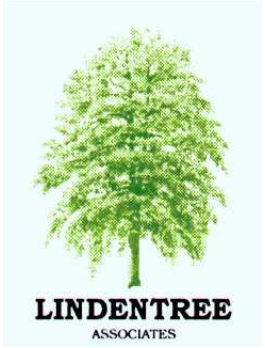


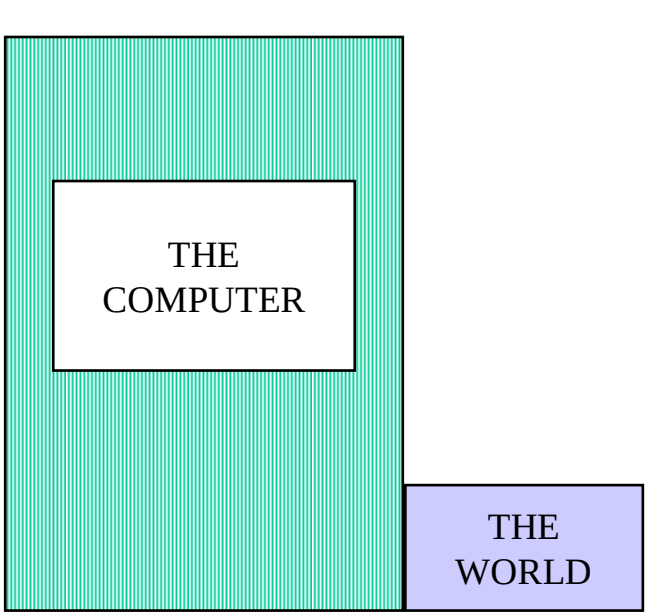
Parkway Research
Embedded Systems Seminars
April 16th 1999

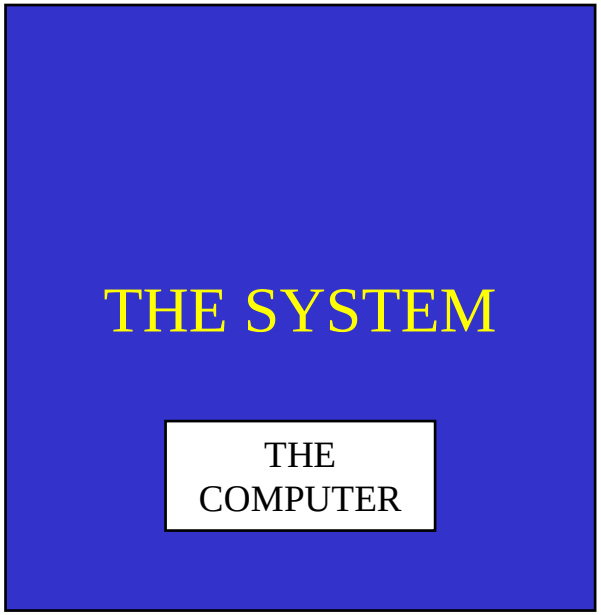
THE DESIGN OF SOFTWARE FOR REAL-TIME SYSTEMS

Jim Cooling - Lindentree Associates/Loughborough University

Niall Cooling - Feabhas Ltd.

Views of the World





Object Oriented Design

A Panacea?

COGNITIVE CONSEQUENCES OF OBJECT-ORIENTED DESIGN

Despite the scarcity of empirical evidence, many researchers agree that object-based problem representations are not natural for every problem.

Rosson and Alpert, Human-Computer Interaction

Object-Oriented Systems in Real-Life: Detailed Case Studies and Observations

- Company name: The company produces sophisticated measurement equipment with embedded software, or controlled by a PC, or a combination.

  Started the first OO projects in 1988 but didn't succeed well until after 1992. The problems were lack of formal training, immature tools, and too much faith in OO so that for instance requirements specification and project management were ignored.

- Applications studied: A PC-based measurement system interacting with special equipment.

- OO-Architecture: The technical architecture. Had big troubles finding out how to handle concurrency (multi-tasking) with OO. Their solution doesn't seem to be a natural part of OO

Søren Lauesen (www.cbs.dk/~slauesen/OocaseStudies/)

Object-Oriented Systems in Real-Life: Detailed Case Studies and Observations

- Seamless transition: No seamless transition. Made an analysis OO model as an appendix to the requirement specification…... The later OO design model was completely different from the analysis model. It modeled the final code, not the more abstract domain.

- Maintainability: The developers say that the system is more easy to maintain because the OO-based design is more carefully planned.

- Reuse: The company has realized that even after two "generations" of OO systems, they cannot reuse any code from one project to another.

Detailed Case Studies and Observations Object-Oriented Systems in Real-Life:

The OO-promoters said that all the promises were true and that I had looked at the wrong cases, or that I was old-fashioned and couldn't adapt to OO. However, they failed to provide evidence for successful applications - even when asked. In some cases they claimed evidence by referring to a successful application, but when I studied the case, it was no better or worse than other things I had seen.

REINDEER

- **A design method.**
- **A design methodology and**
- **A prototype tool for supporting design activities.**

Reindeer

Key Points

- A SYSTEM-BASED APPROACH
- STRUCTURE --- SOFTWARE --- HARDWARE -- PACKAGING
- PERFORMANCE EVALUATION -- An integral part of the process
- DEVELOPMENT PROCESS IS
    - Layered
    - Incremental
    - Complete

Fundamental Design Approach

- Initial (highest level) software design - expressed as an abstract, ideal model.
- Initial software architecture (style) and structuring - defined in conceptual terms.
- Assumption - sufficient processing power ***will always*** be available.
- Reality - at some point this ideal model must be mapped onto physical hardware.
- Outcome - the resulting implementation model has a concurrent structure.
- Mapping – Ideally the mapping should be transparent to the software designer.
- Enabling technologies – ORBs (CORBA, Real-Time CORBA, COM, DCOM).
- Resulting Performance (deadlines, throughput, failure modes, etc.) - ?????????

Experience from integration and system testing of the Voyager and Galileo spacecraft:

"…misunderstanding of interface requirements and lack of detailed requirements for robustness are the primary causes of [safety-related software] errors…"

They accounted for 44% of all logged safety-related errors. The categories were:

- Out-of-range input values.
- Non-arrival of expected inputs.
- Unexpected arrival of inputs.
- Inconsistent code behaviour in response to input signals.
- Invalid input data time-frames.
- Out-of-range arrival rates.
- Lost events.
- Excessive output signal rates.
- Not all output data used.
- Effect of input signal arrival during non-operational modes (startup/offline/shutdown).

Targeting safety-related errors during software requirements analysis,
Lutz,R.R., Sigsoft'93/12/93/CA, pp99-106

