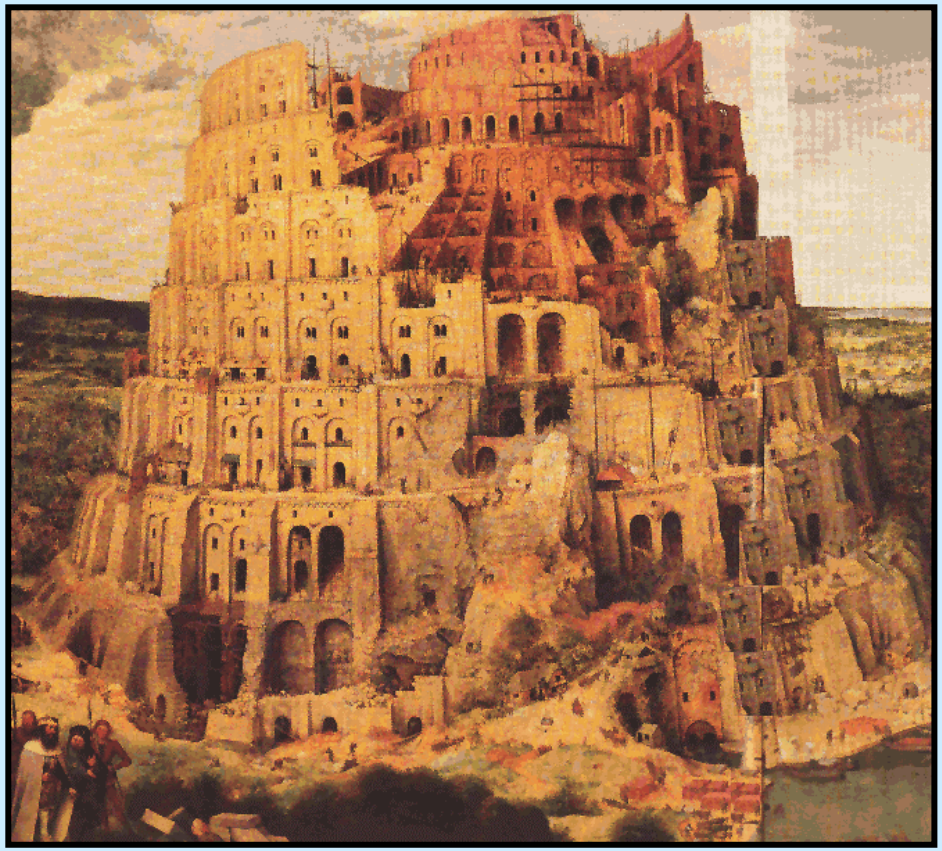
Complex Systems



Tower of Babel, in painting by Bruegel, 1563

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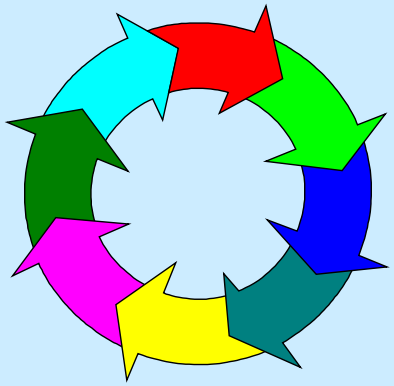
The Problem

- **Cost of system integration**
  - brittleness with new components or capabilities
  - inability to evolve/adapt
  - overdesign for decoupling
  - risk of emergent behavior
  - can't design some systems

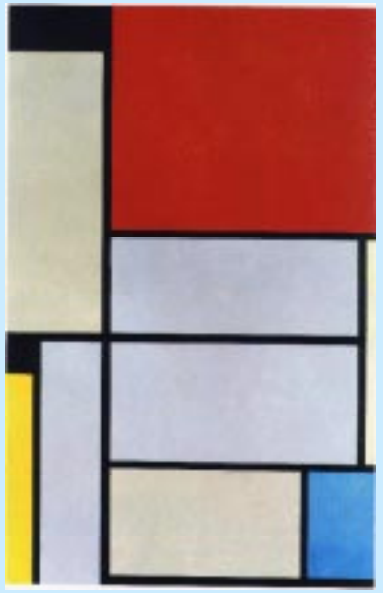


- **Missing technology**
  - recomposition
  - more complete modeling
  - managing heterogeneity

