PHYSICAL SYSTEM REPLICATION

DIGITAL TWIN

March 2019

UNCLASSIFIED

CAD for Prediction & Control Systems

MEASURABLE APPLICATION GOALS:

- Provide an order of magnitude reduction in the time & cost to develop models, simulations & systems;
- Provide 4 to 6 orders of magnitude improvement in simulation/system run-time speed
  -- while cutting costs by orders of magnitude;
- Allow application experts to design, build, and test systems directly;
- Allow newcomers to a project to quickly learn and understand complex systems.

Example Application: Use of Autonomous Vehicles with Network Facilities to achieve High A/J Margins

TAKING PROPER MEASURMENTS:

The principle Measure is the Speed Multiplier - SM:

$$SM = Ts / Tp$$

where Ts is Time to run on a Single Processor - Fast
and Tp is Time to run on a Parallel Processor

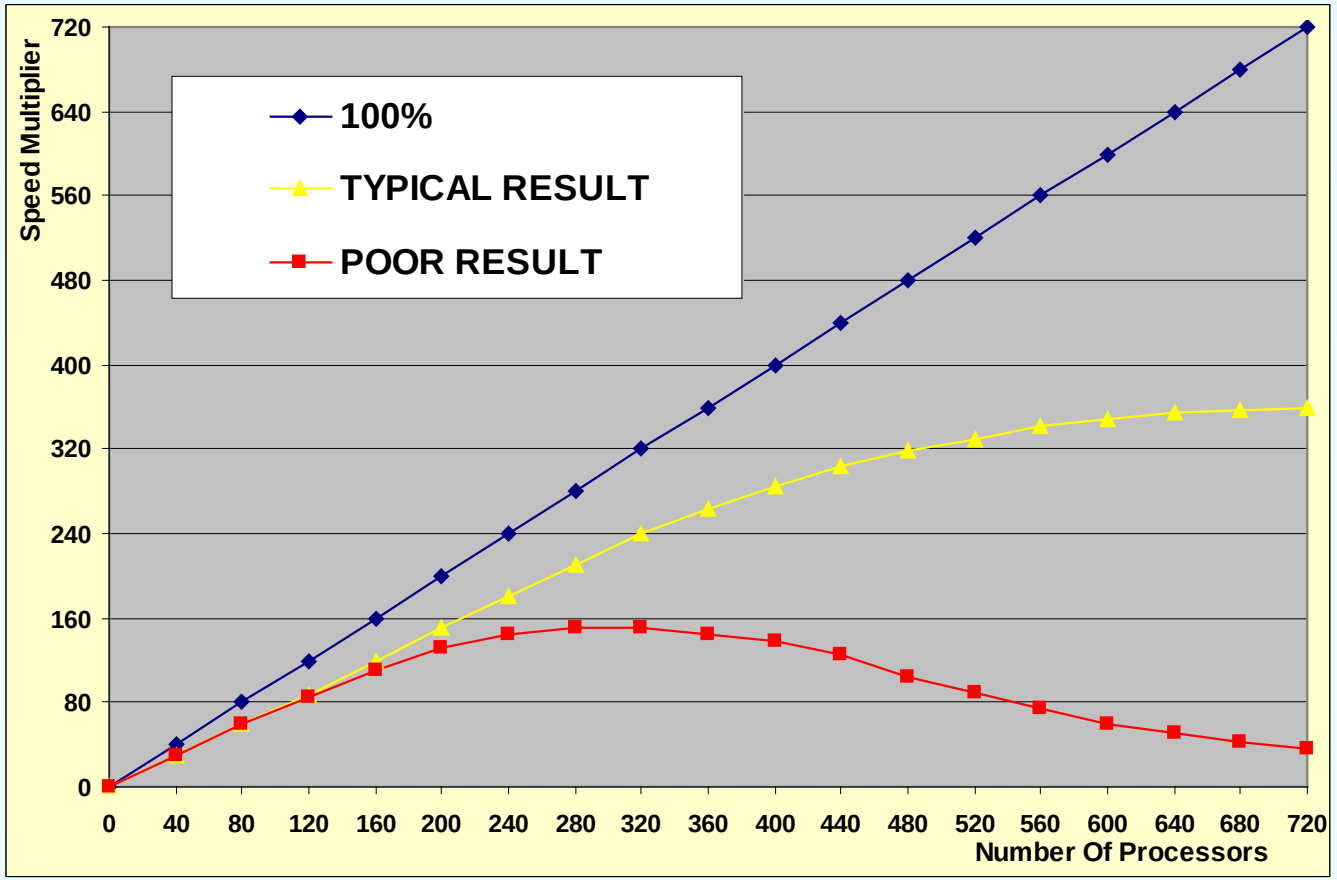
Depending upon the application
– this may be difficult to measure

The critical Measure is Processor Utilization Efficiency:

$$PUE = SM / Np$$

where SM is the Speed Multiplier
and Np is the Number of Parallel Processors

CAD for Prediction & Control Systems



The difference in speeds above is due to the Processor Utilization Efficiency (PUE)

VisiSoft PUEs can be above 95%

Von Neumann's

Instruction Set Architecture

- the ISA for Single Processors

must be extended by VSI's

Application Space Architecture

- the ASA - for Parallel Processors

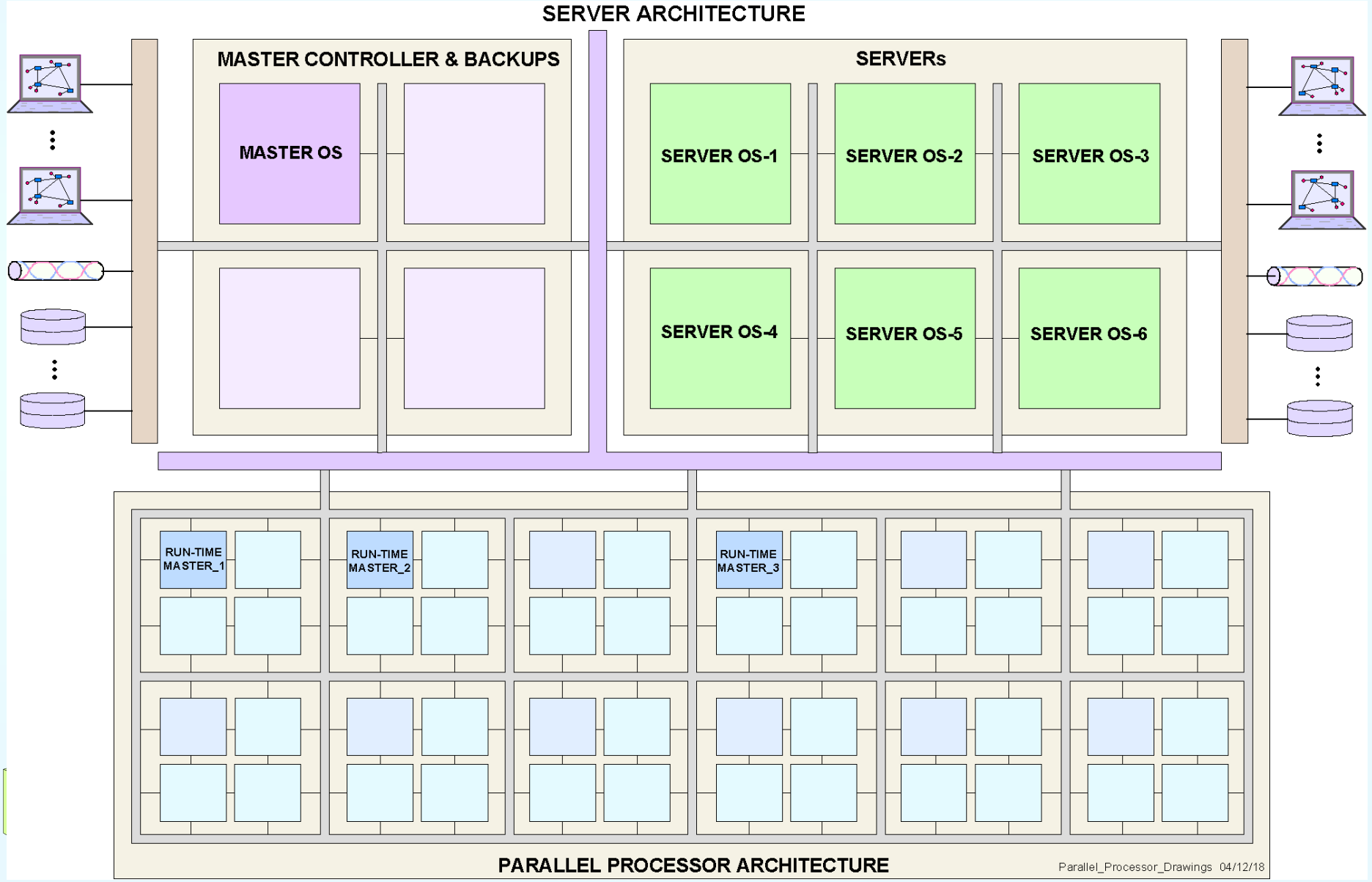
CAD for Prediction & Control Systems

REPRESENTATIVE PARALLEL APPLICATIONS:

- Adaptive Control of Large Groups of Autonomous Moving Platforms
- Human Body Organ simulation
- Human Brain – Artificial Intelligence modeling
- Global Climate prediction
- Currency Market prediction
- Chemical - Molecular structure simulation
- Scanning, sorting, and correlating massive databases (Big Data)
- Weather prediction in mountainous terrain
- Power distribution simulation
- Electro-magnetic wave simulation
- Global HF power transmission
- Global Military Planning - Multiple moving platform simulation

THESE ARE NOT SERVER REQUIREMENTS!