Reindeer

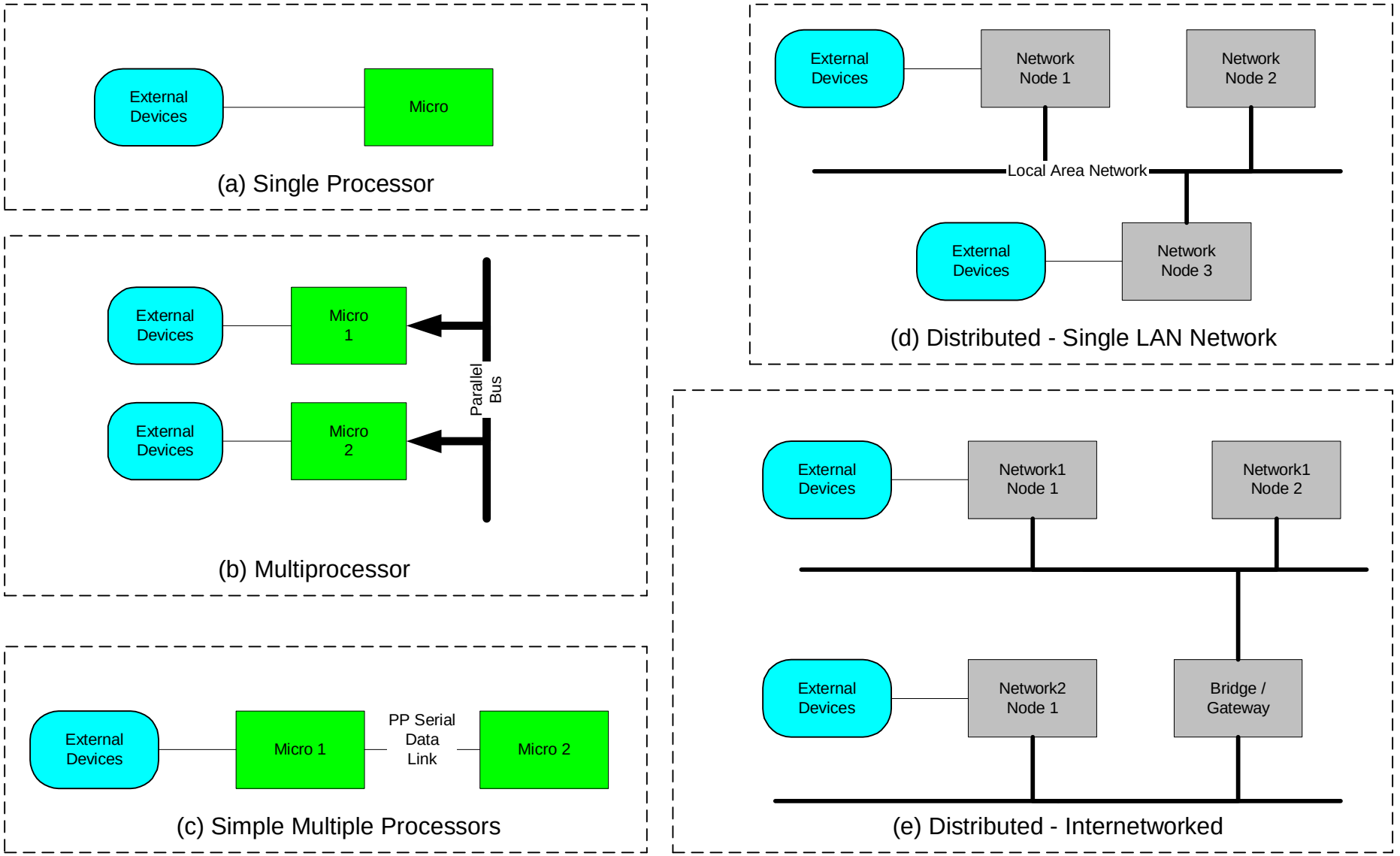
Design Method and Diagramming Aspects

Some Important Considerations

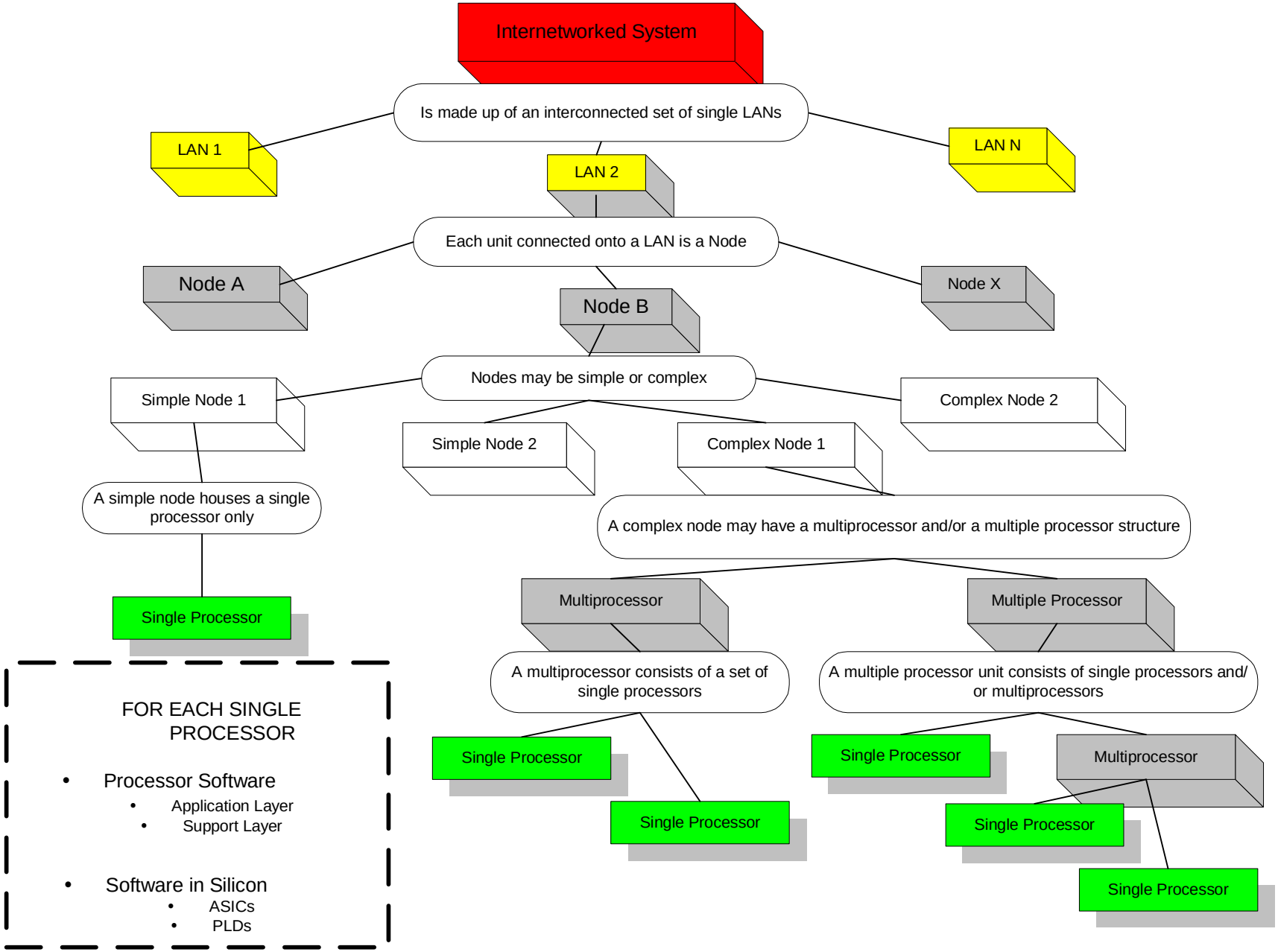
- Prescriptive? --- NO
- Descriptive? -- YES
- Precise? -- YES (but adaptable/configurable)
- Concise? -- Attempts to strike a balance between complexity and obscurity
- Conceptual Models? -- Both client/server and materials flow mode supported

FUNDAMENTAL SOFTWARE MODELS

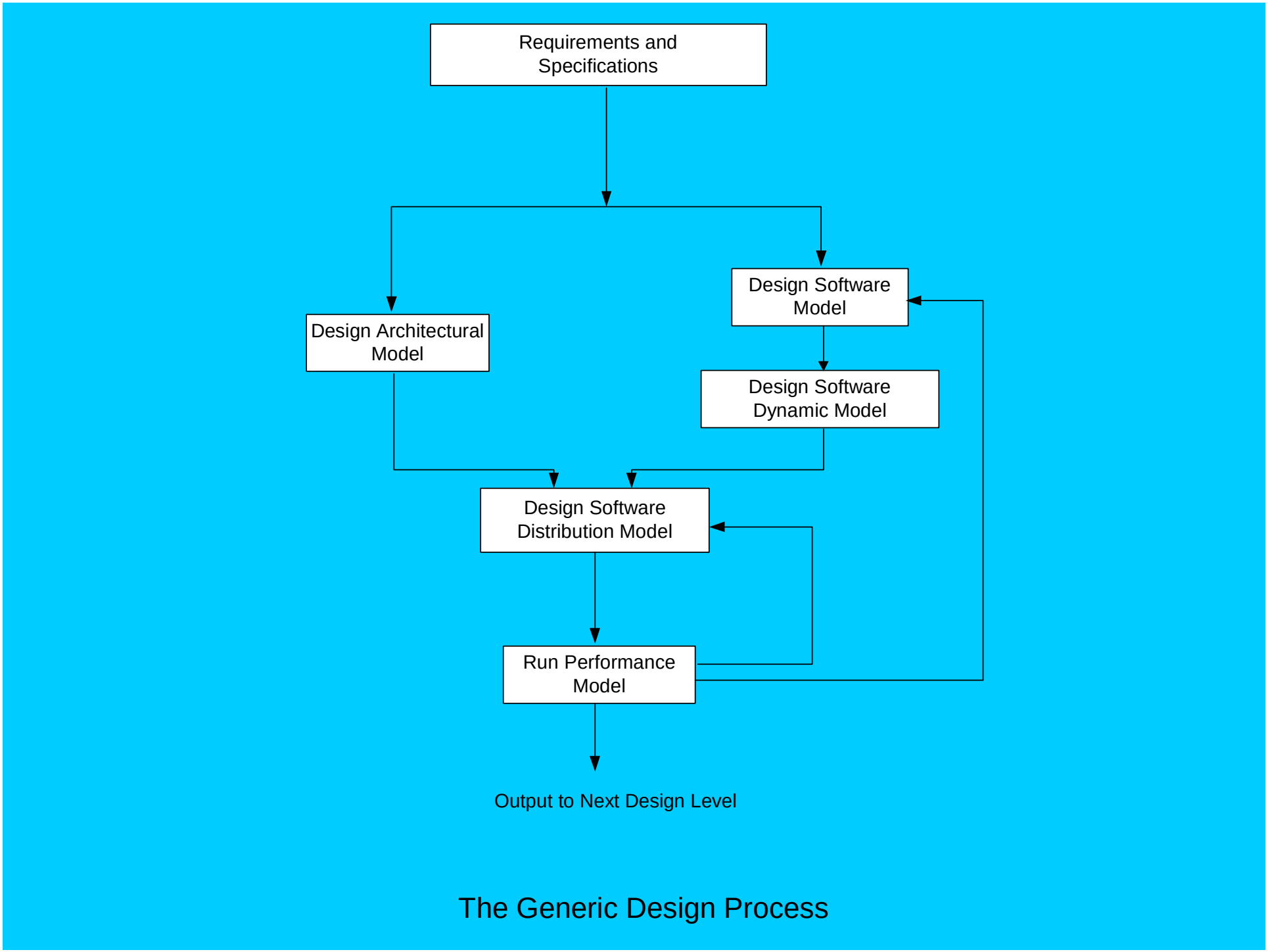
- Client/Server
- Materials flow



Embedded Systems - Some Common Architectures



Typical Hardware-Software Structural Relationship



The Generic Design Process

Performance Engineering

Two distinct approaches can be used to try and ensure that systems meet their performance objectives.

Reactive

- design and build the system
- measure the performance
- If unsatisfactory, modify the design and repeat the process

Proactive

- predict performance during system design
- improve the design if necessary
- build the system
- measure the performance
- If unsatisfactory, modify the design and repeat the process

The Reactive Approach

- Performance is not addressed prior to system test
- Systems are built on the premise that:
  - Tuning can be applied if necessary and/or
  - Faster hardware can be used if necessary and/or
  - A new version of software can be used if necessary

- Blindly optimistic that any performance problem can be easily overcome.

The Reactive Approach

The problems with this approach is that performance problems are not predicted, only discovered. Highest risk in attaining acceptable performance.

Consequences:

- slipped release dates - customer dissatisfaction or
- roll-out with poor performance - customer dissatisfaction
- Greater cost of change.
- Project may be scrapped.