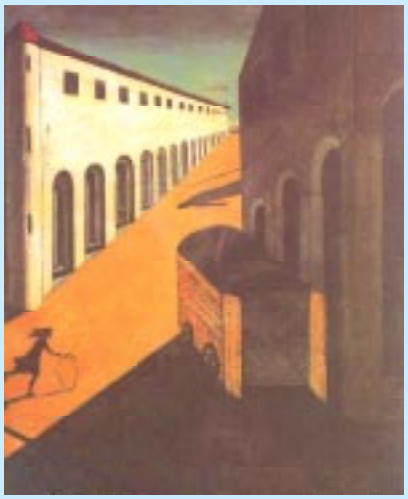
The Study in January

- The use of abstraction





- Modeling in an artificial universe



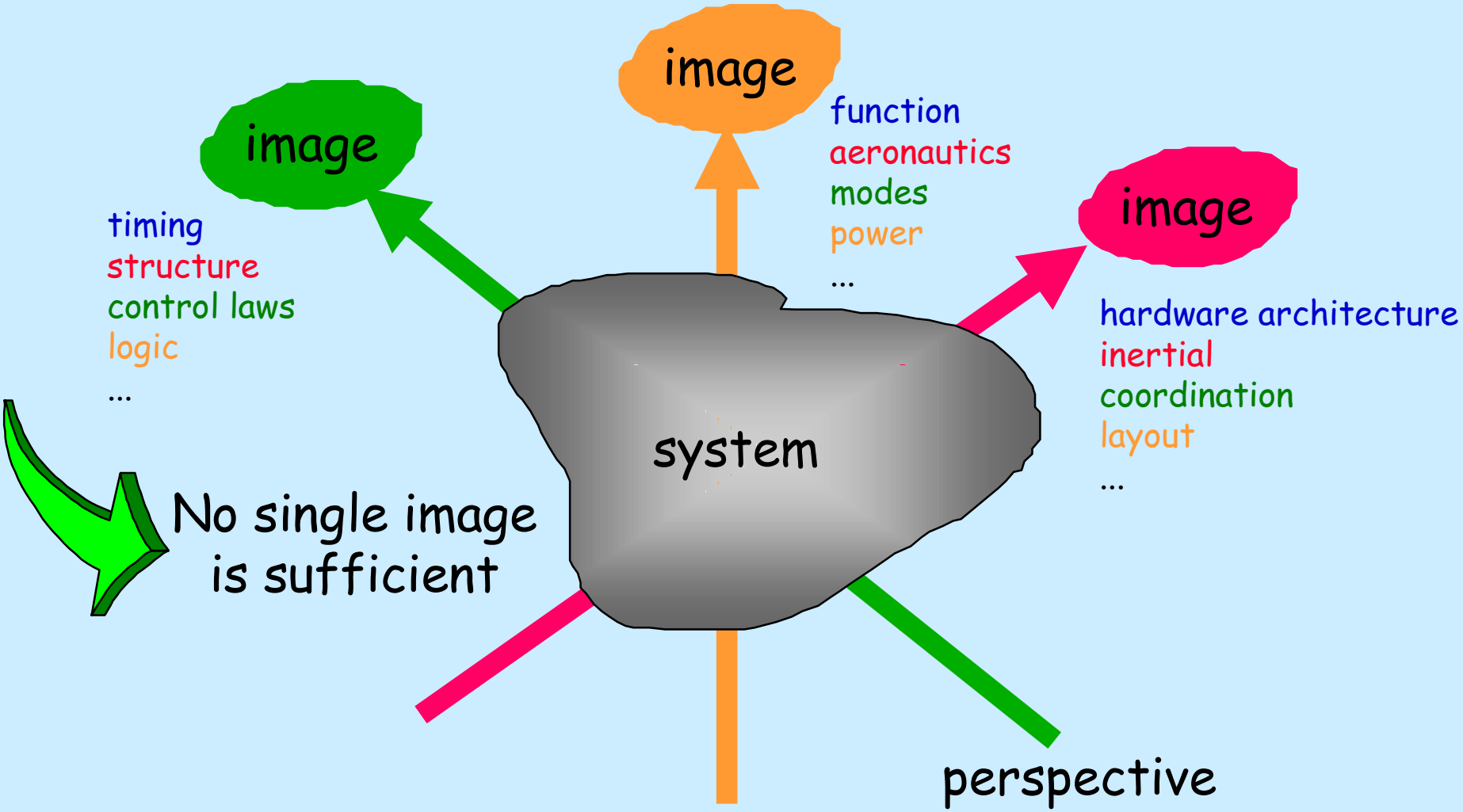

The Study in May

- Heterogeneous modeling
- Metamodeling (models of modeling techniques)
- Formal models

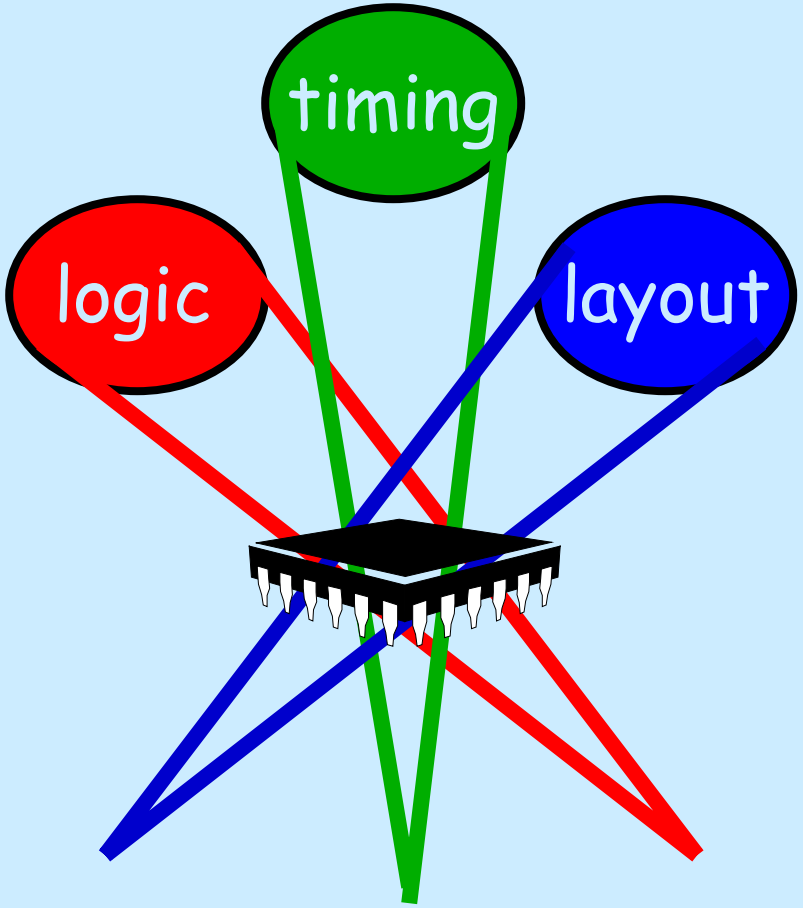
Validation is not about "proving correctness" but rather about finding flaws early.