And: - Servers Are Not Parallel Processors
- A Multi-Tasking OS is Not a Parallel OS



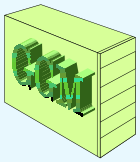
CAD for Prediction & Control Systems

SOFTWARE IS AN EXTENSION OF MATHEMATICS:

- Must pick the “Best Spaces” to represent the problem;
- The Best Spaces provide independence (Kalman);
- They simplify the algorithms;
- Simple algorithms run much faster;
- Simple algorithms are much easier to understand;
- Newcomers to a project quickly learn the software

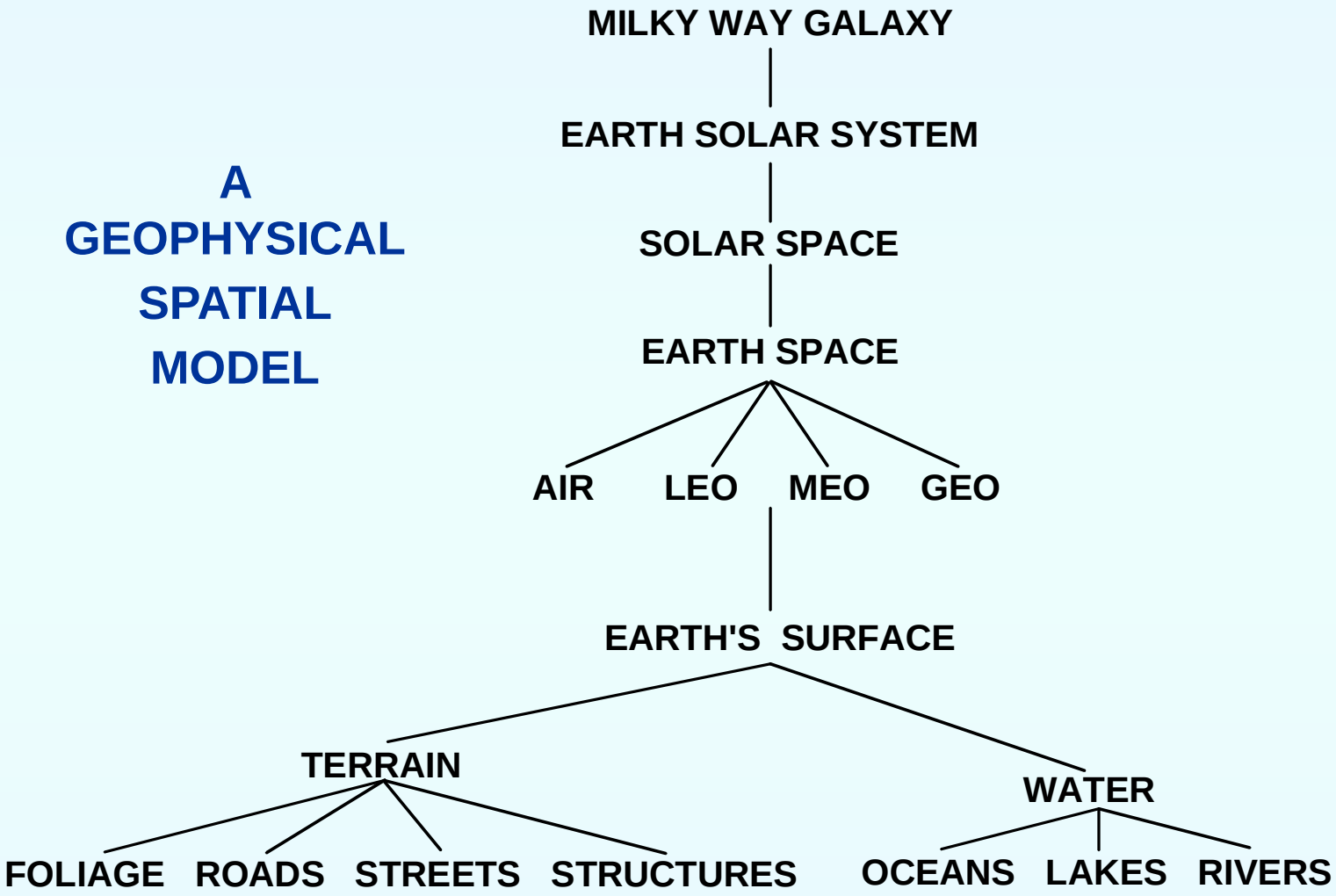
Also, What is a “Software Module” ?
And, What is “Software Architecture” ?