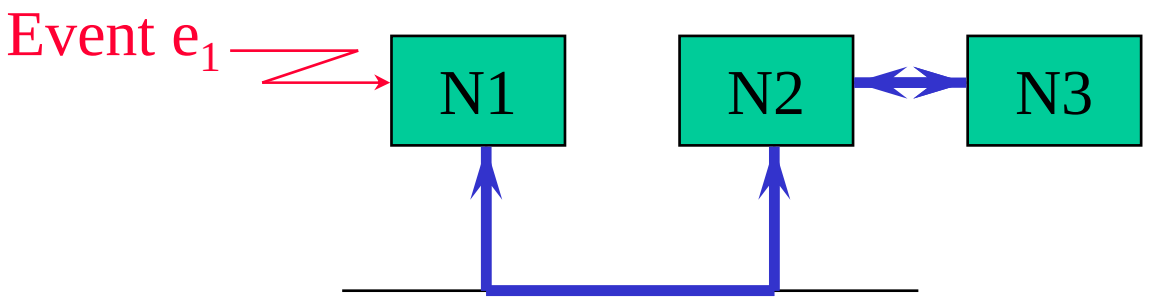
Reindeer - A Proactive Approach

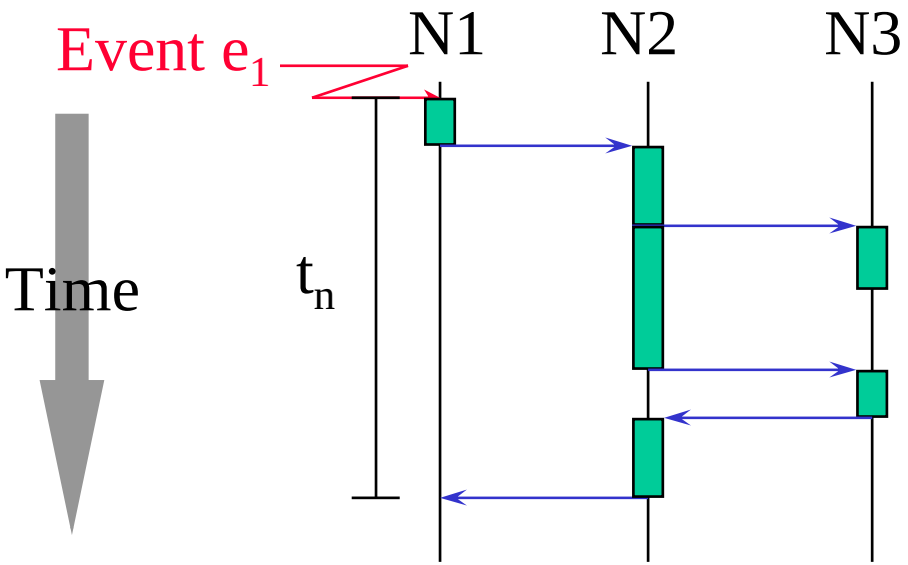
The proactive approach involves building performance into the system by developing and analyzing models of systems throughout the project lifecycle.

Advantages

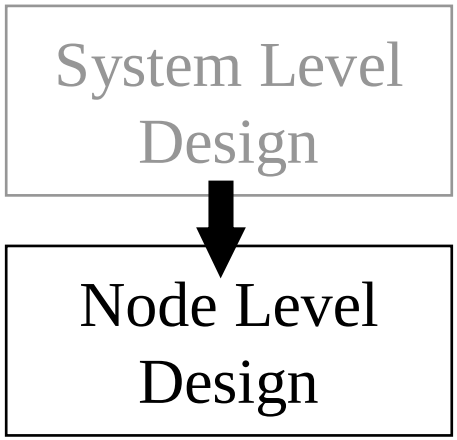
- It is a fast and inexpensive way to evaluate alternatives and identify performance problems before they arise.
- It can provide performance estimates long before there is anything to measure.
- Testing can be performed that is impossible outside of a live environment.
- Experiments can be performed that would be impractical with a real system.

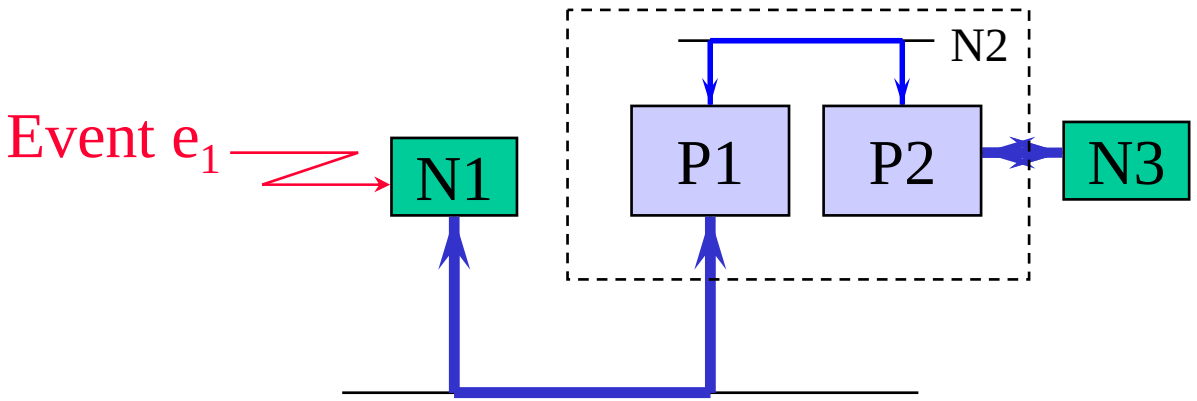
System Level Design

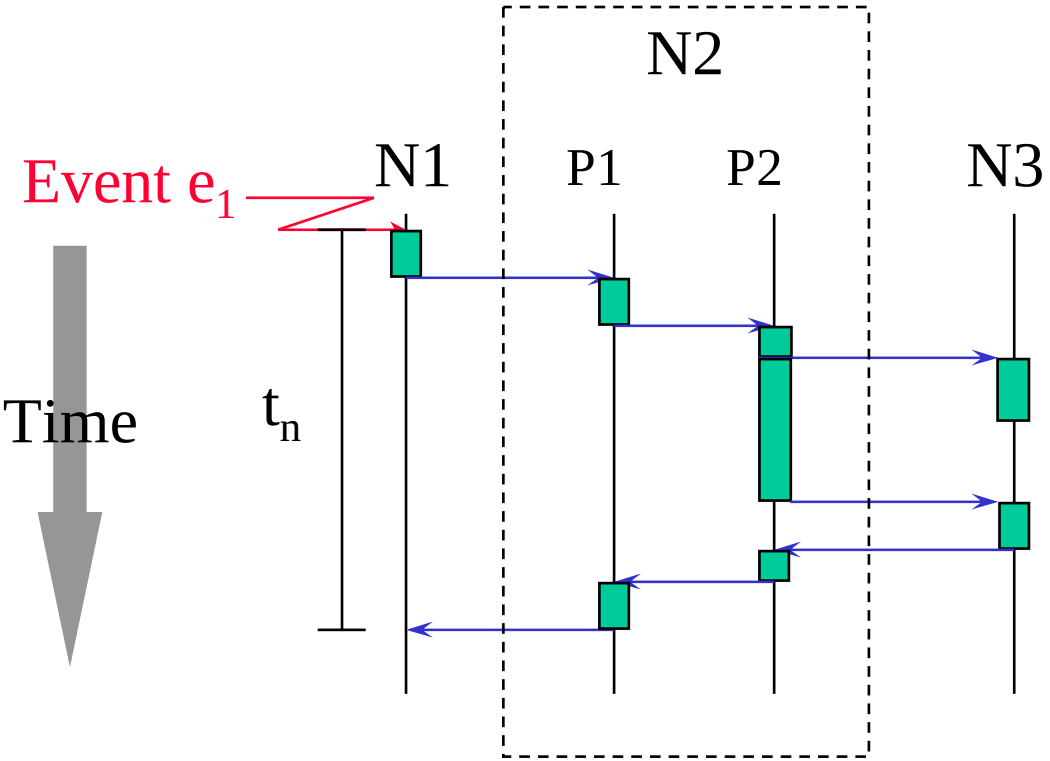




- Events
  - arrival rates
  - response deadline
- Inter-node Messages
  - message size
  - blocking / non-blocking
- Node processing
  - performance budget