August - Perspectives on a System

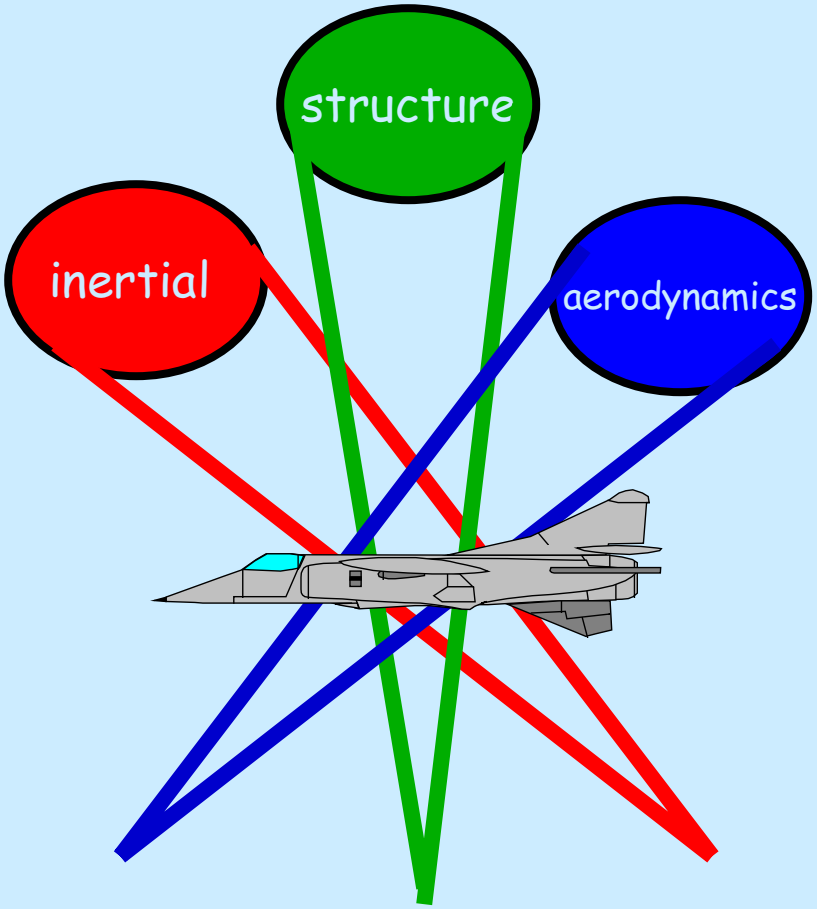
Designers, users, maintainers interact with images



Examples of Increasing Coupling



Deep submicron increases coupling



High performance increases coupling

Fixed Points

"slow variants" - Images that Last

- Physical Platform
- Hardware Architecture
- Communication formats
- Standards
- Operating systems

- **Faster variants:**
  - **mission** (e.g., Intel x86 mission has changed drastically several times)
  - **components** (e.g. Every piece of your computing environment has been replaced several times)

How do you design a system with a 20 year life span whose components change every few months?

Current Design Methodology

- Perspectives are not chosen
- Images are created in isolation
- Integration is by prototyping or simulation
- Fixed points are accidental

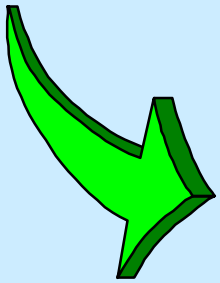
Cost:

- financial
- reduced functionality
- loss of performance
- schedule slip
- loss of flexibility/adaptability

Better Methodology: *Frameworks*

Theory and techniques that relate multiple perspectives

- helps select perspectives
- institutionalizes fixed points
- helps compose multiple perspectives
- helps track dependencies across perspectives



A framework *does not* subsume perspectives (it is *not* a grand-unified theory of everything!)

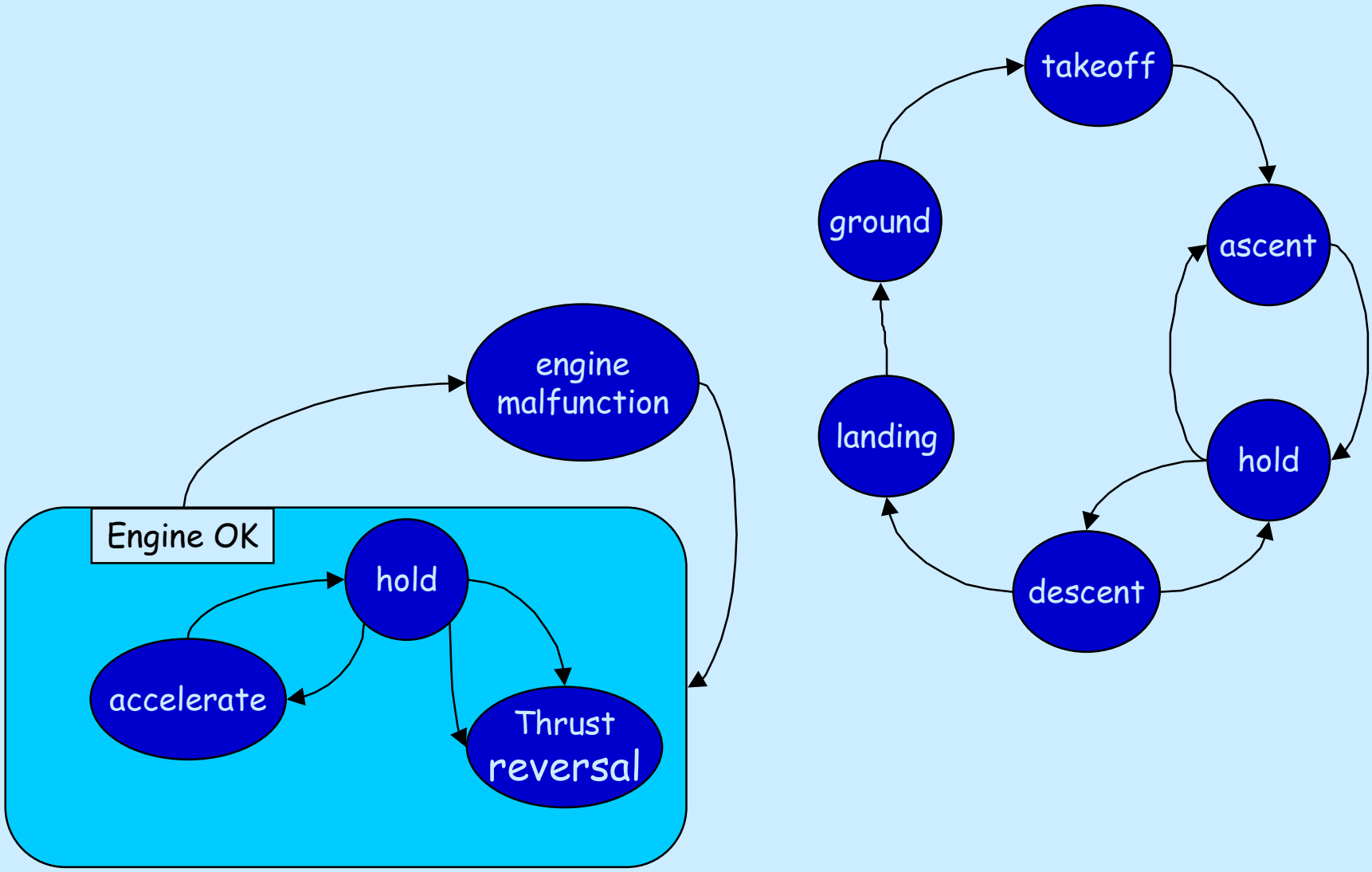
Framework Research

To develop theory and techniques supporting the use, coordination, and integration of multiple perspectives.

