    - MPI Communicator Groups
  - ⇒ Manual Argument Redistribution
    - Who dictates layout reconciliation?
      - → Caller or Callee…?

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# MxN and Climate (MCT / ESMF)

- Climate-specific coupling models & technology
  - ⇒ Amenable to generalized MxN specification
  - ⇒ Two-way integration underway…
    - Re-package MCT/ESMF as CCA components
    - Build MxN component on top of MCT/ESMF



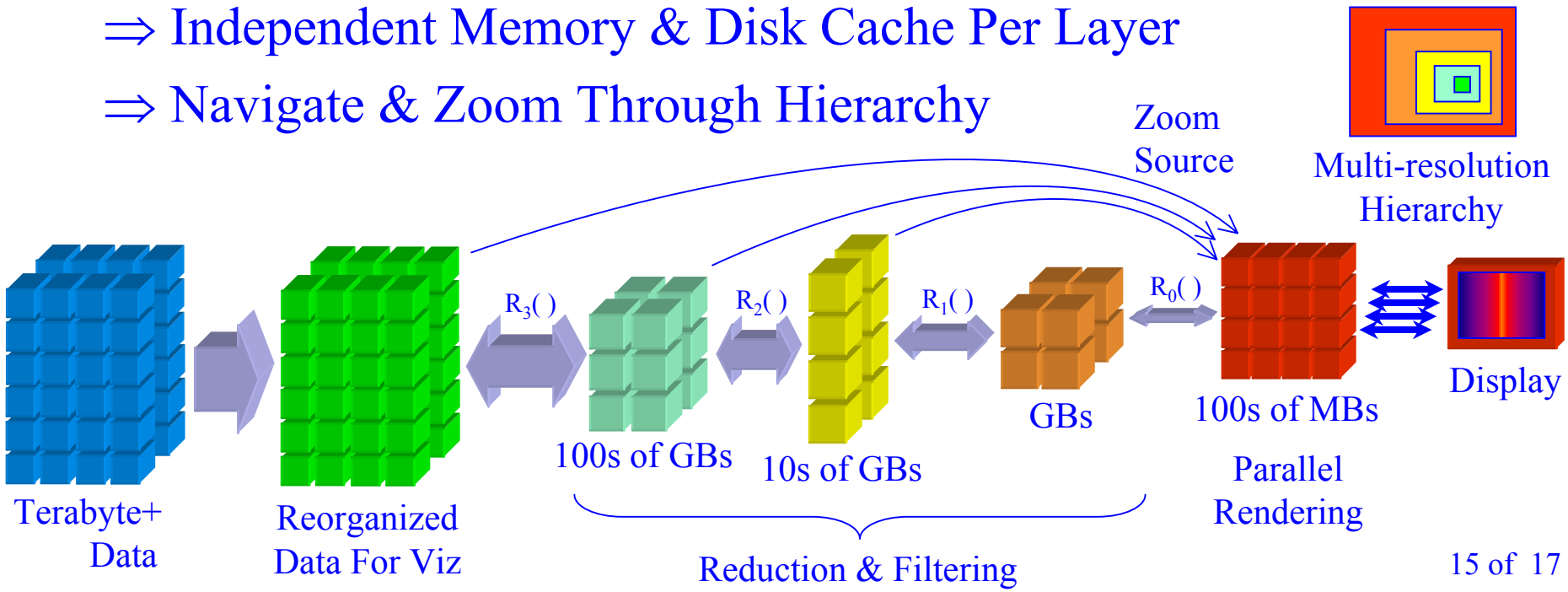
- Ongoing reconciliation of terms and concepts
  - ⇒ Between MxN and MCT, and CCSM and ESMF…
- Componentization of CCSM models
  - ⇒ Atmosphere, ocean, sea-ice, land-surface, river-runoff, plus flux couplers…

# Scalable Visualization Cache Architecture

- Increasingly Massive Scientific Data Sets
  - ⇒ Too Large to Fully Explore / Visualize Interactively
- Modular, Layered Viz Cache Framework
  - ⇒ Parallel Storage, Analysis & Reduction Per Layer
  - ⇒ Independent Memory & Disk Cache Per Layer
  - ⇒ Navigate & Zoom Through Hierarchy

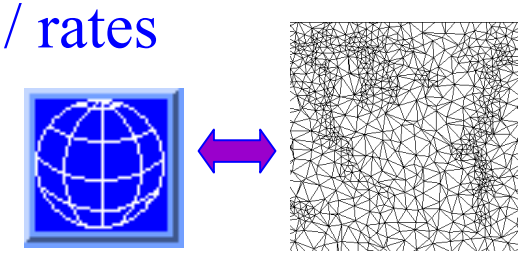
CCA / MxN
CUMULVS

SDM & ASPECT
Data Reduction



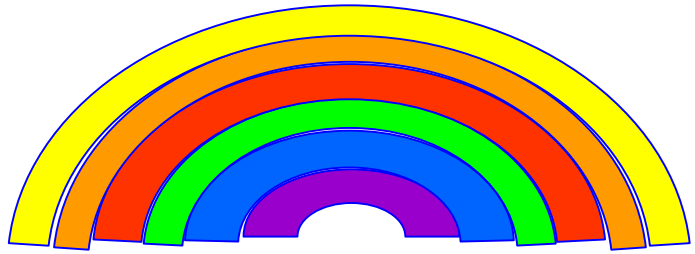
# “Real” Model Coupling…

- MxN parallel data redistribution is just the beginning of real model coupling…
- Need interpolation and data translation
  - ⇒ Spatial ~ different meshes & coordinate spaces
  - ⇒ Temporal ~ different time frames / rates
  - ⇒ Flux Conservation
  - ⇒ Units Conversion



- Must explore composing “filters” with MxN
  - ⇒ Pipeline efficiency and compound “Quality of Service”

# MxN Summary



- Stable MxN specification and component solutions
  - ⇒ Next step ~ implicit framework services
- Parallel Remote Method Invocation (PRMI)
  - ⇒ Initial semantics being defined, much to do…
- Distributed MxN Framework Experiments (DCA)
  - ⇒ Culminating Generalization of Parallel/Distributed…
- Tip of the iceberg for production model coupling
  - ⇒ Need development of suite of interpolation “filters”…

http://www.csm.ornl.gov/cca/mxn/