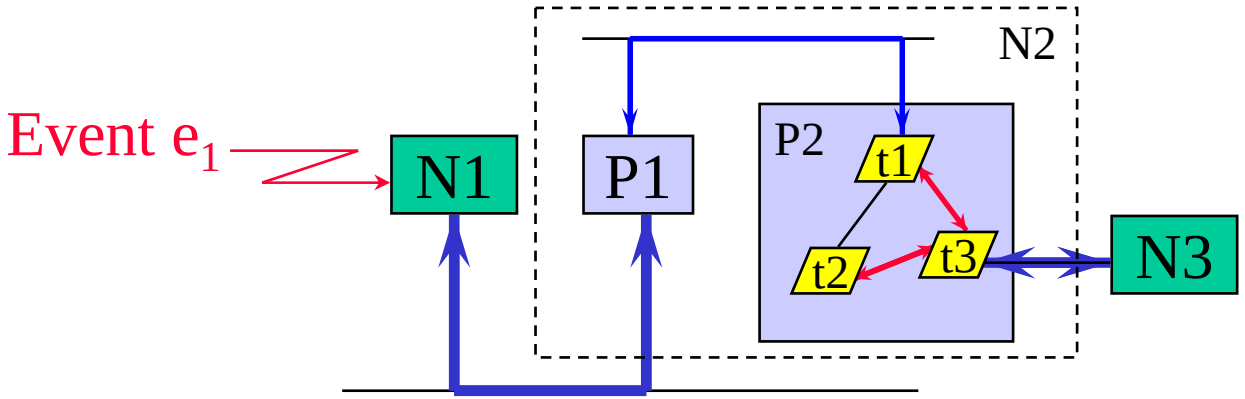


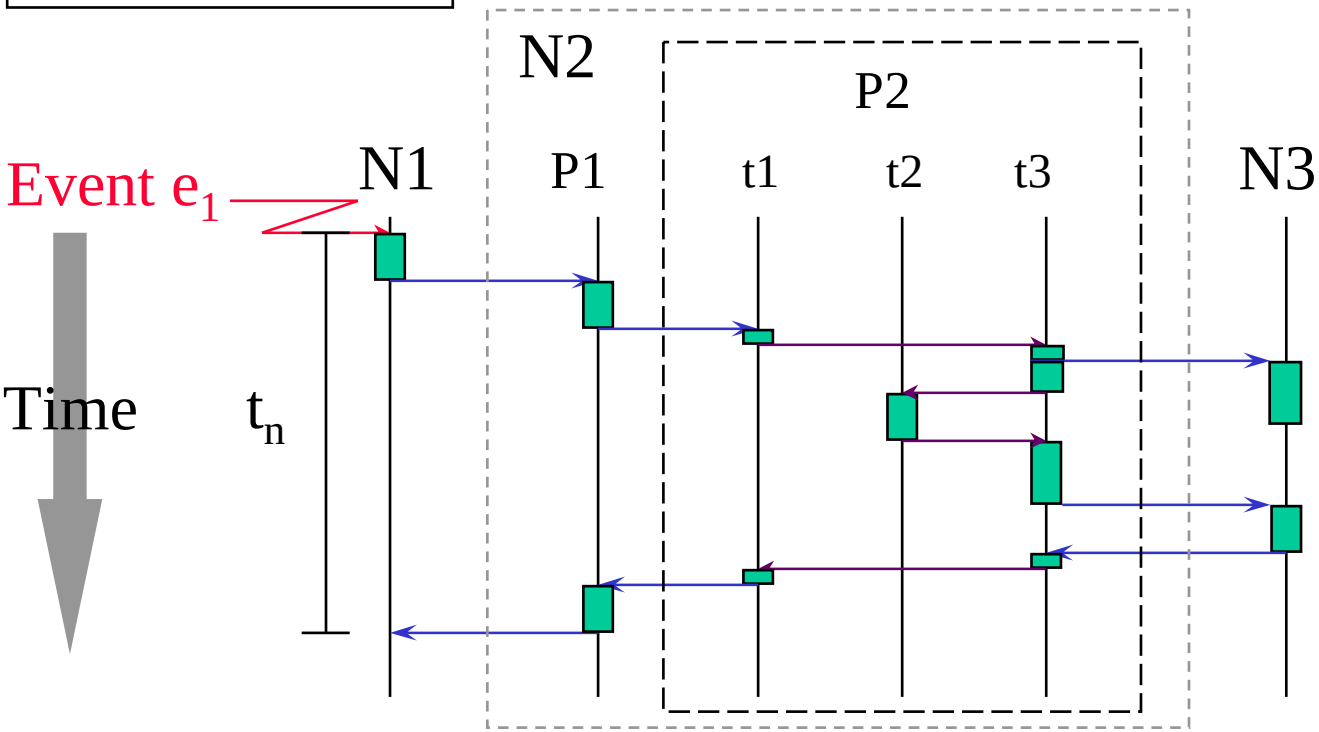
- Inter-processor Messages
  - message size
  - blocking / non-blocking
- Processor Processing
  - performance budget of node allocated across processors