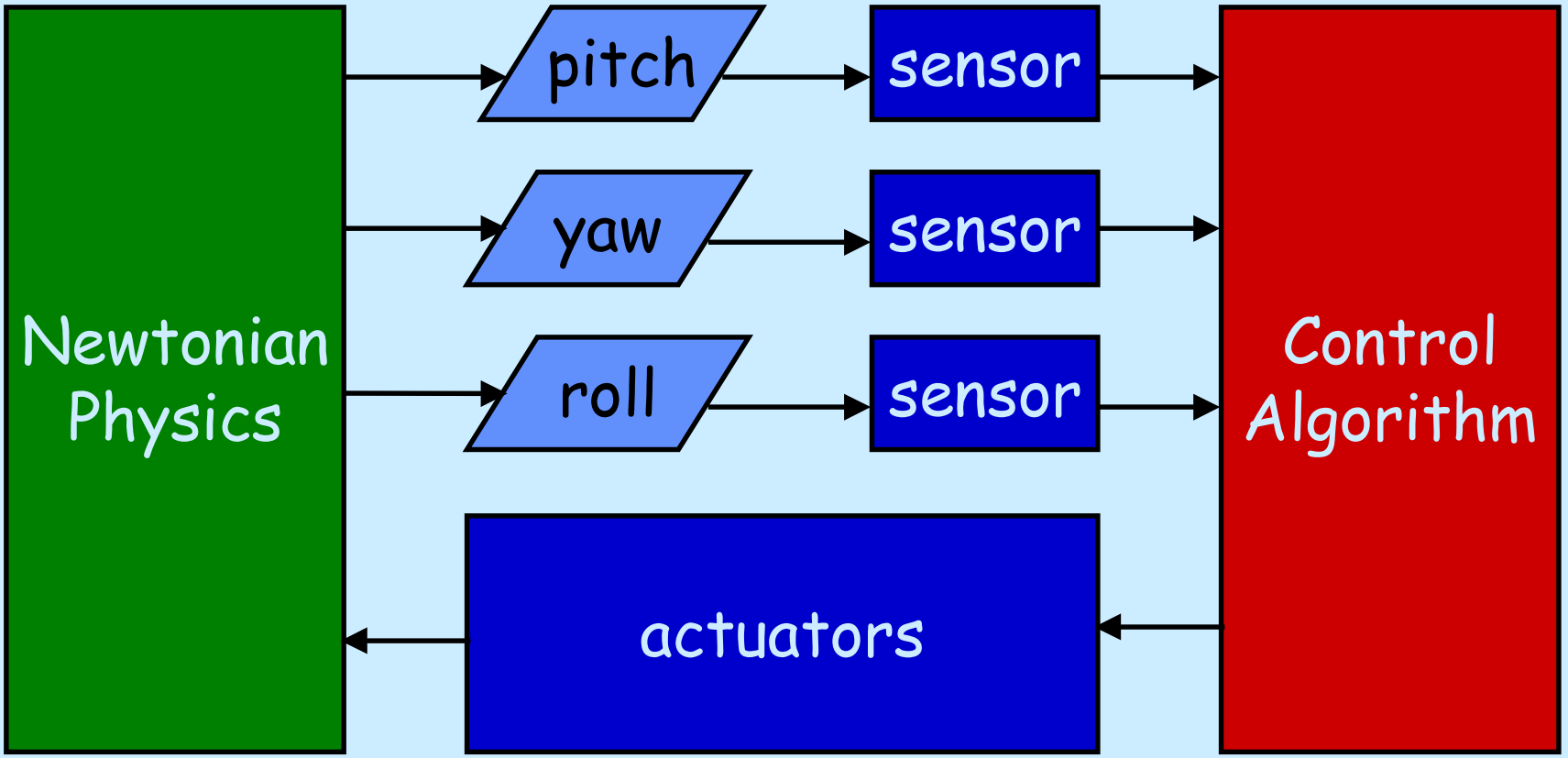
Aviation Scenario

- **Avionics**
  - Flight control
  - Guidance
  - Navigation
  - Sensors, ...
- **Mission control**
- **Aerodynamics**
- **Structure**
- **Propulsion**
- **Coordination**