These terms are used throughout the literature – *undefined!*



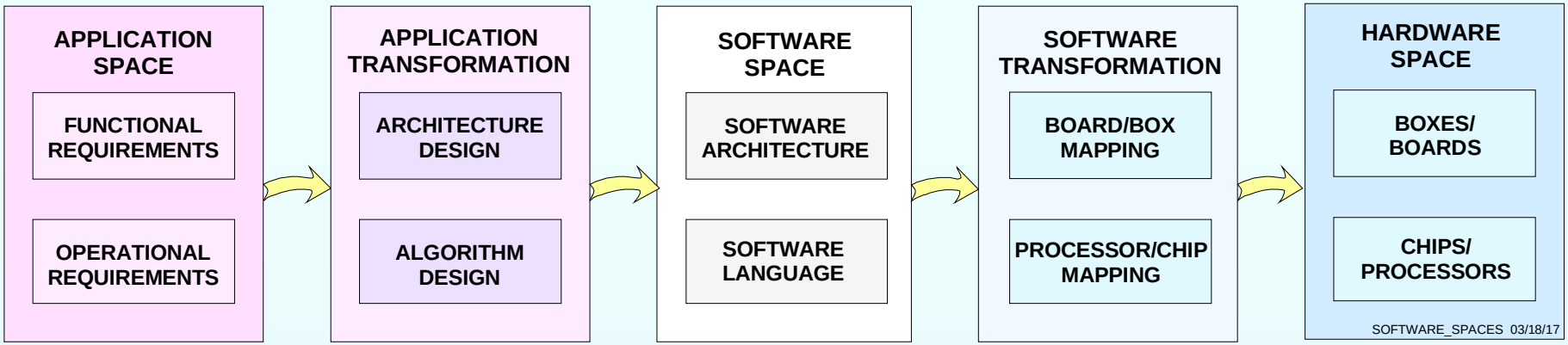
EXAMPLE OF A MODEL SPACE HIERARCHY

A GEOPHYSICAL SPATIAL MODEL



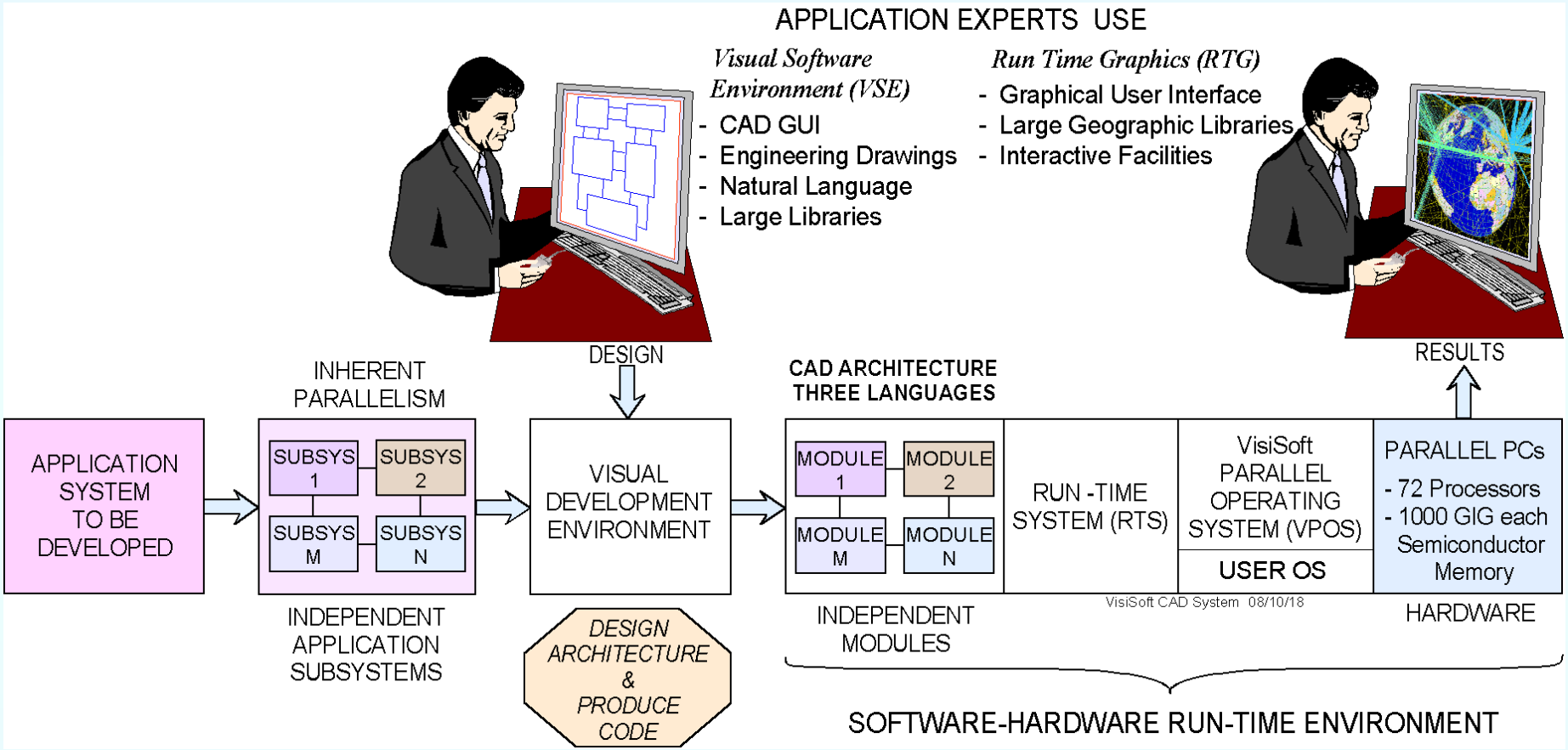
SUCH MODELS SUPPORT HETEROGENEOUS HIERARCHIES WITH ACCURACIES DOWN TO 1.1 CM

Spaces for Translation of Application Requirements into Software Requirements & then into Hardware Requirements



Defining the: Application Space Architecture (the ASA)

CAD for Prediction & Control Systems



Visual Software Engineering Using A CAD System For Building Real-Time Control Systems

CAD for Prediction & Control Systems

a RESOURCE

-

Contains Hierarchical Data Structures To Easily Map Complex Spaces

```
RESOURCE: TRANSCEIVER                    INSTANCES: TRANSMITTER
                                                    RECEIVER

GENERAL_PARAMETERS
    1  TRANSMITTER_POWER          REAL   INITIAL_VALUE 100
    1  RECEIVER_THRESHOLD         REAL   INITIAL_VALUE 120

RADIO
    1  TRANSCEIVER                STATUS TRANSMITTING
                                         RECEIVING
                                         IDLE
                                         OFF
    1  LOCATION
       2  X_POSITION             REAL
       2  Y_POSITION             REAL
       2  ELEVATION              REAL
    1  ANTENNA_HEIGHT             REAL
    1  ANTENNA_GAIN               REAL

RECEIVER_CONNECTIVITY_VECTOR
    1  POWER_AT_RECEIVER          REAL
    1  TOTAL_NOISE_POWER          REAL
    1  CONNECTIVITY_MATRIX
       2  PROPAGATION_LOSSES
          3  TERRAIN_LOSS         REAL
          3  FOLIAGE_LOSS         REAL
          3  TOTAL_LOSS           REAL
       2  SIGNAL_POWER           REAL
       2  SIGNAL_TO_NOISE_RATIO  REAL
       2  LINK_DELAY             REAL
       2  LINK                   STATUS GOOD
                                        FAIR
                                        POOR

TRANSCEIVER_RULES
    1  TRANSCEIVER_PROCESS        RULES  GOOD_RECEPTION
                                         CONFLICTING_RECEPTION
                                         CONFLICTING_BROADCAST
```

A Space / Data Structure

CAD for Prediction & Control Systems

a PROCESS

-

Contains Hierarchical Rule Structures That Support One-in One-out Independent Control Structures (Mills)

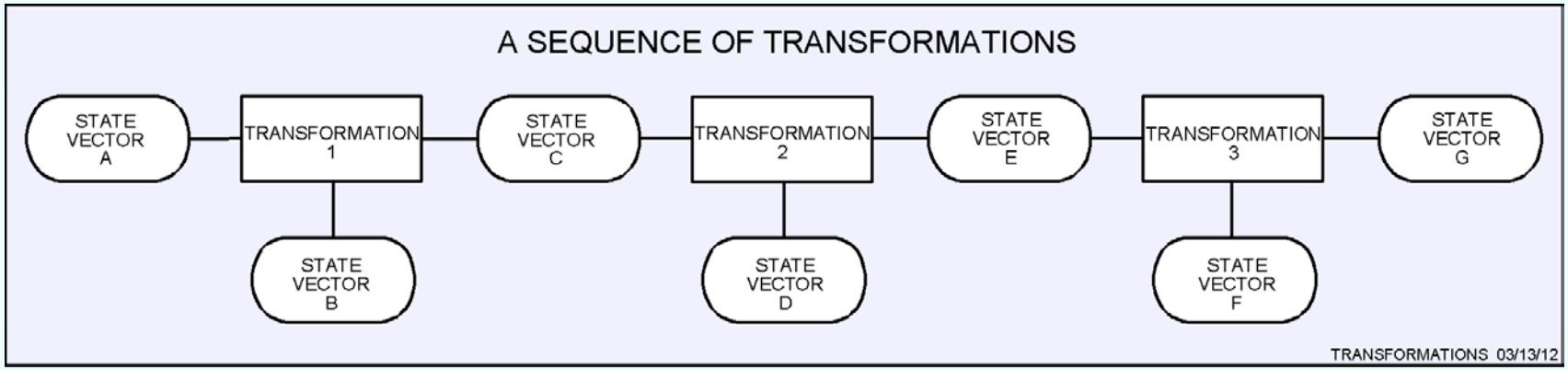
```
PROCESS: RECEPTION                    RESOURCES: TRANSCEIVER
INSTANCES: TRANSMITTER                           MESSAGE_FORMATS
           RECEIVER                              TRANSMITTER_OUTPUT
```

```
START_RECEPTION
    IF TRANSCEIVER IS IDLE
        EXECUTE GOOD_RECEPTION
    ELSE IF TRANSCEIVER IS RECEIVING
        EXECUTE CONFLICTING_RECEPTION
    ELSE IF TRANSCEIVER IS TRANSMITTING
        EXECUTE CONFLICTING_BROADCAST .

GOOD_RECEPTION
    IF SIGNAL_TO_NOISE_RATIO IS GREATER THAN RECEIVER_THRESHOLD
        SET TRANSCEIVER  TO RECEIVING
        ADD SIGNAL_POWER TO TOTAL POWER_AT_RECEIVER .
        CALL DECODE_MESSAGE .

    IF  MESSAGE TYPE IS FORMAT_A
    AND SYNC_CODE    IS VALID
    AND LAST_SYMBOL  IS A TERMINATOR
         EXECUTE SEND_ACKNOWLEDGEMENT .

CONFLICTING_RECEPTION
    IF POWER_AT_RECEIVER IS GREATER THAN SIGNAL_POWER
         SCHEDULE ABORT_RECEIVE NOW .

CONFLICTING_BROADCAST
    CANCEL END_RECEIVE NOW
    SCHEDULE START_RECEIVE IN EXPON(0.83) MILLISECONDS
        WITH PRIORITY 80

SEND_ACKNOWLEDGEMENT
    MOVE ACKNOWLEDGEMENT TO TRANSMIT_MESSAGE_BUFFER
    IF DESTINATION IS BROADCAST
        SEARCH LINK_CONNECTIVITY_VECTOR OVER RECEIVER
             EXECUTING TRANSMISSION
                  WHEN LINK IS GOOD
    ELSE EXECUTE TRANSMISSION .

TRANSMISSION
    SCHEDULE LINK_RECEPTION
        IN LINK_DELAY MICROSECONDS
            USING TRANSMITTER, RECEIVER
```