System Level Design

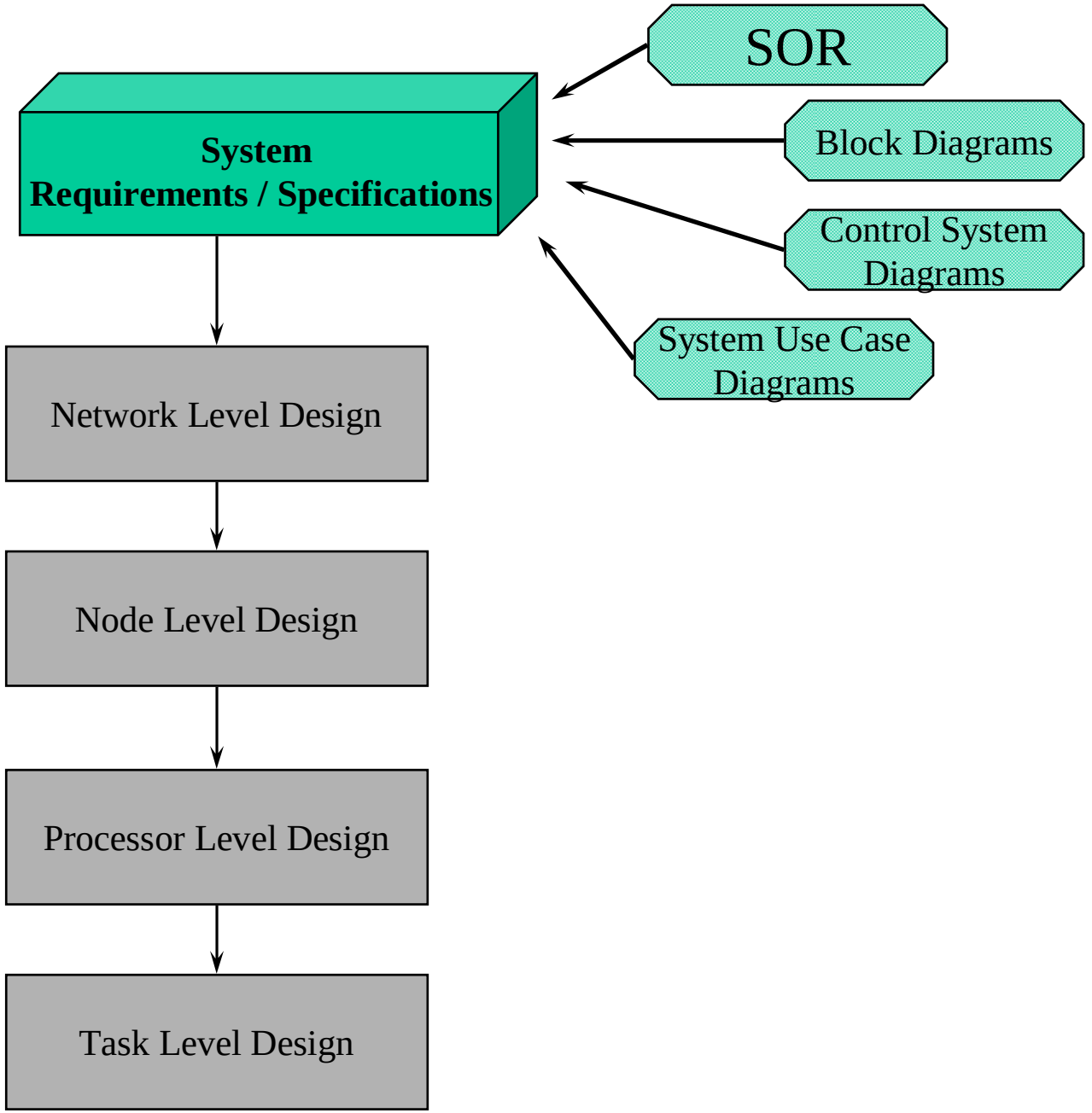
Node Level Design

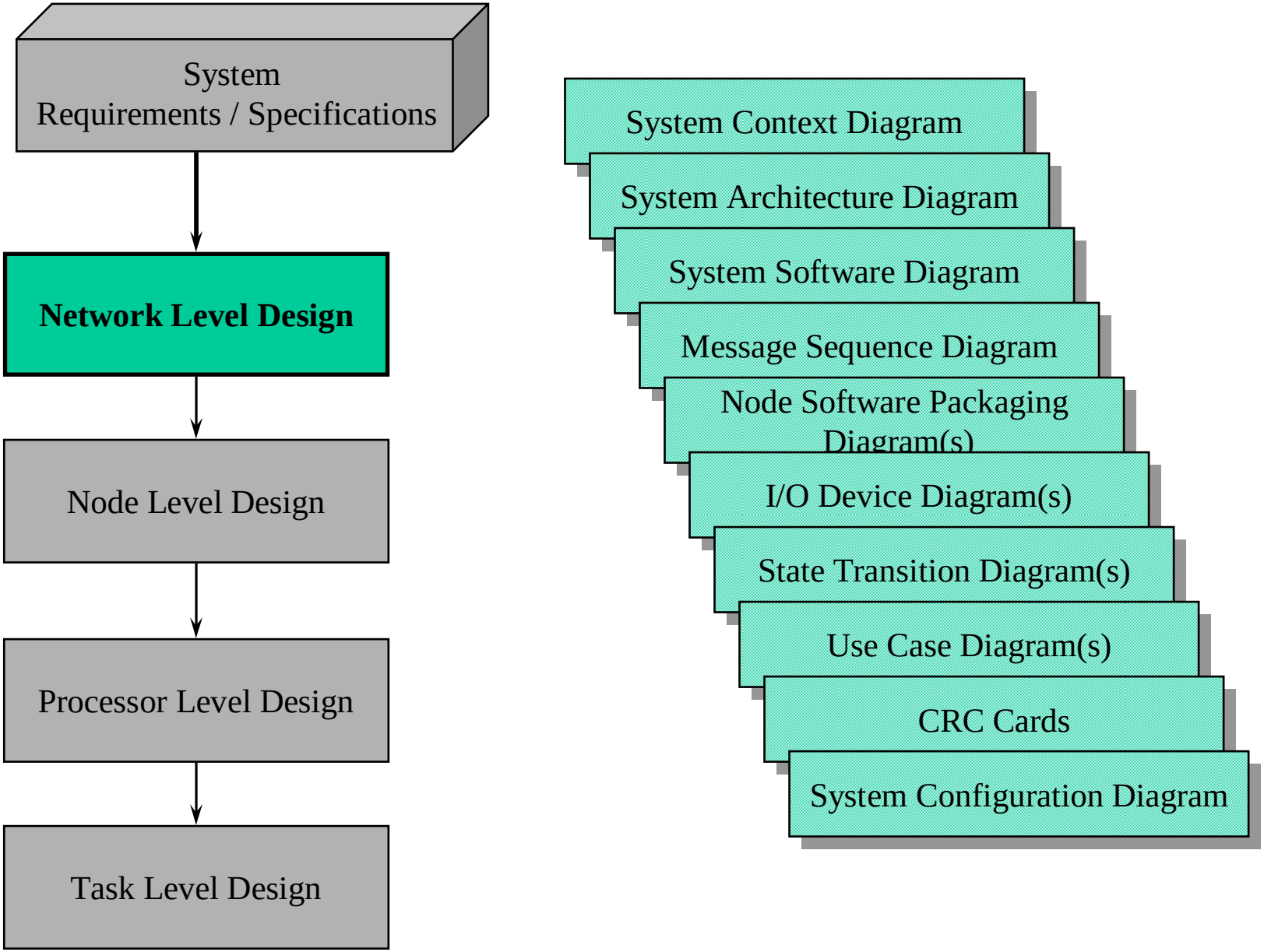
Processor Level Design

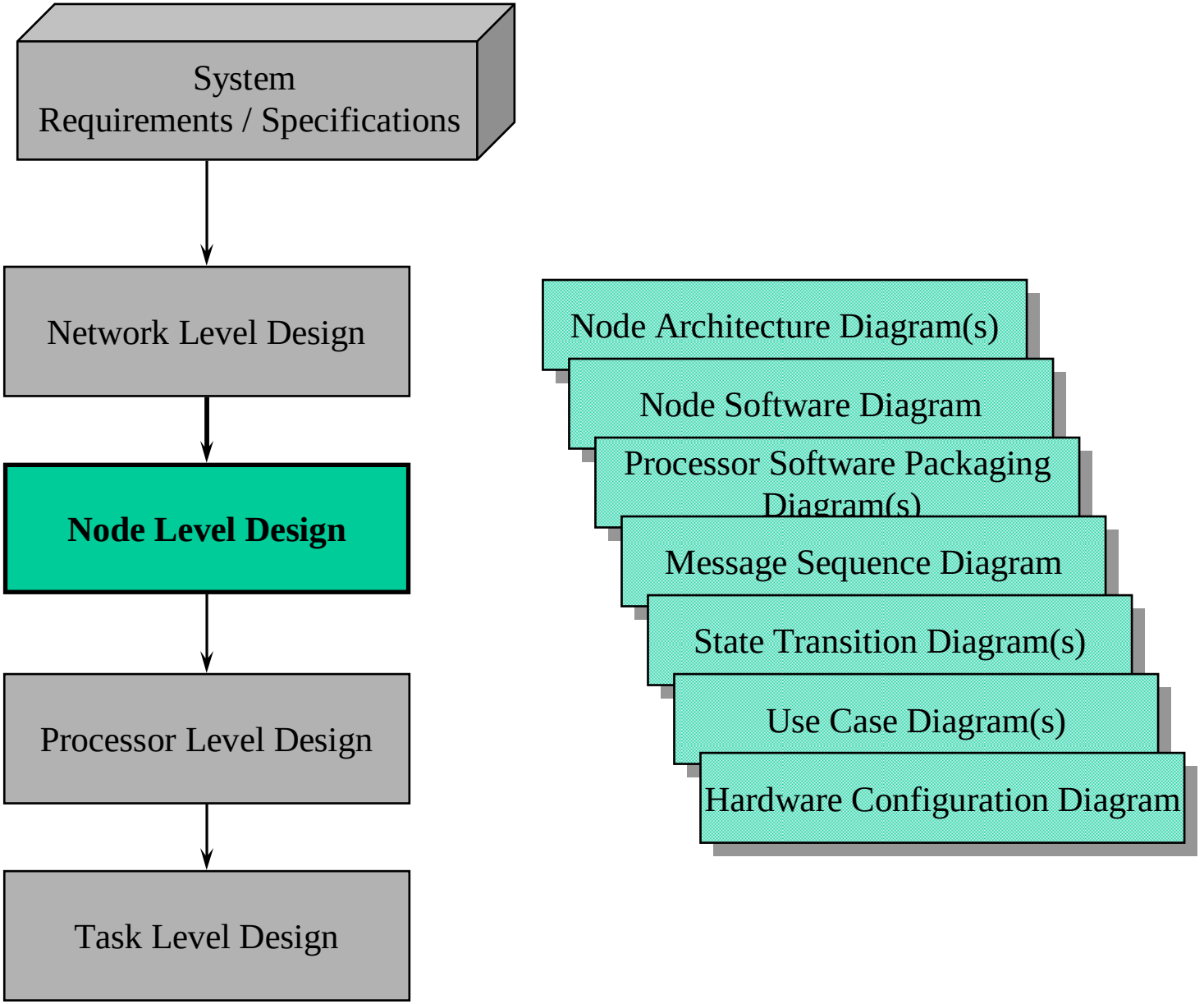


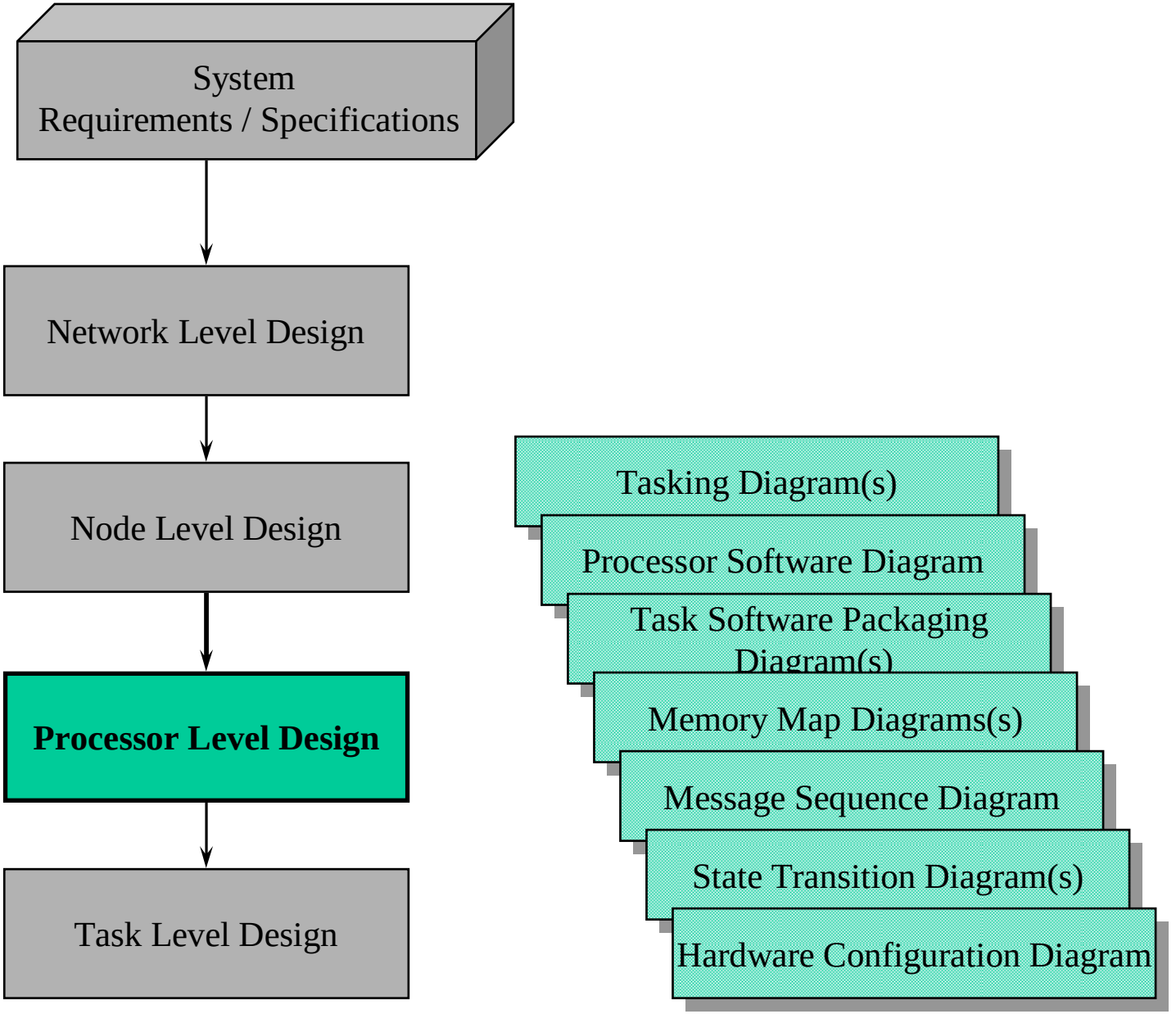


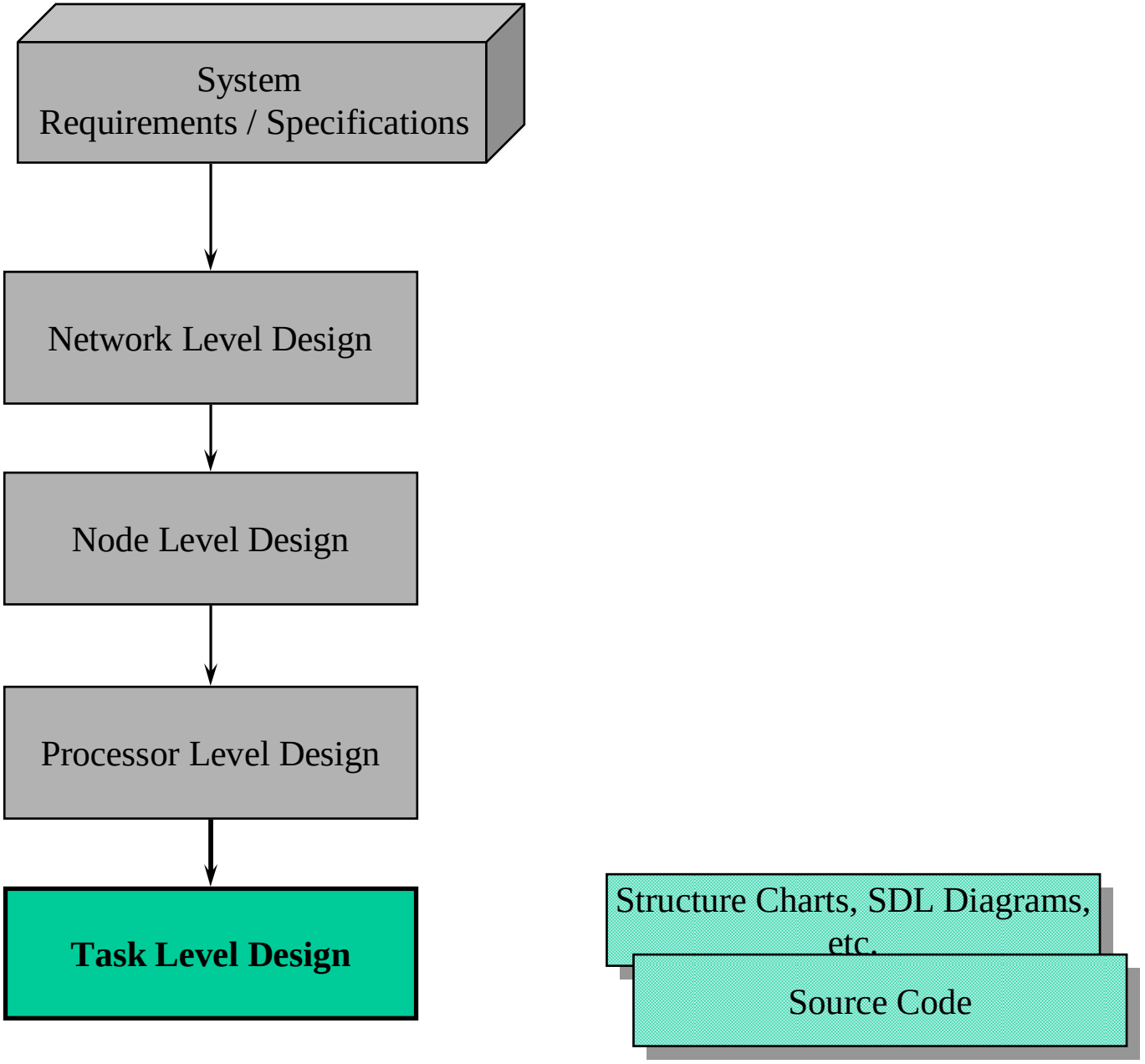
- Intra-processor Messages
  - message size
  - blocking / non-blocking
  - OS primitive
- Task Processing
  - performance budget of processor allocated across tasks
  - Task priorities

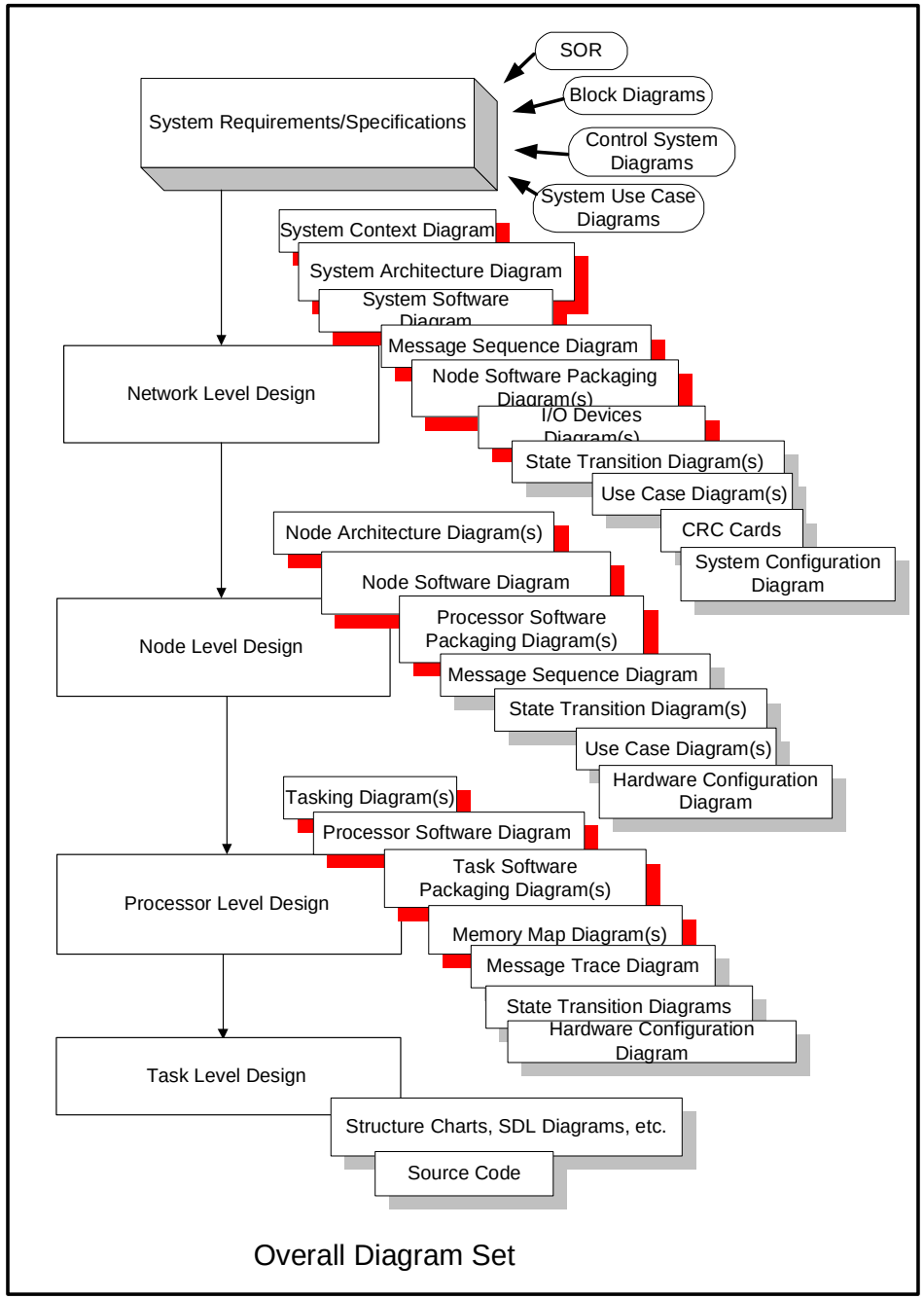

SOR
System
Requirements / Specifications
Block Diagrams
Control System
Diagrams
System Use Case
Diagrams
Network Level Design
Node Level Design
Processor Level Design
Task Level Design


System