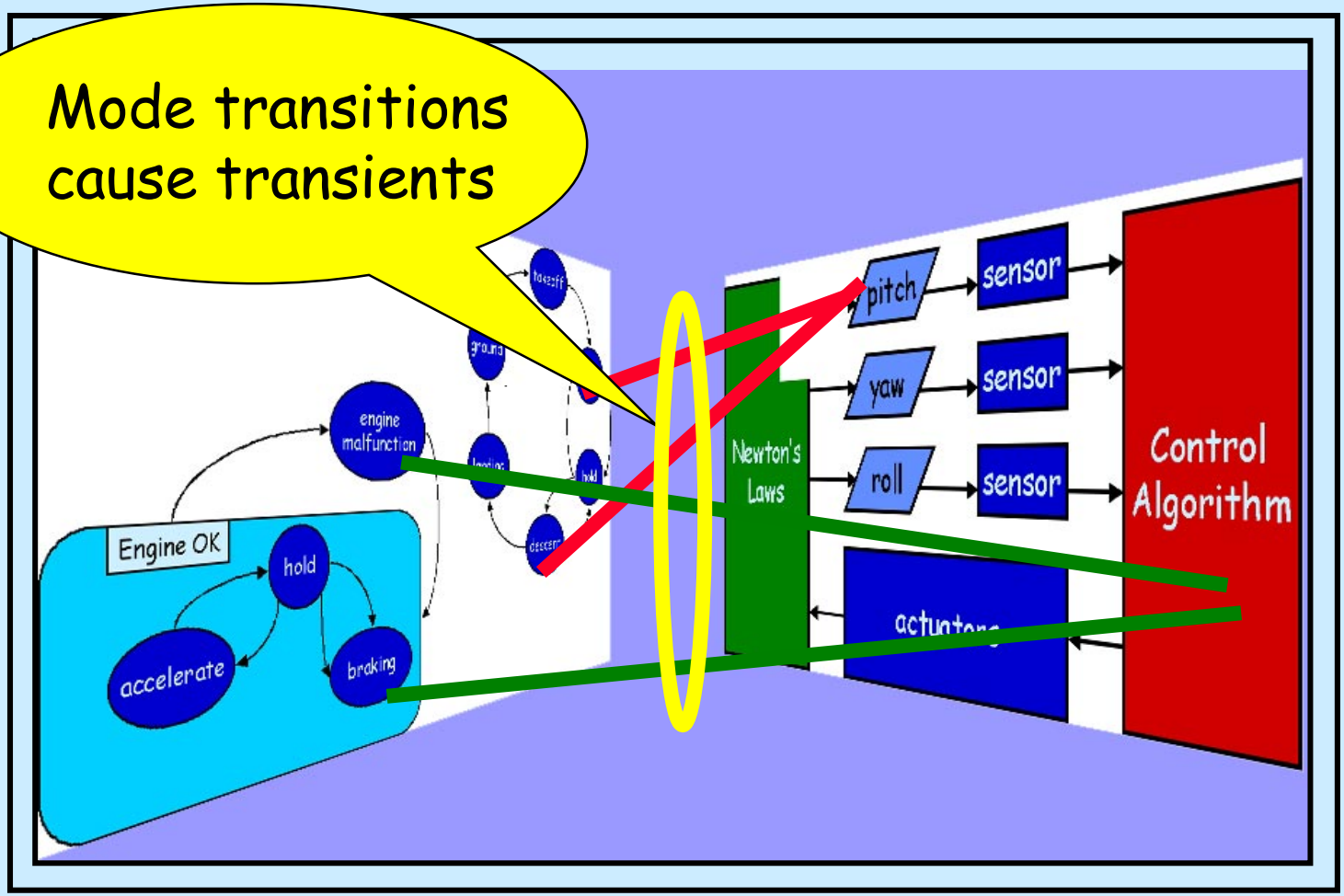
Modal Image


takeoff
ground
ascent
engine
malfunction
landing
hold
descent
Engine OK
hold
accelerate
Thrust
reversal

Control Image

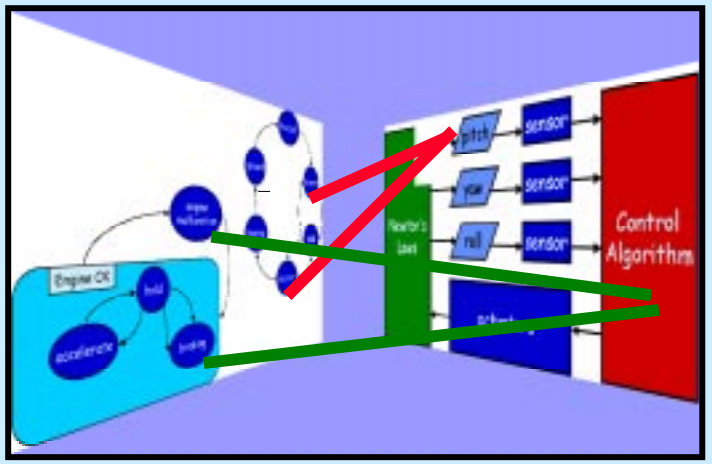


Modal and Control Images Are Related



Framework

A framework that composes modes and control permits the study of mode transients and stability in mode transitions.

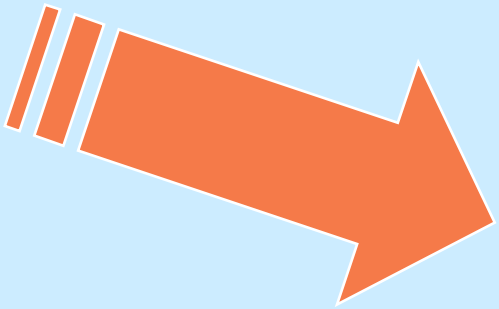


Today's "framework" is a test plane

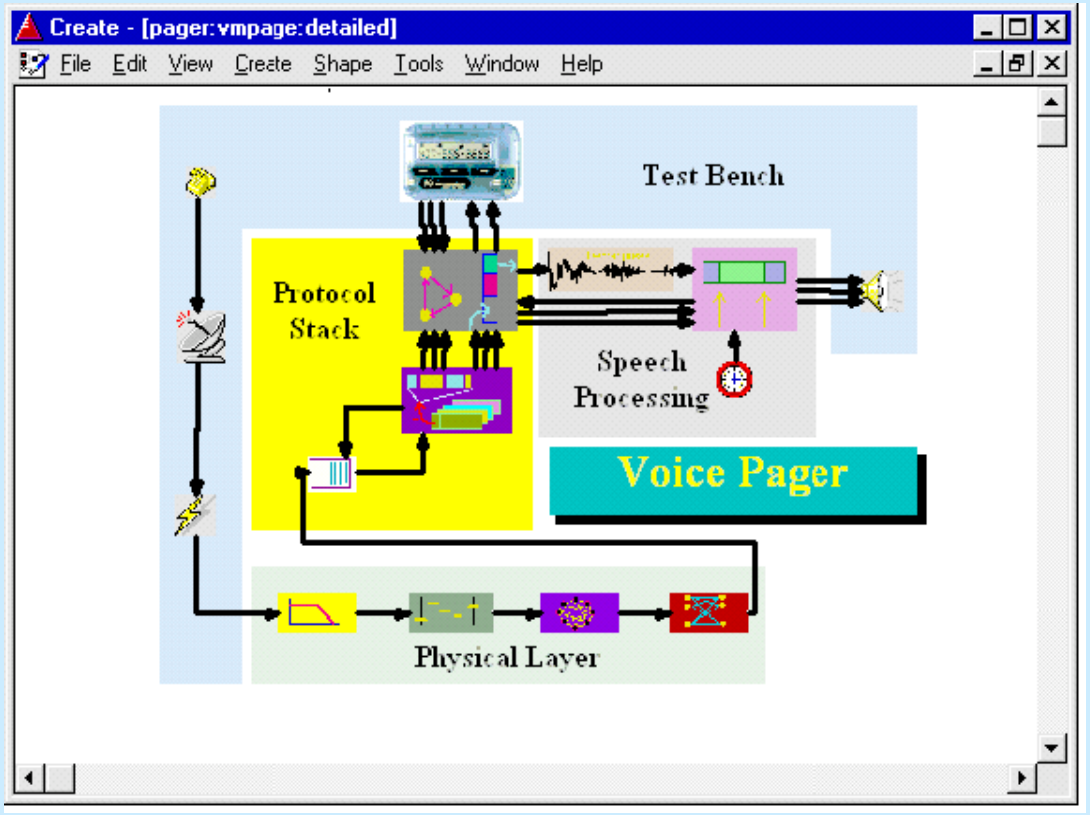
So called "Hybrid systems" and related software provide the beginnings of a more formal framework supporting this particular combination.