A Transformation / Rule Structure

PREDICTION & CONTROL SYSTEMS ENGINEERS

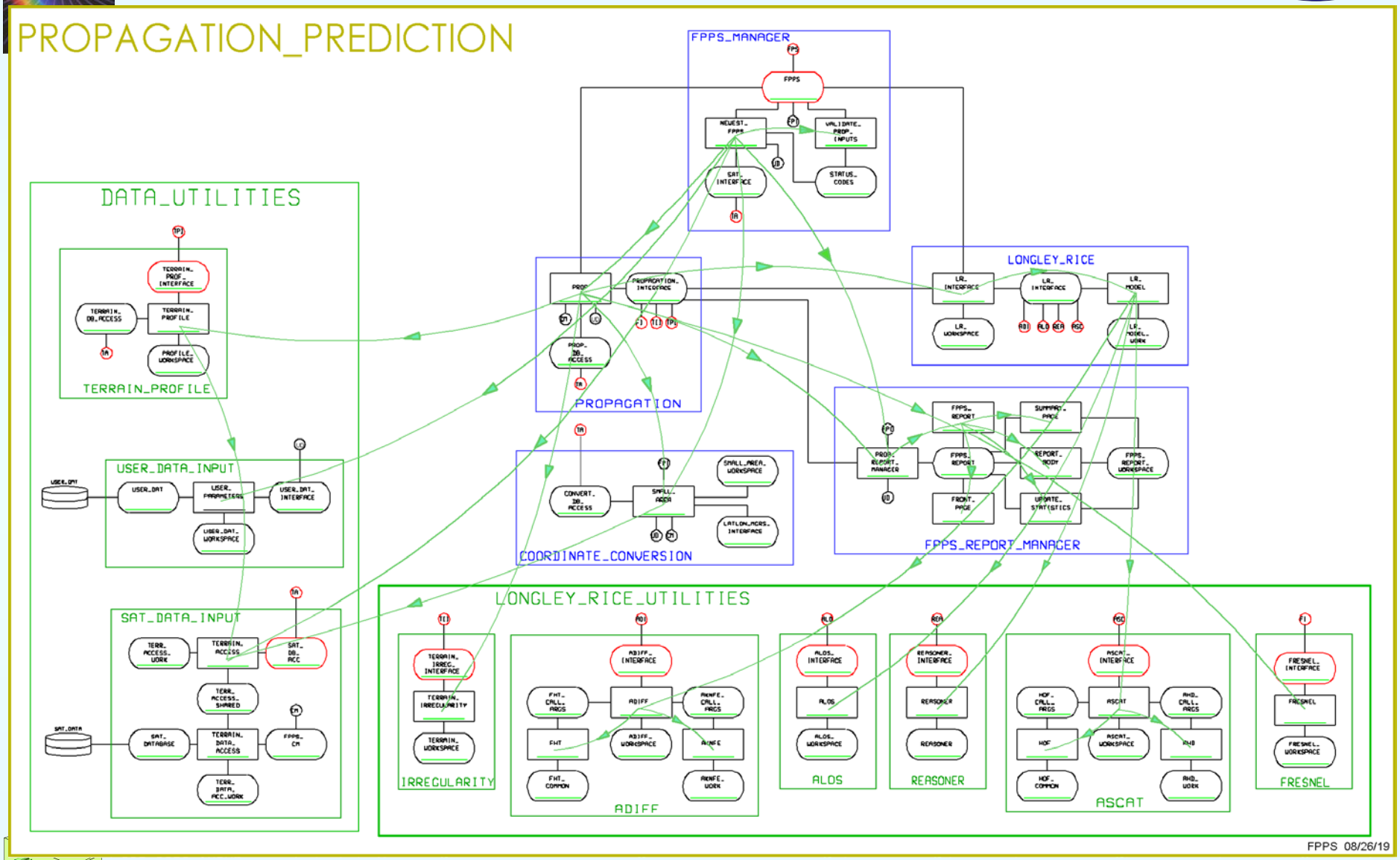
Spaces for Translation of Application Requirements into Software & Hardware



Connecting Resources & Processes to Create a Sequence of Transformations

- *Mathematically Defining a Module*

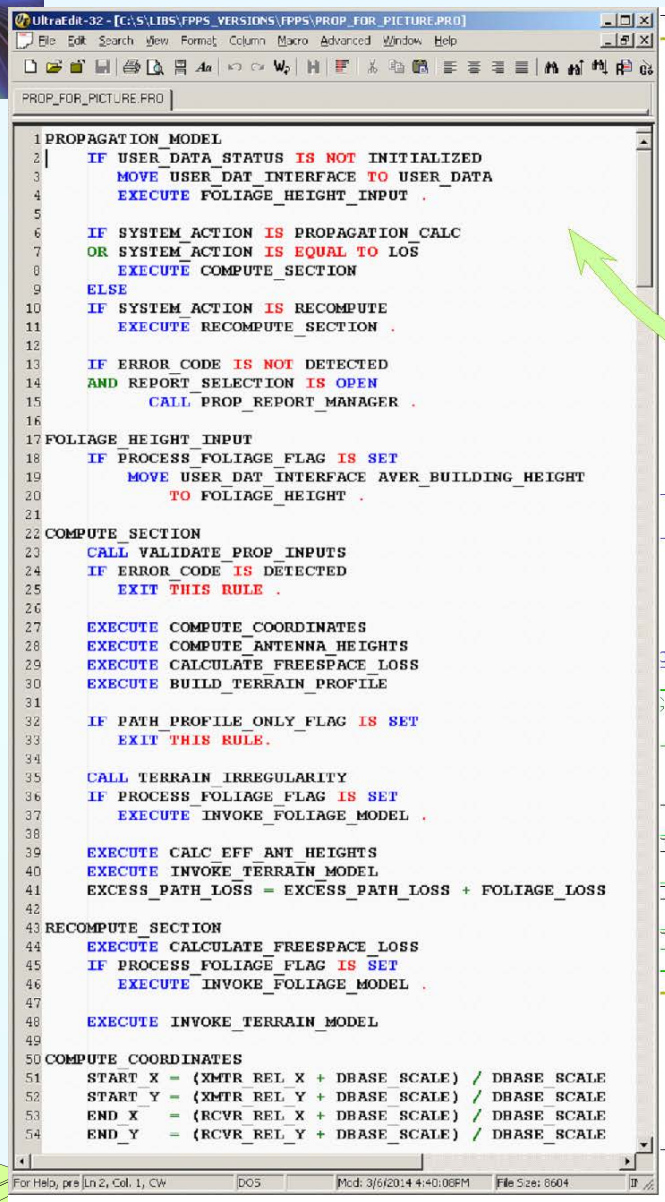
CAD for Prediction & Control Systems

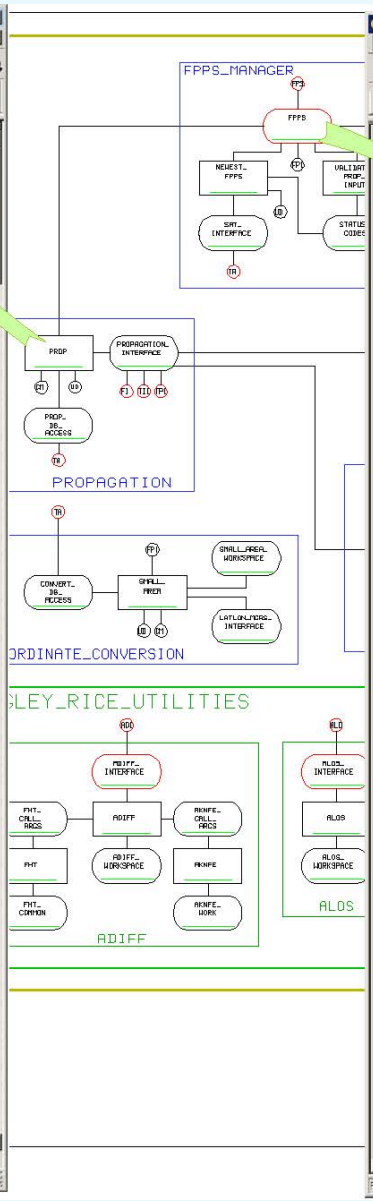


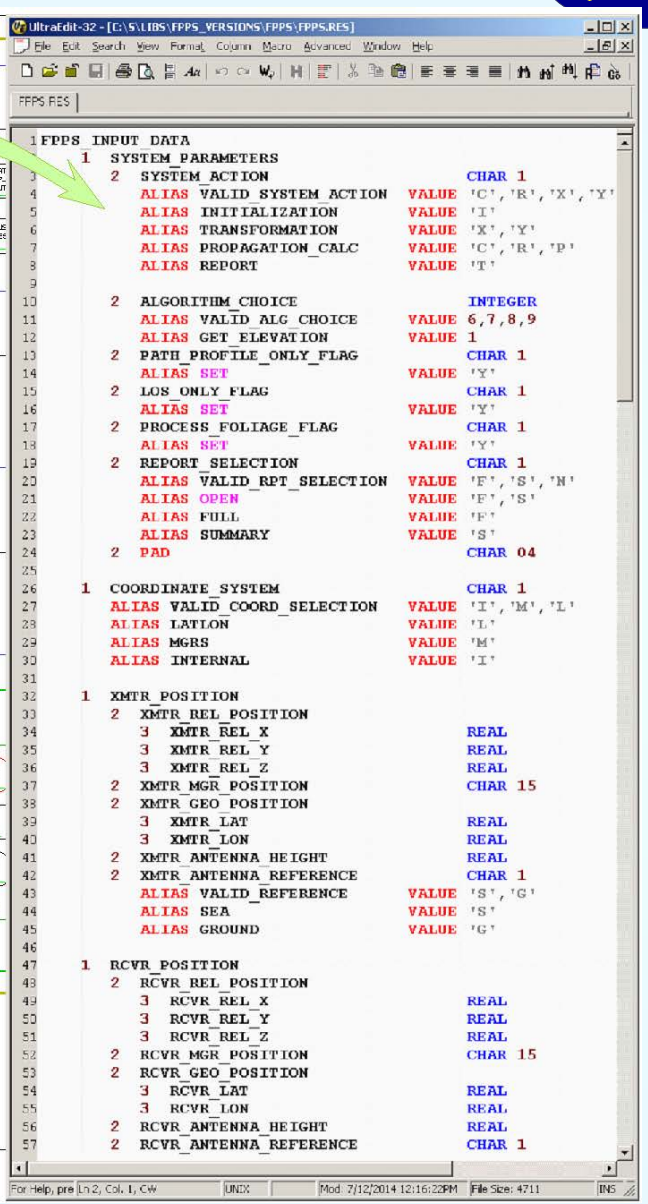
An Architecture - a Hierarchy of Modules