Requirements / Specifications
Network Level Design
Node Level Design
Processor Level Design
Task Level Design
System Context Diagram
System Architecture Diagram
System Software Diagram
Message Sequence Diagram
Node Software Packaging
Diagram(s)
I/O Device Diagram(s)
State Transition Diagram(s)
Use Case Diagram(s)
CRC Cards
System Configuration Diagram

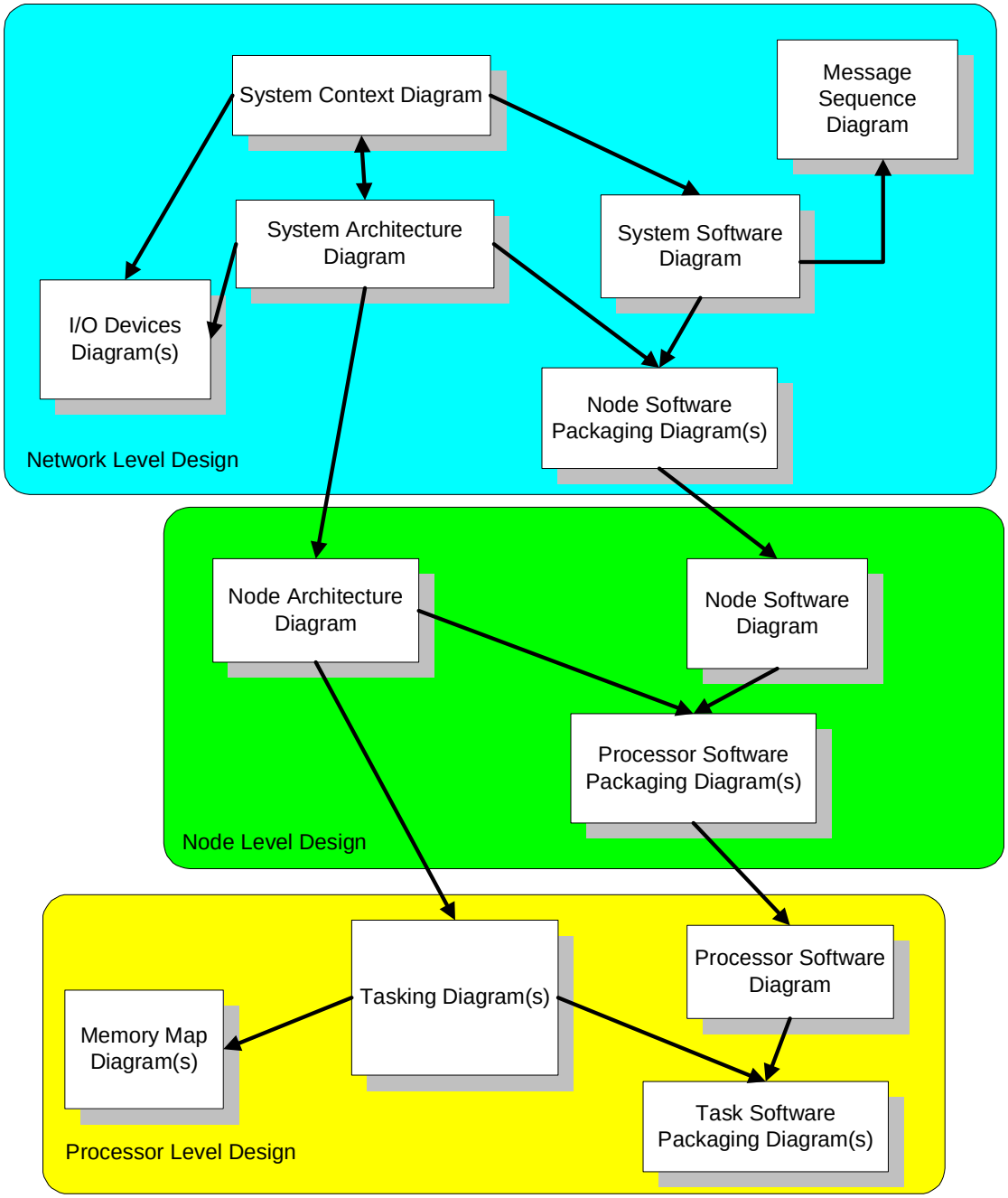

System
Requirements / Specifications
Network Level Design
Node Level Design
Processor Level Design
Task Level Design
Node Architecture Diagram(s)
Node Software Diagram
Processor Software Packaging Diagram(s)
Message Sequence Diagram
State Transition Diagram(s)
Use Case Diagram(s)
Hardware Configuration Diagram