Voice Pager Scenario

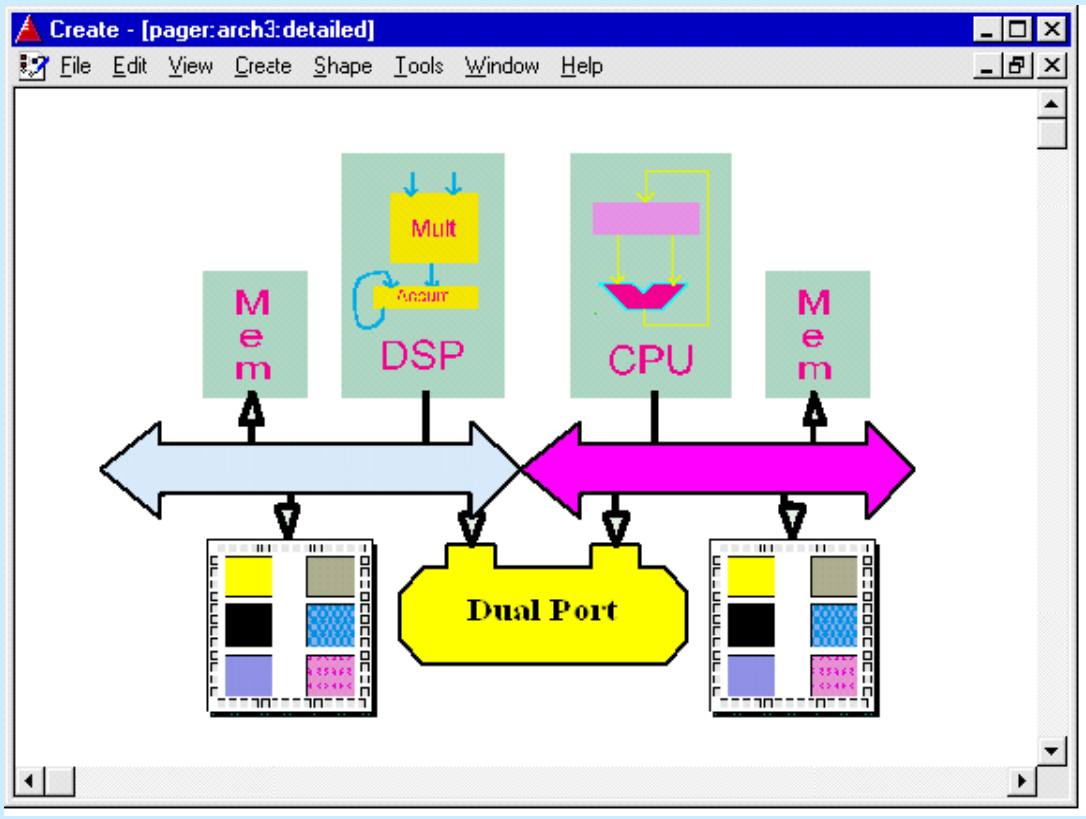
- Deliver messages asynchronously
- Entire system: base, pager
- Users can listen when able
- Decompression on playback