PREDICTION & CONTROL SYSTEMS ENGINEERS

CAD for Prediction & Control Systems





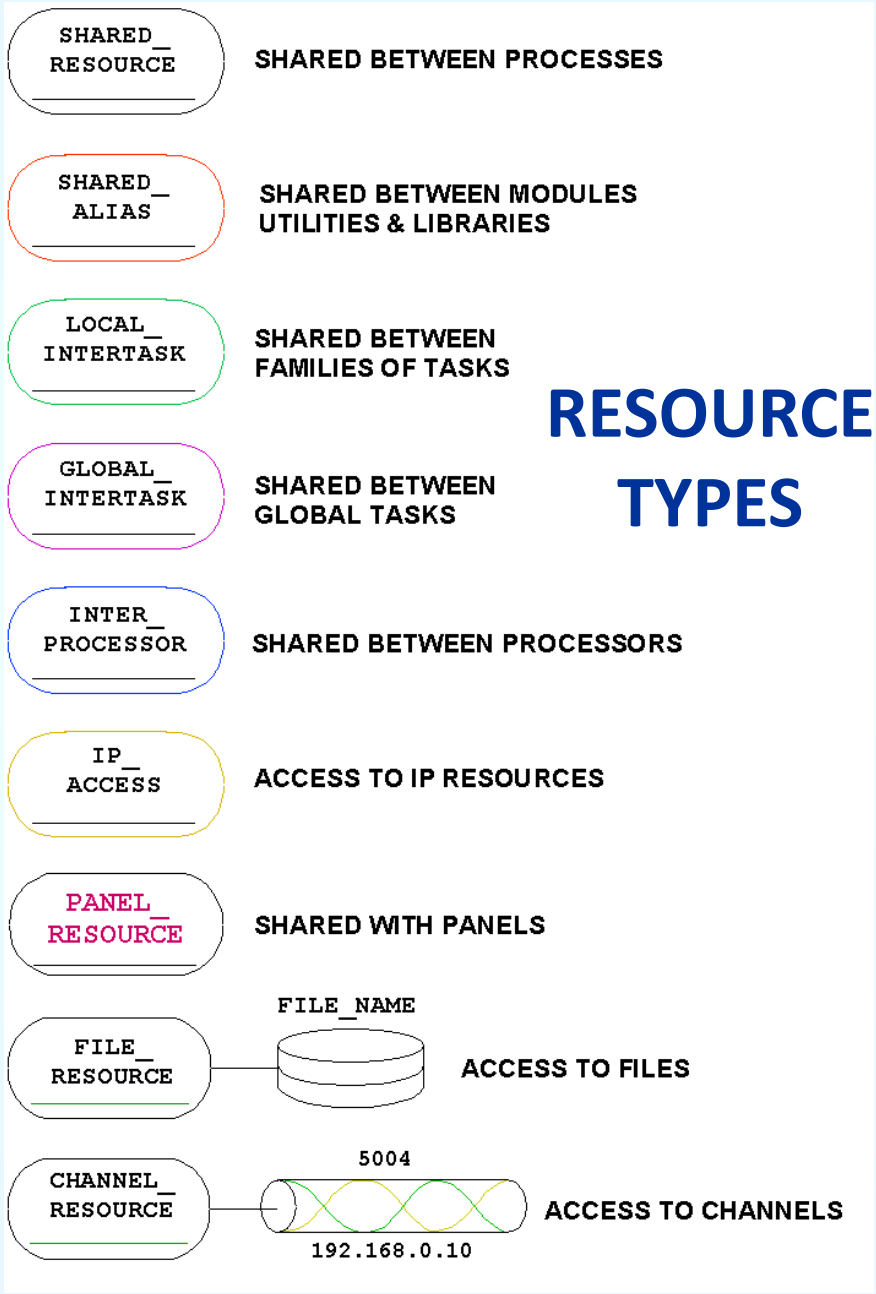


Double Click To Edit The Code

PREDICTION & CONTROL SYSTEMS ENGINEERS

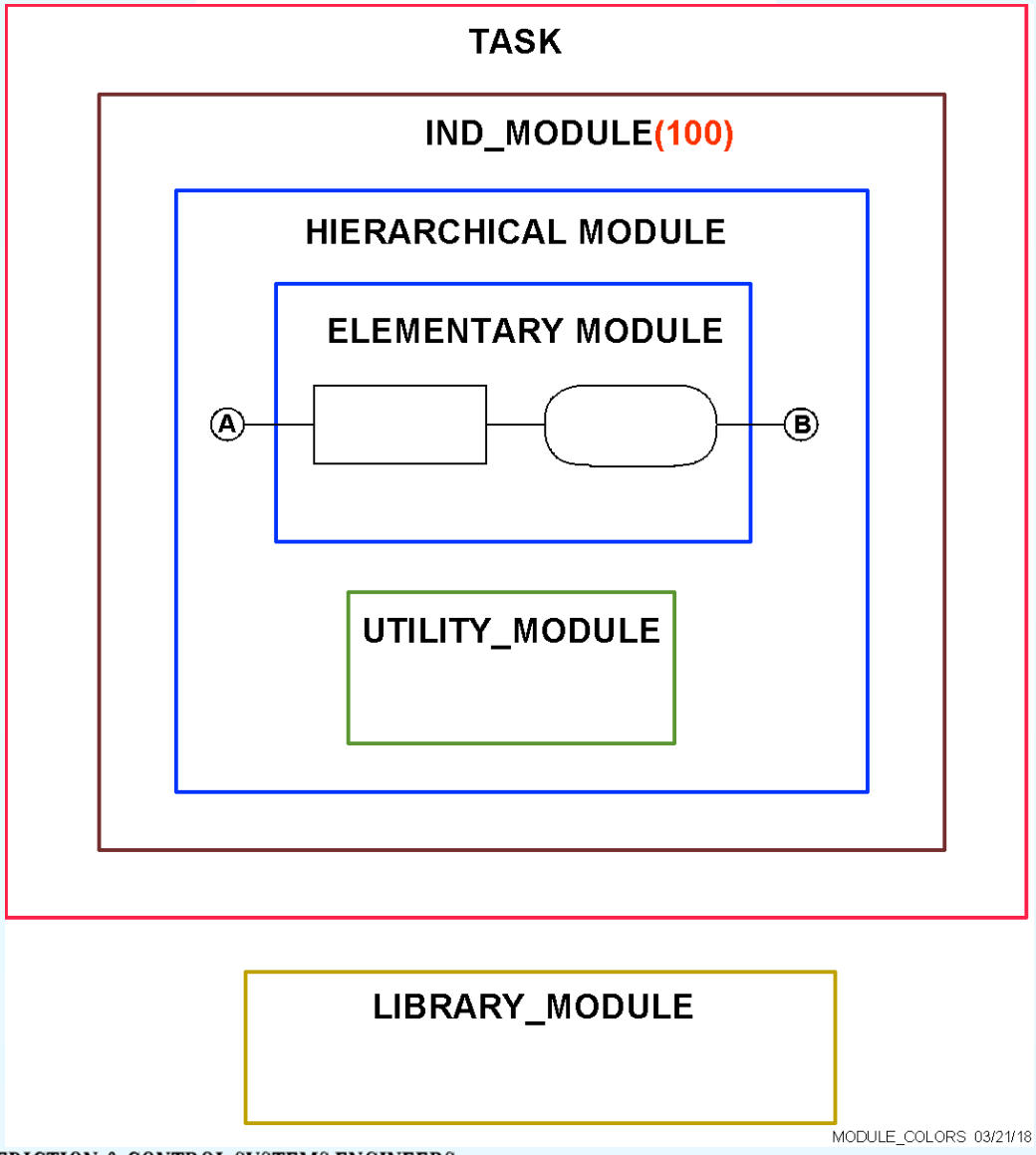
CAD for Prediction & Control Systems

RESOURCE TYPES ARE CRITICAL TO SHARING DATA & MAPPING MODULES ONTO PARALLEL PROCESSORS



MODULE TYPES

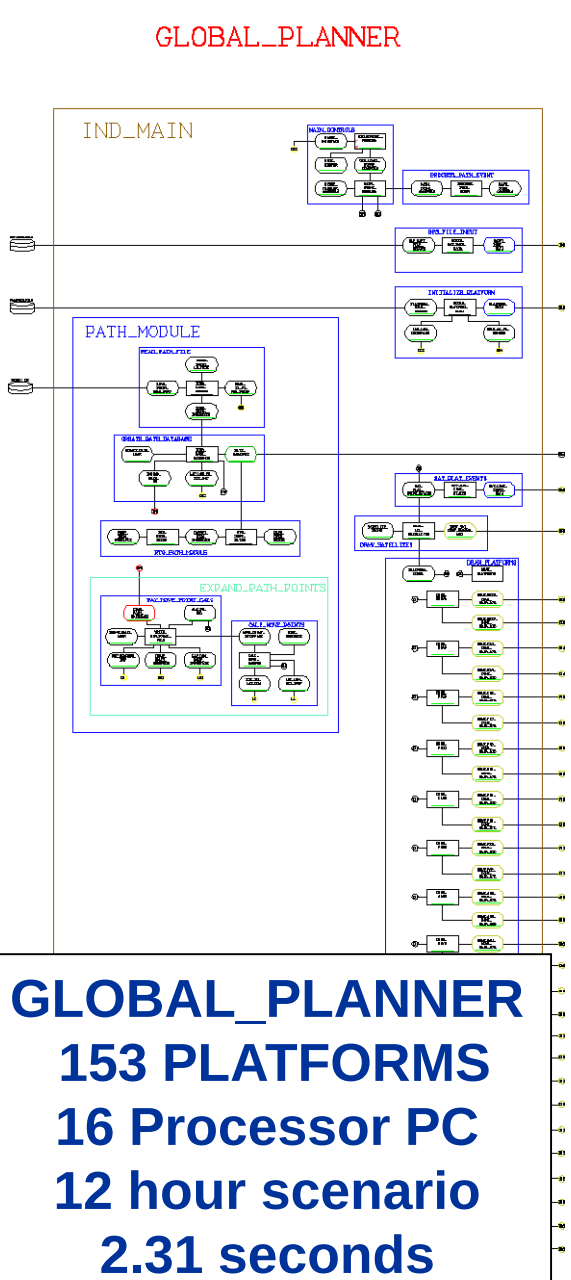
MODULE TYPES ARE CRITICAL TO *INDEPENDENCE* & ARCHITECTURAL MAPPING OF MODULES ONTO PARALLEL PROCESSORS

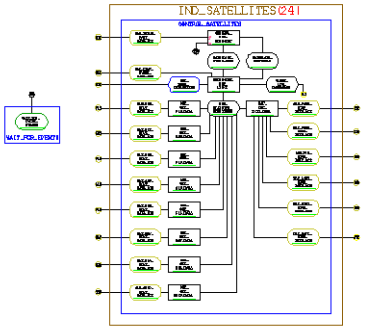


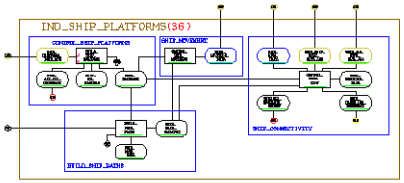
MODULE_COLORS 03/21/18

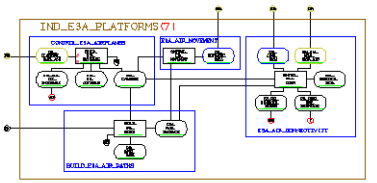
CAD for Prediction & Control Systems

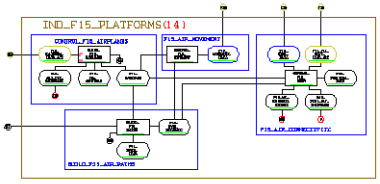
A Parallel Processor Simulation Architecture