System
Requirements / Specifications
Network Level Design
Node Level Design
Processor Level Design
Task Level Design
Tasking Diagram(s)
Processor Software Diagram
Task Software Packaging
Diagram(s)
Memory Map Diagrams(s)
Message Sequence Diagram
State Transition Diagram(s)
Hardware Configuration Diagram


System
Requirements / Specifications
Network Level Design
Node Level Design
Processor Level Design
Task Level Design
Structure Charts, SDL Diagrams, etc.
Source Code

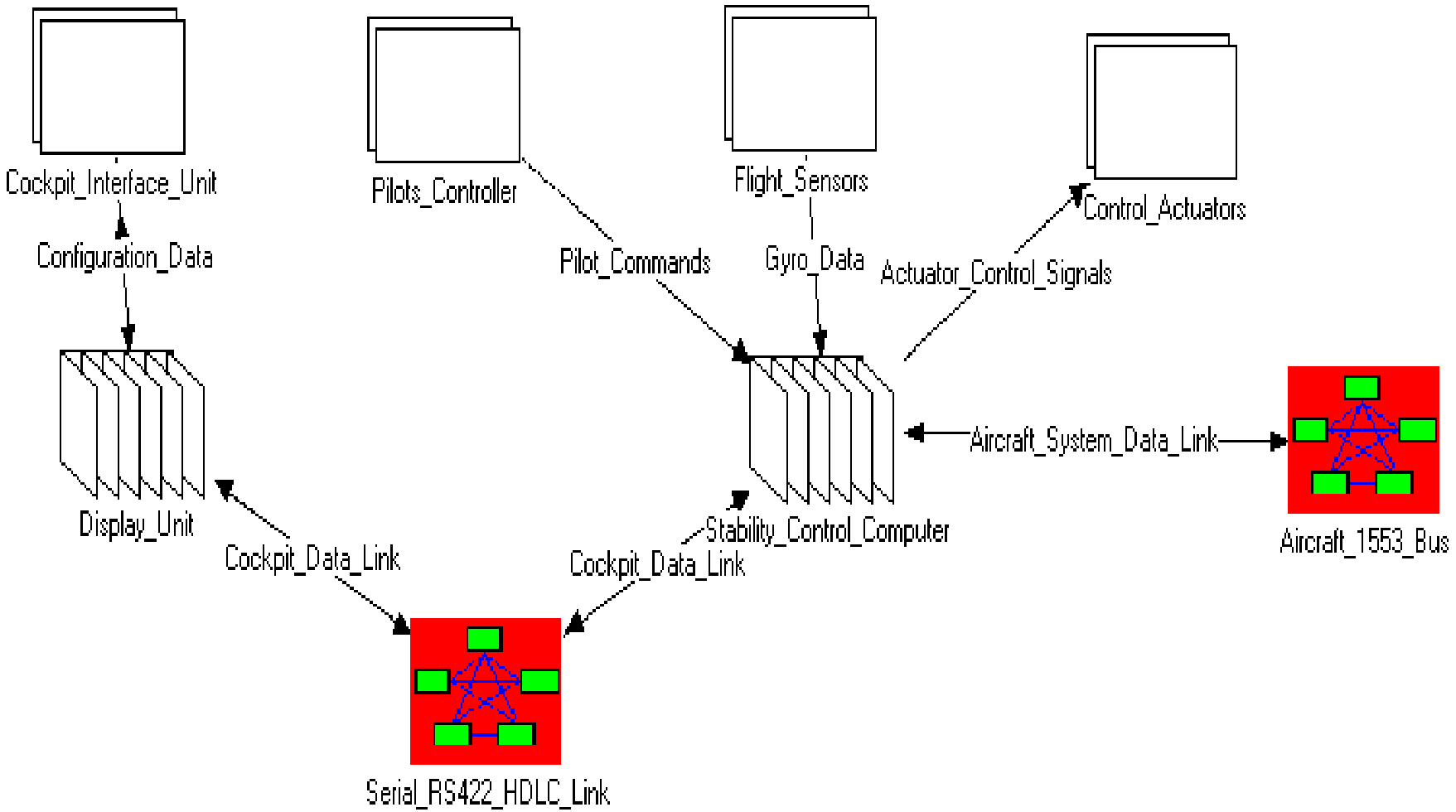


Overall Diagram Set

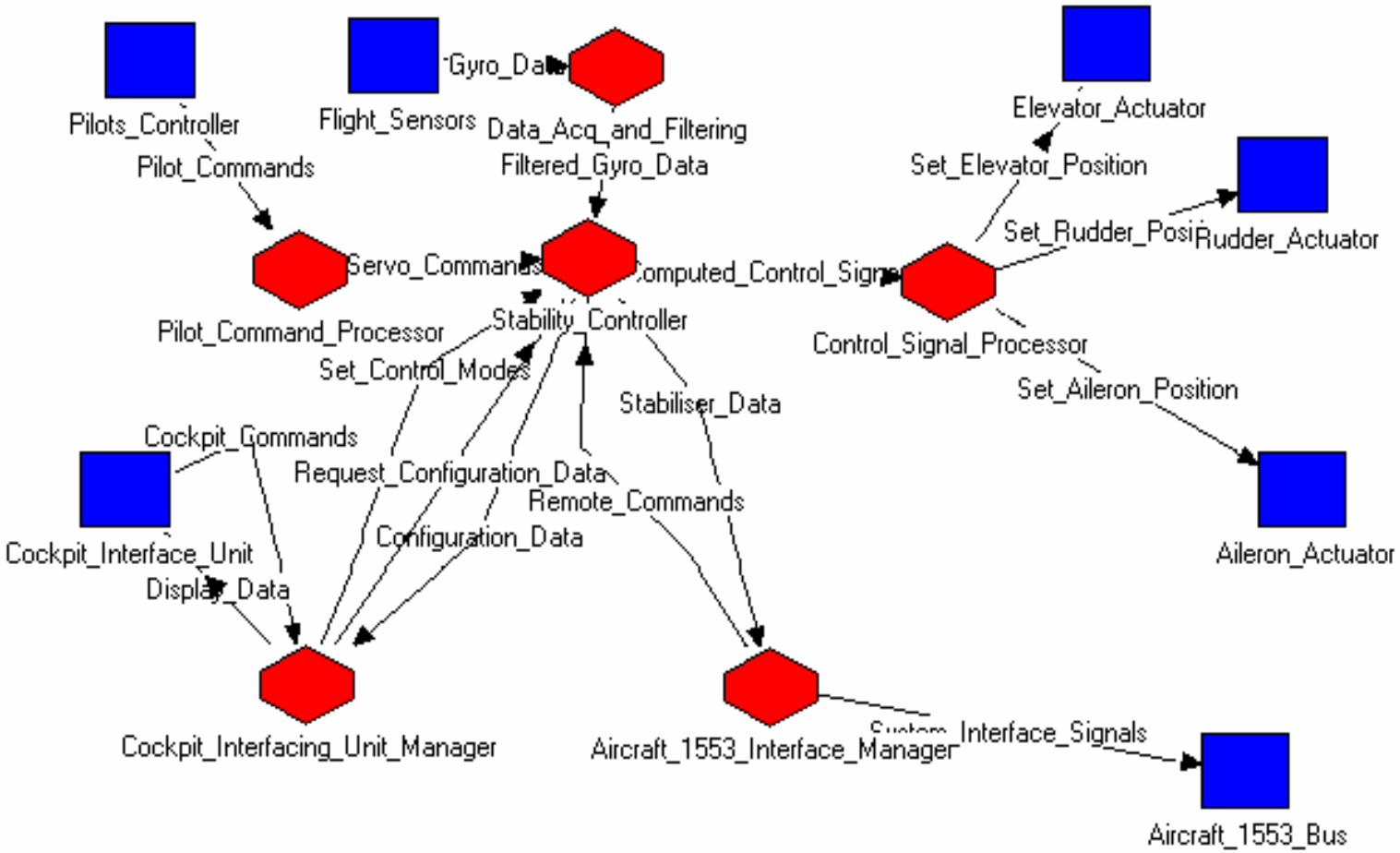


Relationship between Diagrams

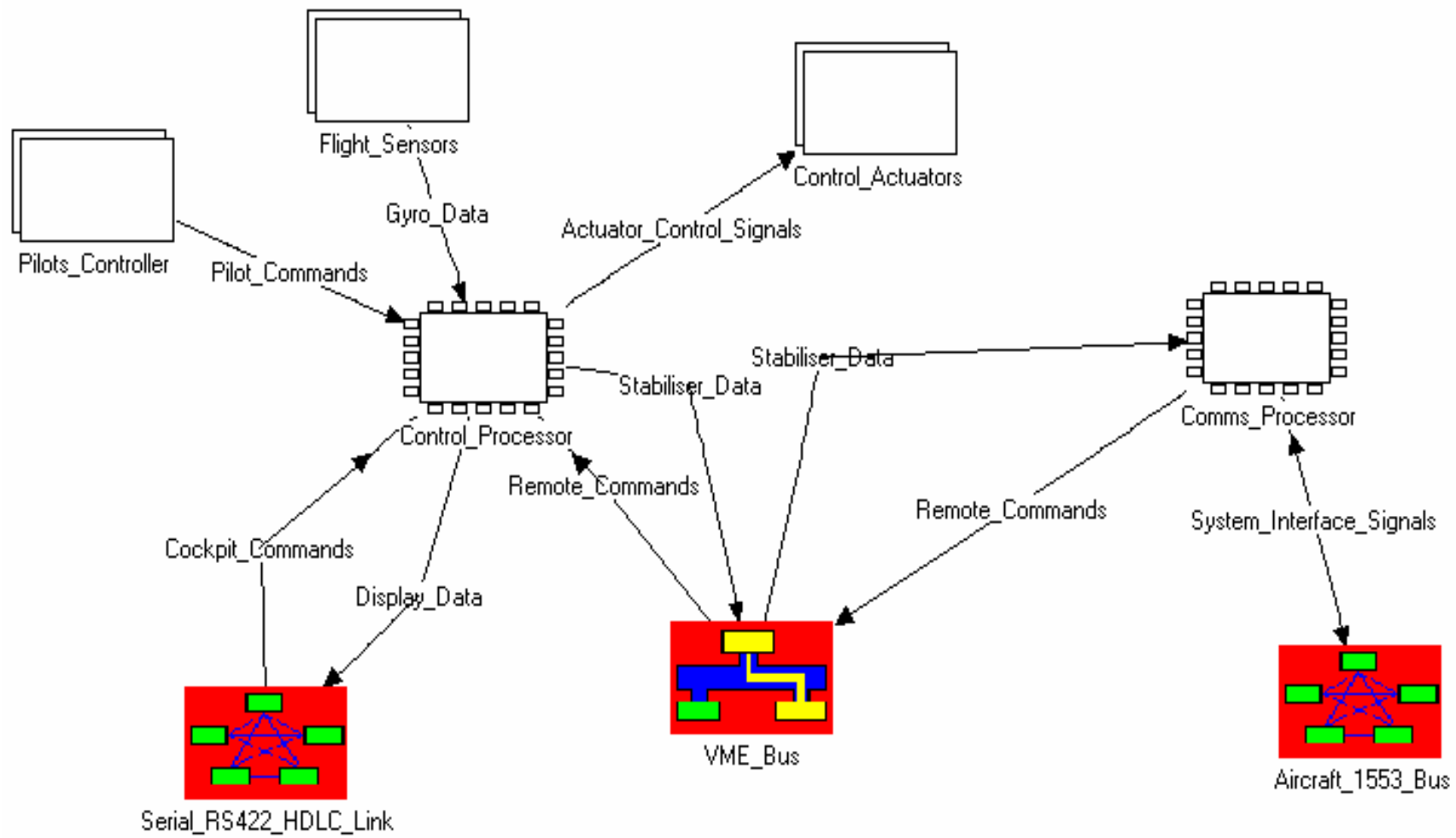
System Architecture Diagram



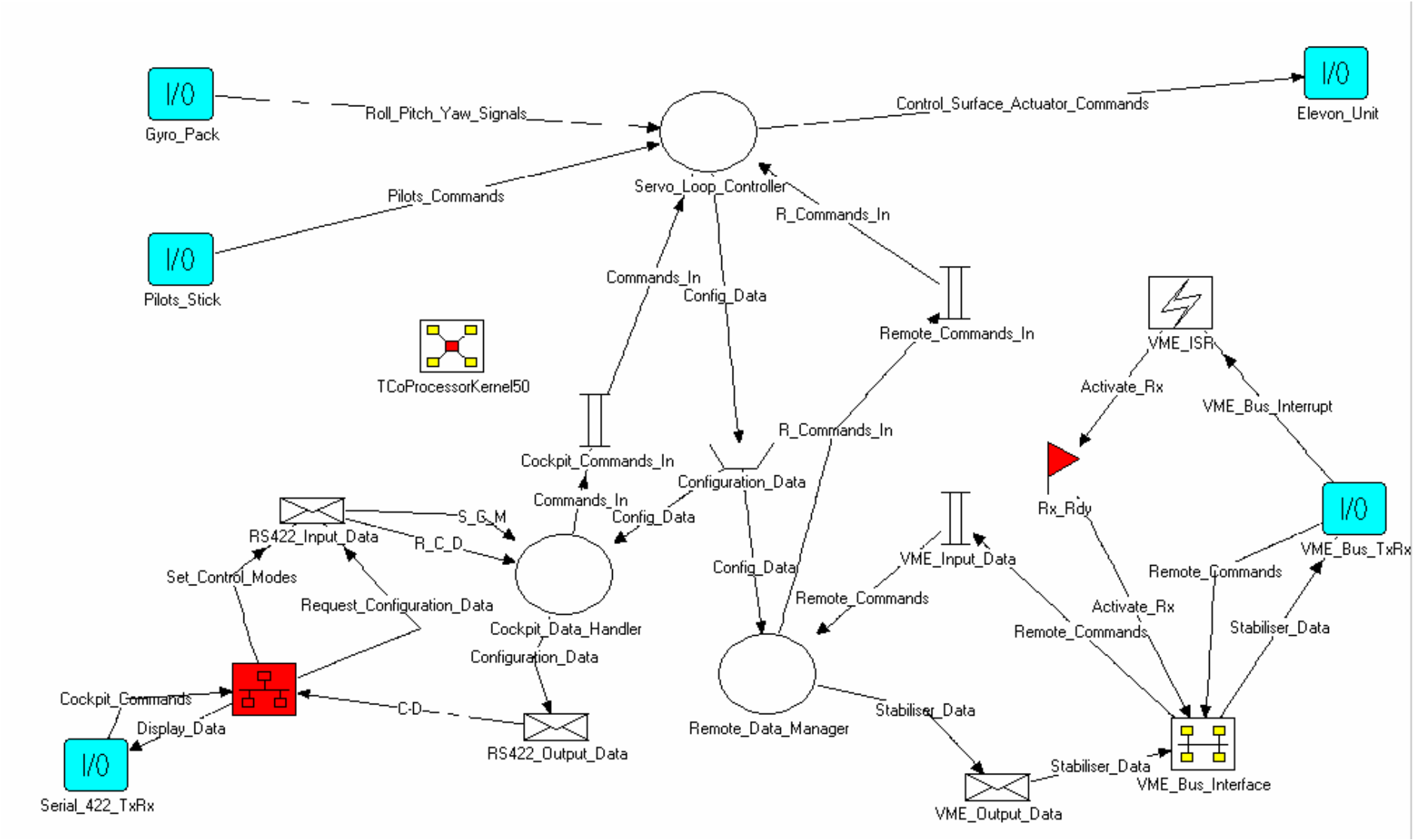
System Software Diagram



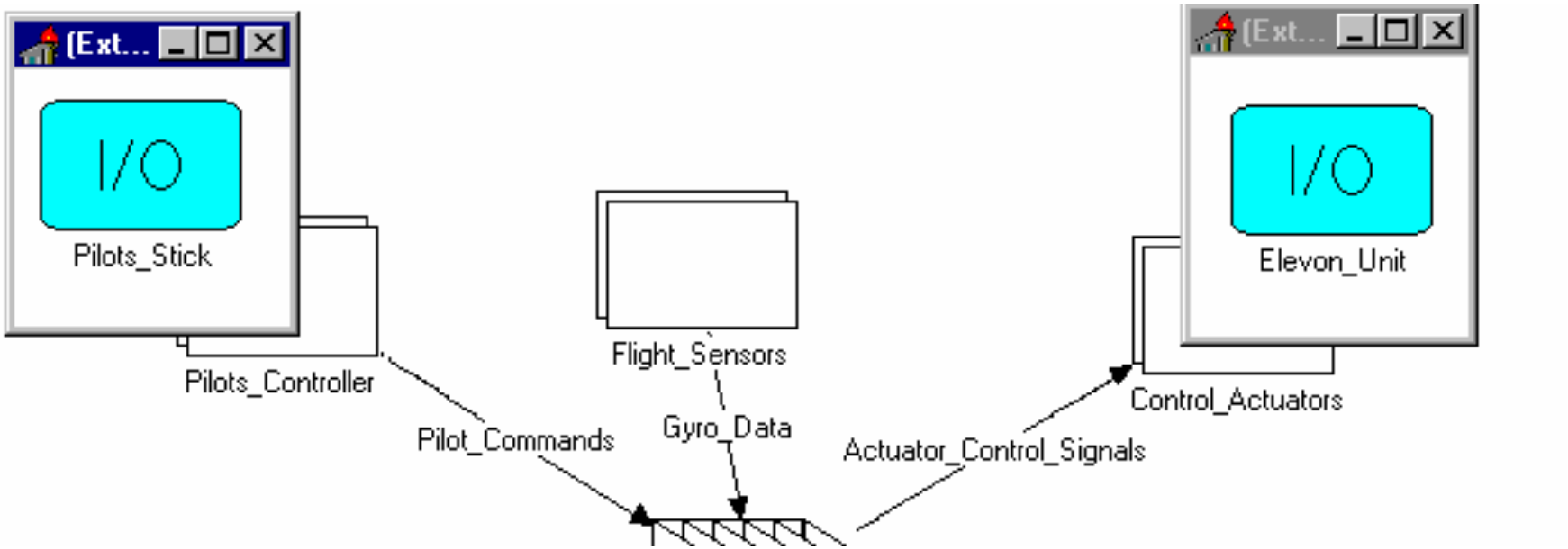
Node Architecture Diagram



Tasking Diagram



I/O Device Diagram



REINDEER

AN INTEGRATED DESIGN APPROACH FOR REAL-TIME SYSTEMS

- An overall integrated design method capable of dealing with multiple-processor, multiprocessor and single processor configurations (including combinations of such configurations).
- A means to partition software across such configurations, including specific techniques for the design of multitasking software.
- The application of simulation techniques for performance modelling and prediction in such a variety of configurations.
- The ability to select scheduling policies (e.g. priority preemptive, rate monotonic, etc.) in order to provide optimum performance in a multitasking environments.
- Facilities to handle low-level processor-specific features such as interrupt handling as an integral part of the design method.
- Features to incorporate co-design techniques (for the design of ASICs, PLDs, etc.) into the design process.