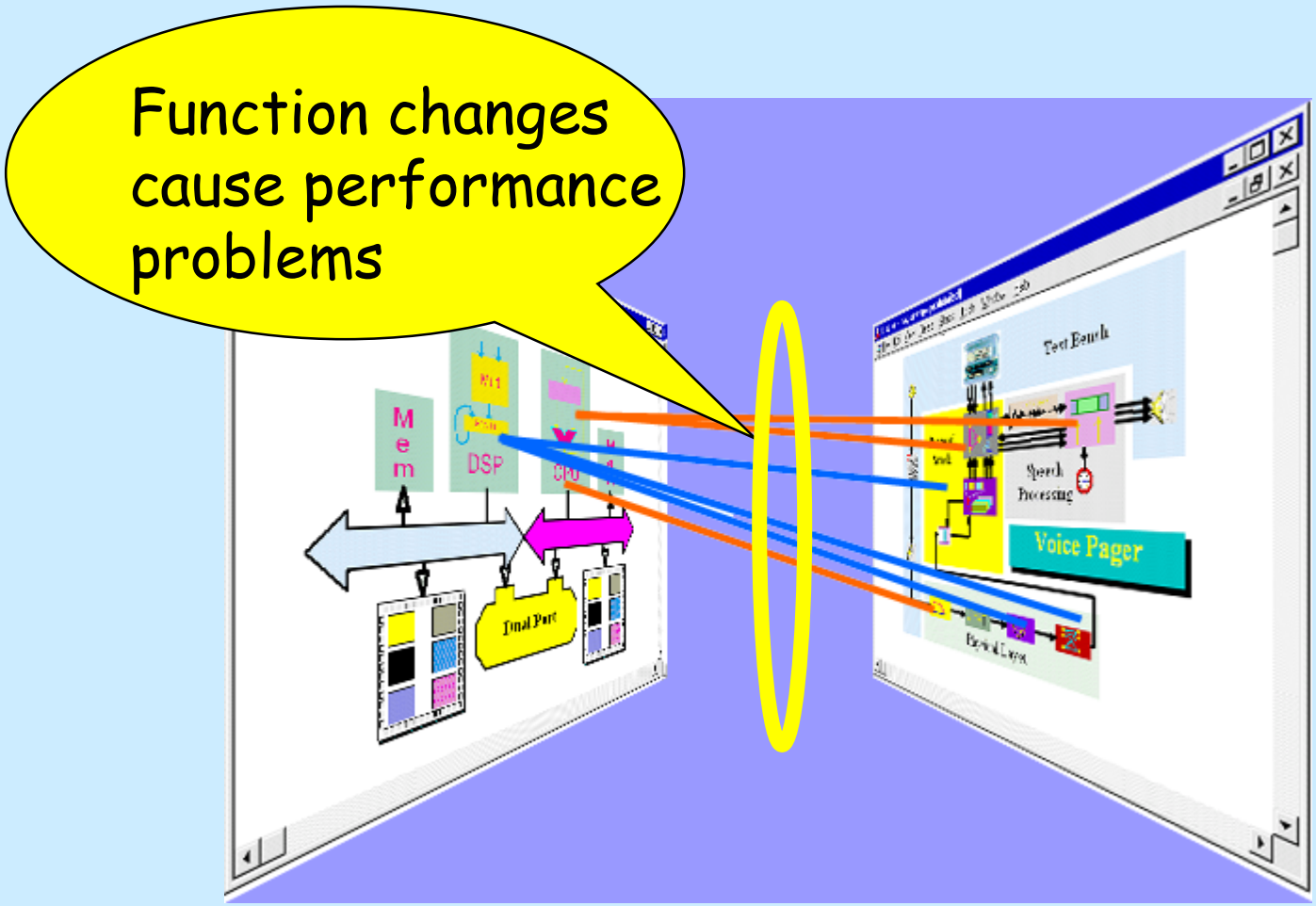
Functional Perspective



HW Architecture Perspective

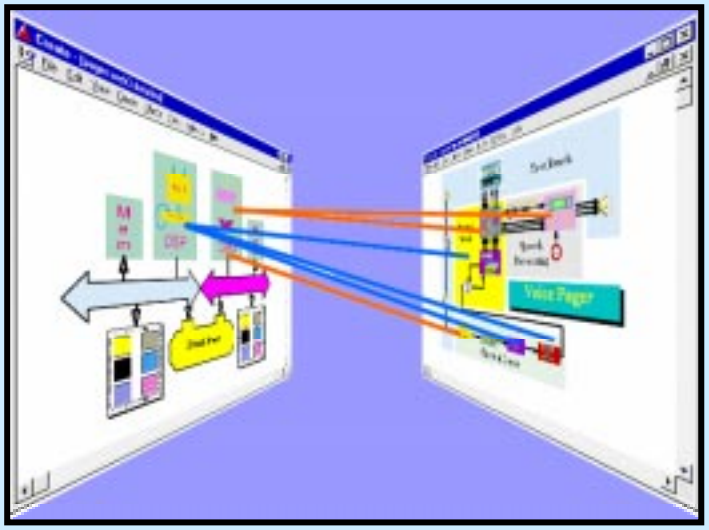


Function and Architecture Are Related



Framework

A framework that composes hardware architecture and functionality permits the study of capacity/performance tradeoffs.

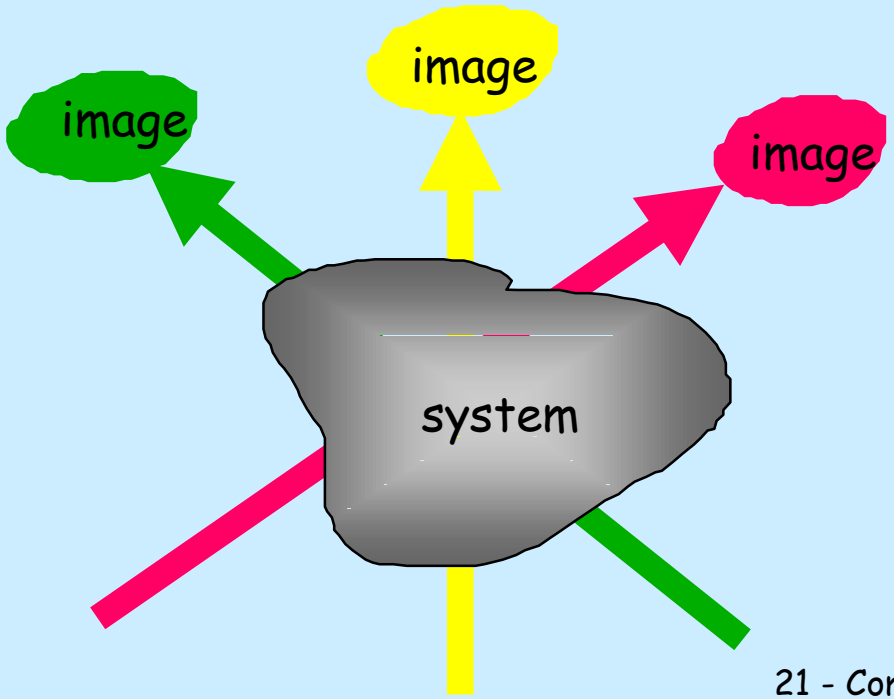


Today's "framework" is a hardware prototype.