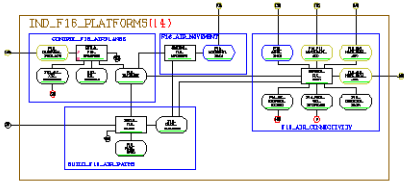


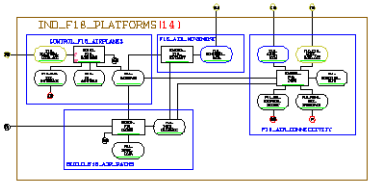


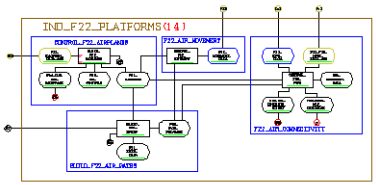


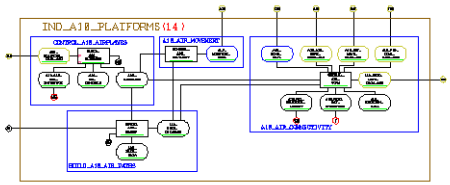


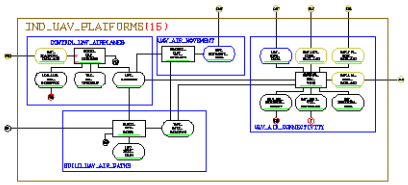


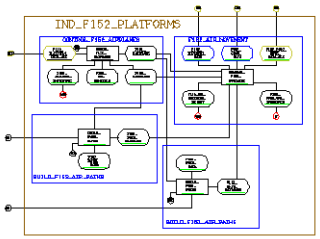


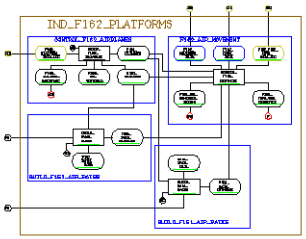


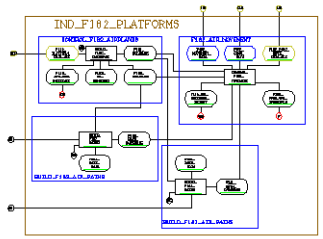


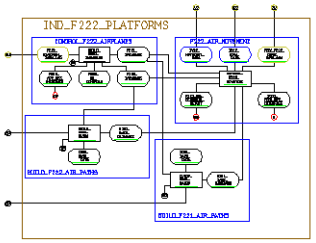


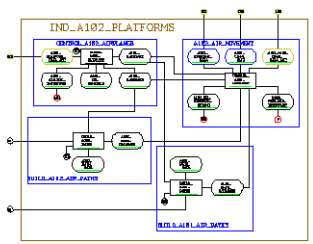


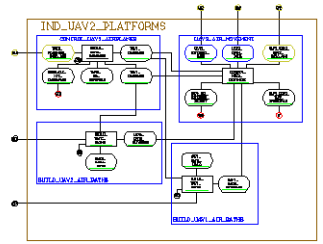










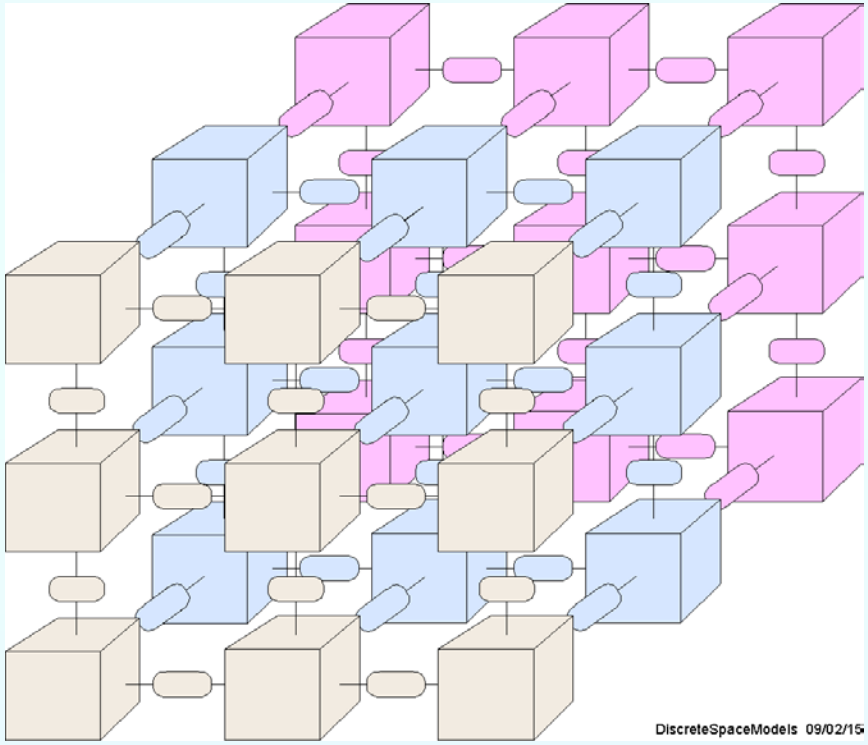


GLOBAL_PLANNER
153 PLATFORMS
16 Processor PC
12 hour scenario
2.31 seconds

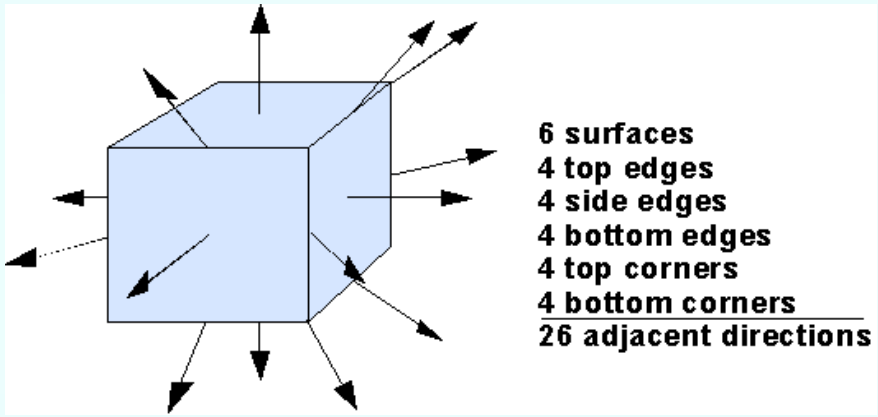
BACKUP SLIDES

Most Physical Systems Can Be Modeled Using 3-Dimensional Cells

A 3-D matrix of cells



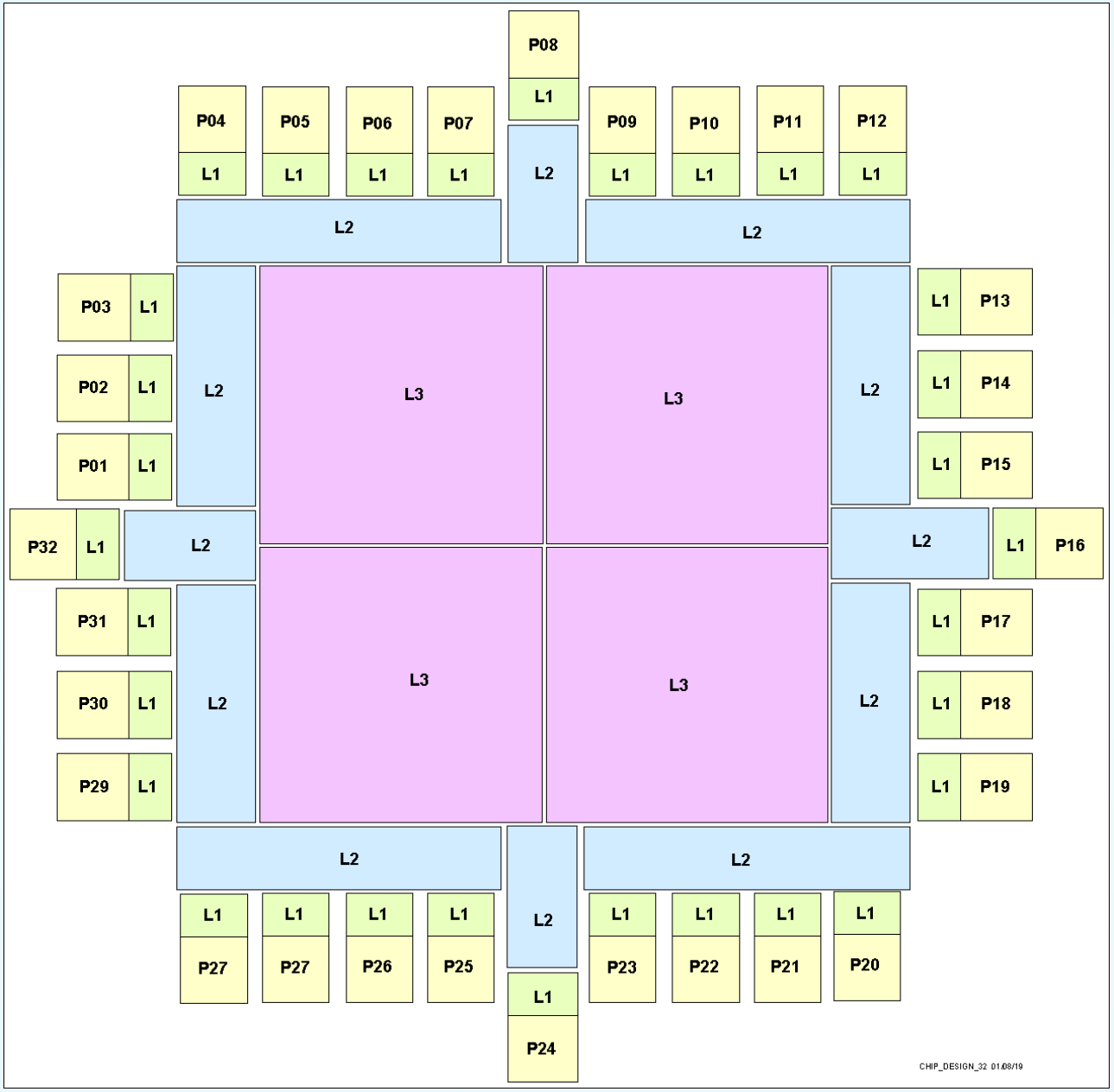
A single resource is shared between the adjacent face of each major cell



Each cell may contain huge numbers of minor sub-cells

Cells need only interface with adjacent neighbors!

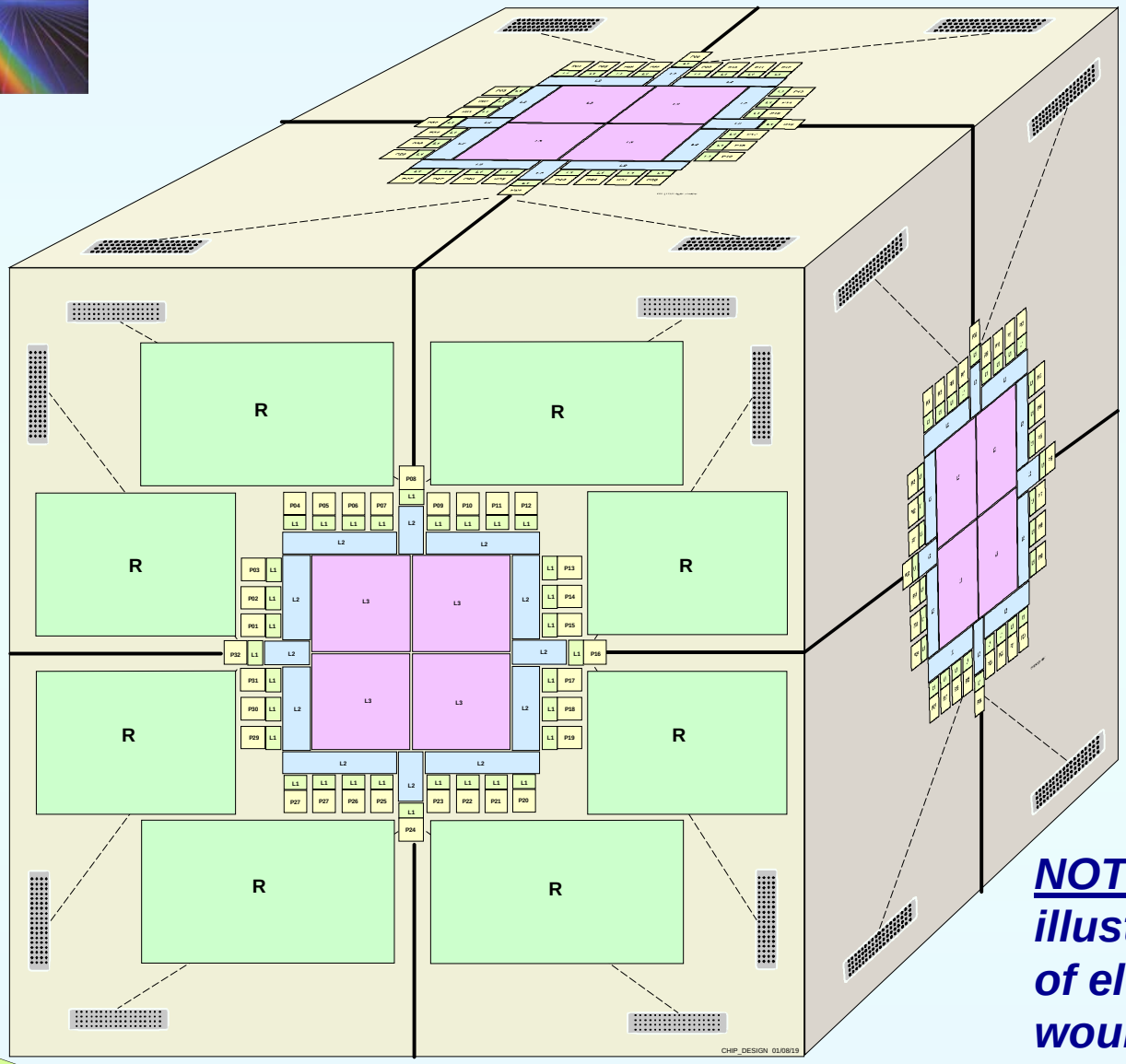
CAD for Prediction & Control Systems



Start with the basic Chip design

- Greatly Simplified

CAD for Prediction & Control Systems



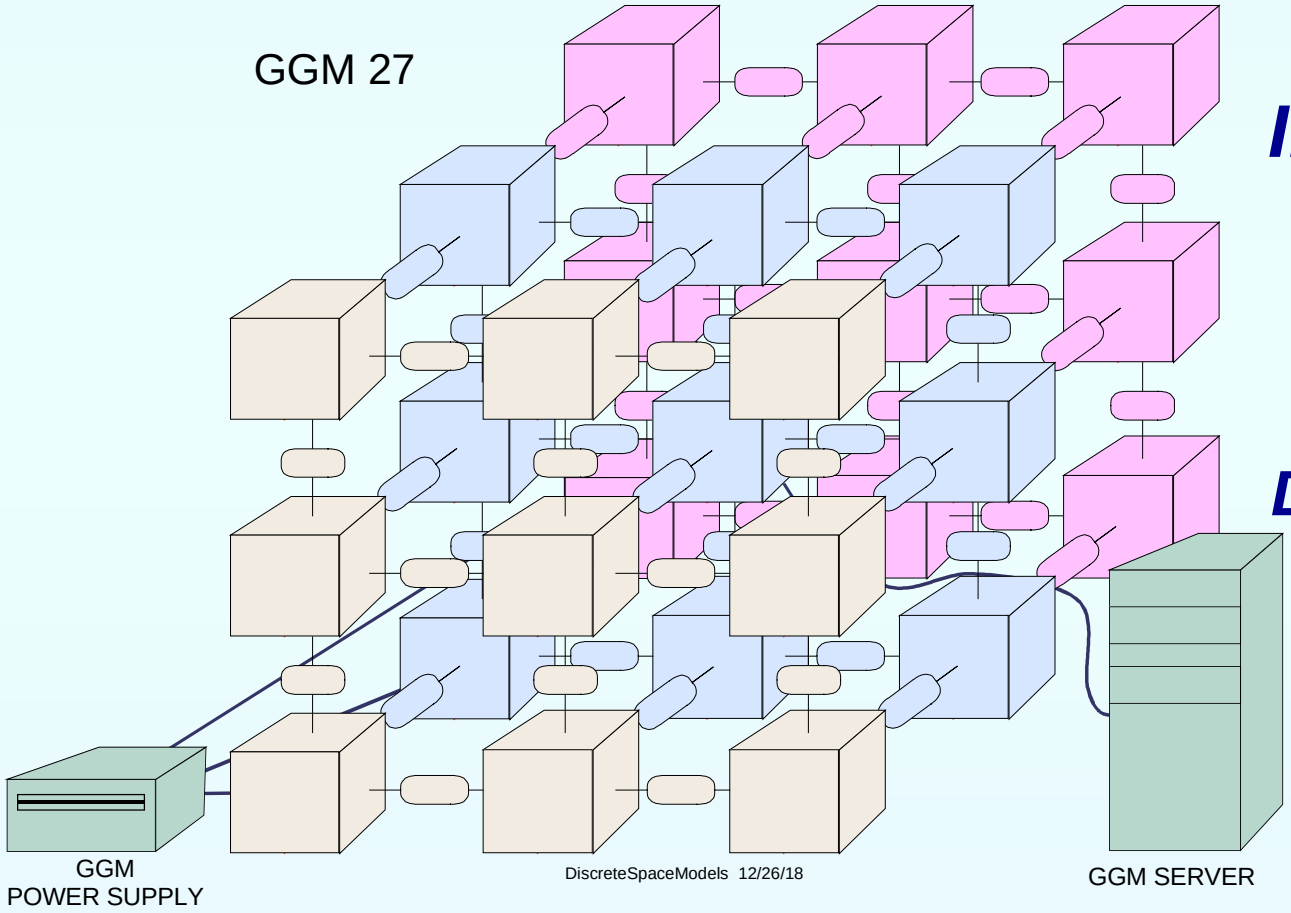
Then use the 3-D Box Design - with all DMA Channels

NOTE: ***This drawing only illustrates relative placement of elements - not where they would reside! For example, chips will be located on the inside of the boards.***

CAD for Prediction & Control Systems

BASED ON THE:

APPLICATION SPACE ARCHITECTURE

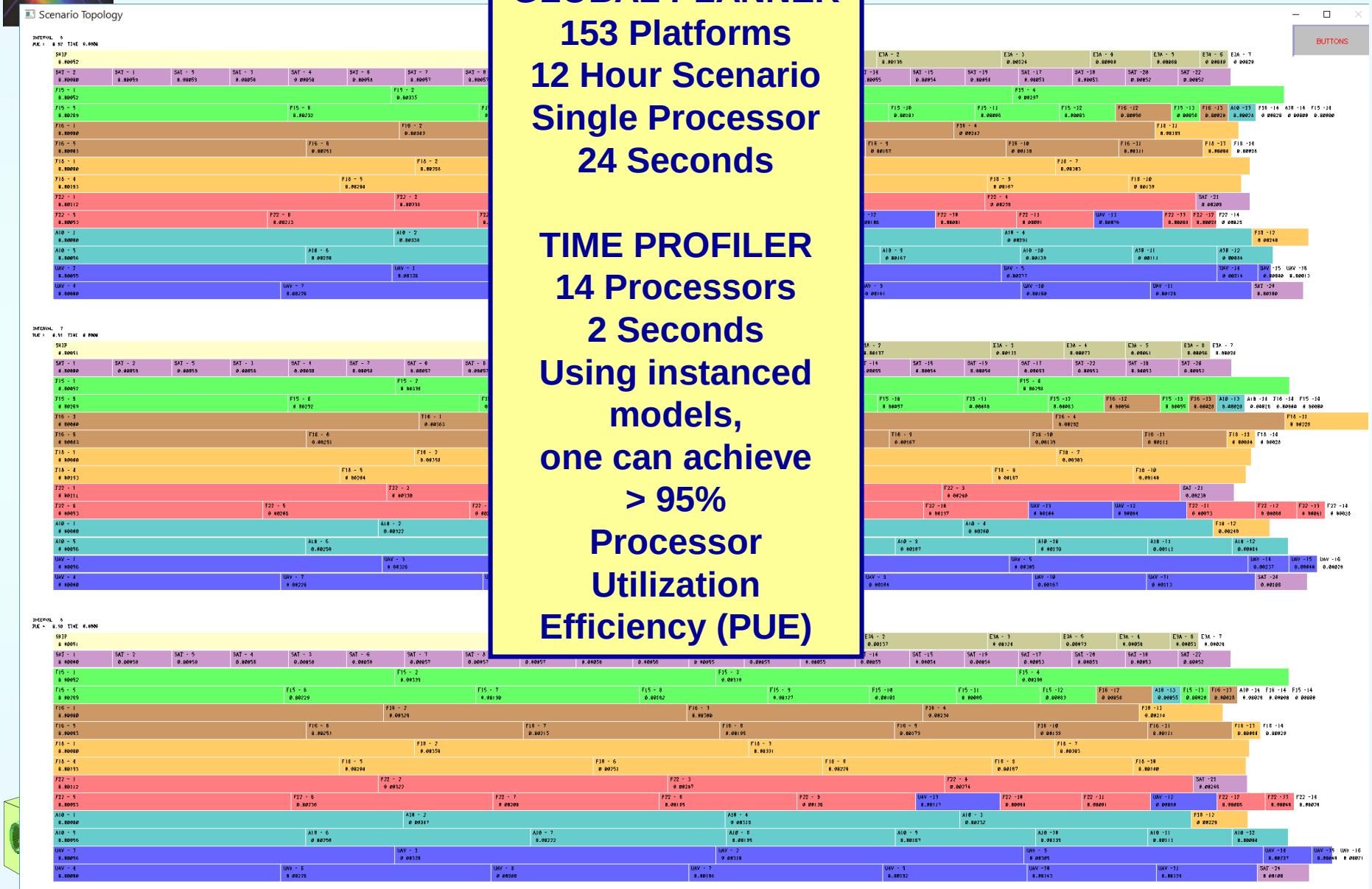


Just Interconnect the boxes
- In 3-D
- With all DMA Channels

CAD for Prediction & Control Systems

GLOBAL PLANNER
153 Platforms
12 Hour Scenario
Single Processor
24 Seconds

TIME PROFILER
14 Processors
2 Seconds
Using instanced models,
one can achieve
> 95%
Processor Utilization Efficiency (PUE)



CAD for Prediction & Control Systems

Consider a comparison of Green Gene Machines with other Parallel Processors

Green Gene Machine	Number of Processors	Power (KW) Consumed	Equivalent* Processors	Power (KW) Consumed
Green Gene 1	32	0.6	3200	12
Green Gene 2	64	0.8	7000	25
Green Gene 3	128	1.2	16000	60
Green Gene 01	192	4.0	50,000	188
Green Gene 04	768	16.0	400,000	1,500
Green Gene 09	1728	36.0	1,600,000	6,000
Green Gene 27	5184	108.0	5,000,000	18,750

Then just look at the energy savings from the reduced number of processors

*Equivalent Processor differences depend upon applications

PREDICTION SYSTEMS, INC.

PREDICTION & CONTROL SYSTEMS ENGINEERS

309 Morris Ave - Suite J
Spring Lake, NJ 07762

Telephone: (732) 449-6800
Fax: (732) 449-0897

Web Site: www.predictsys.com
E-Mail: psi@predictsys.com