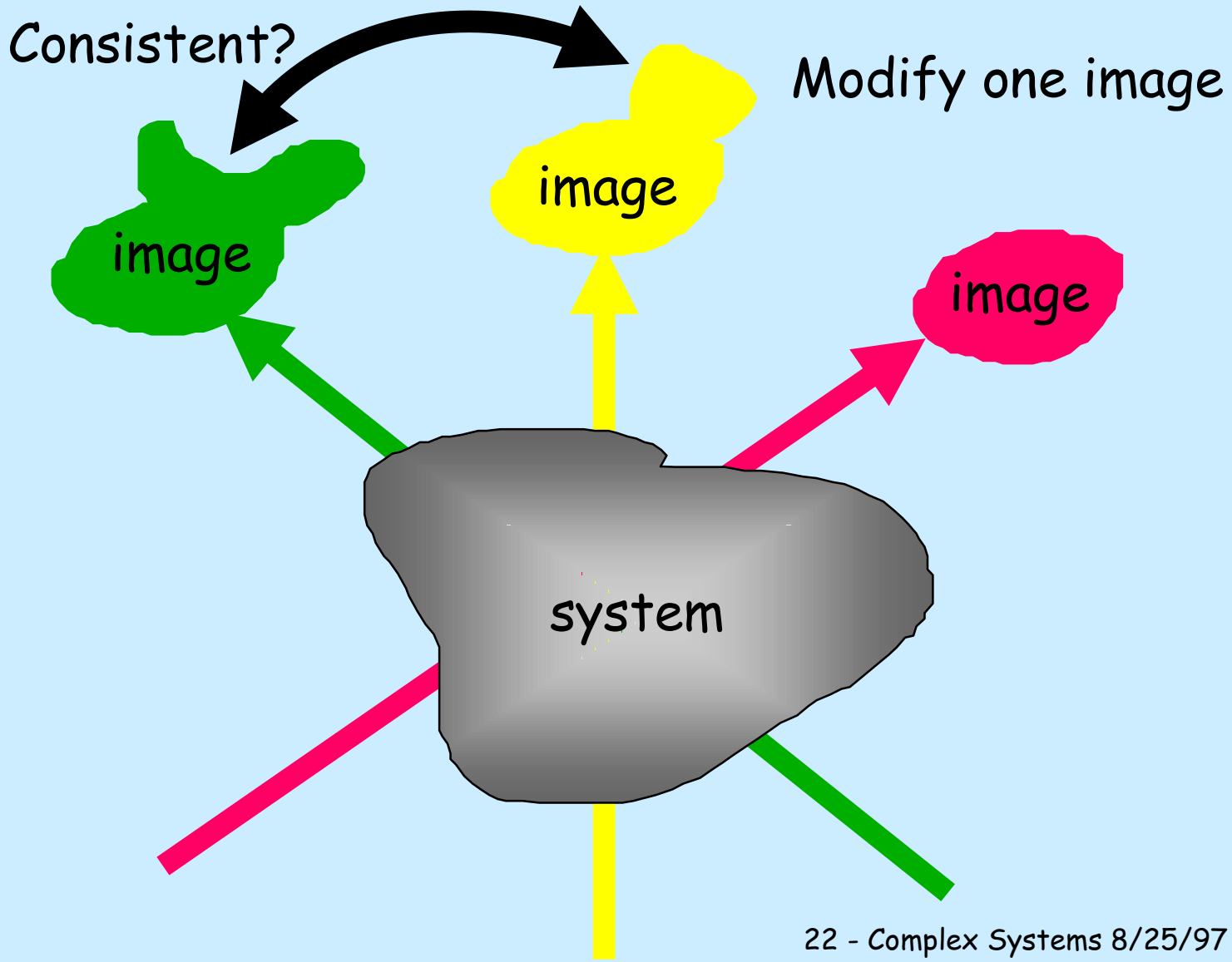
So called "system-level design tools" in VLSI CAD provide the beginnings of a framework supporting this particular combination.

Framework Research

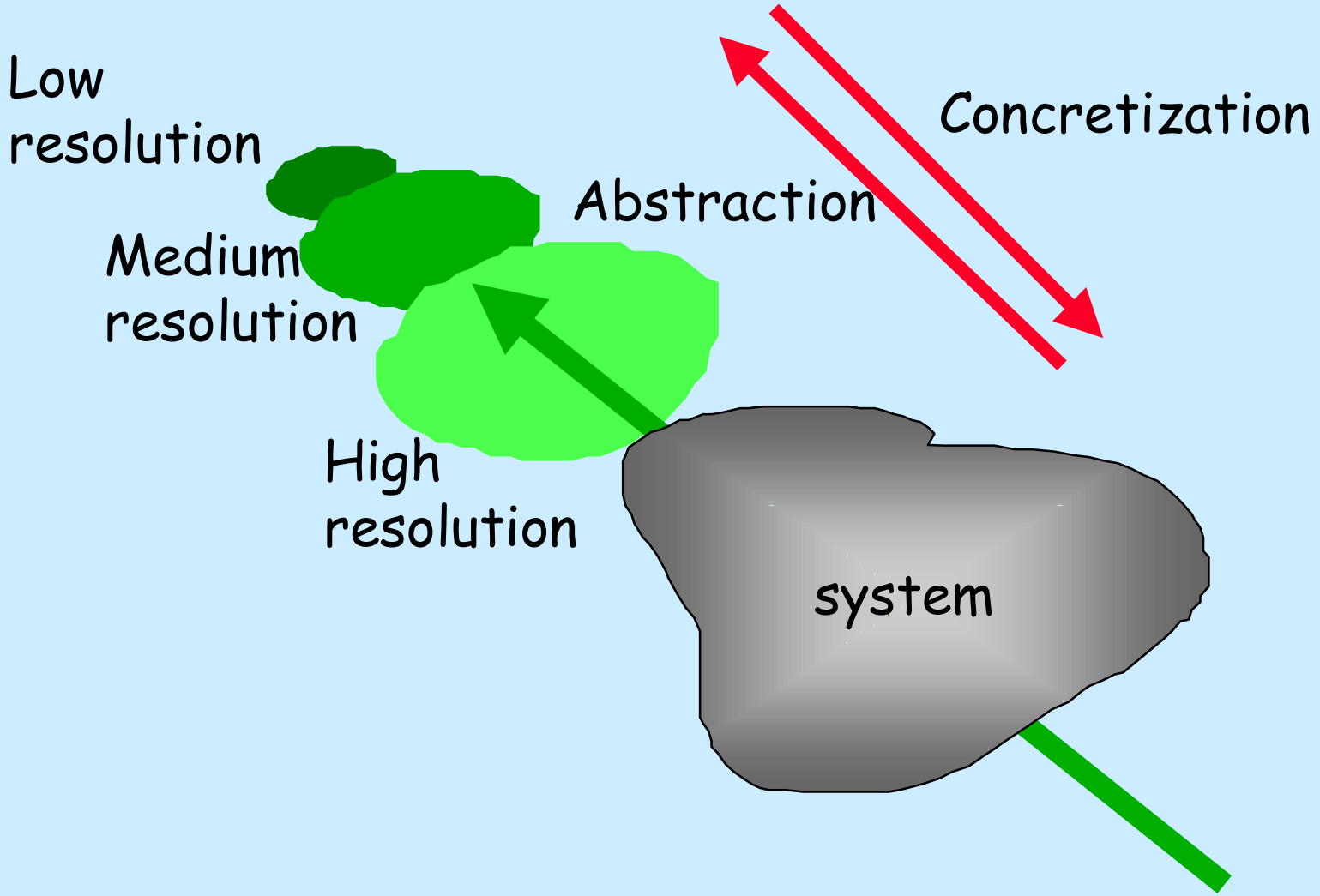
To develop theory and techniques supporting the use, coordination, and integration of multiple perspectives.



Interactions

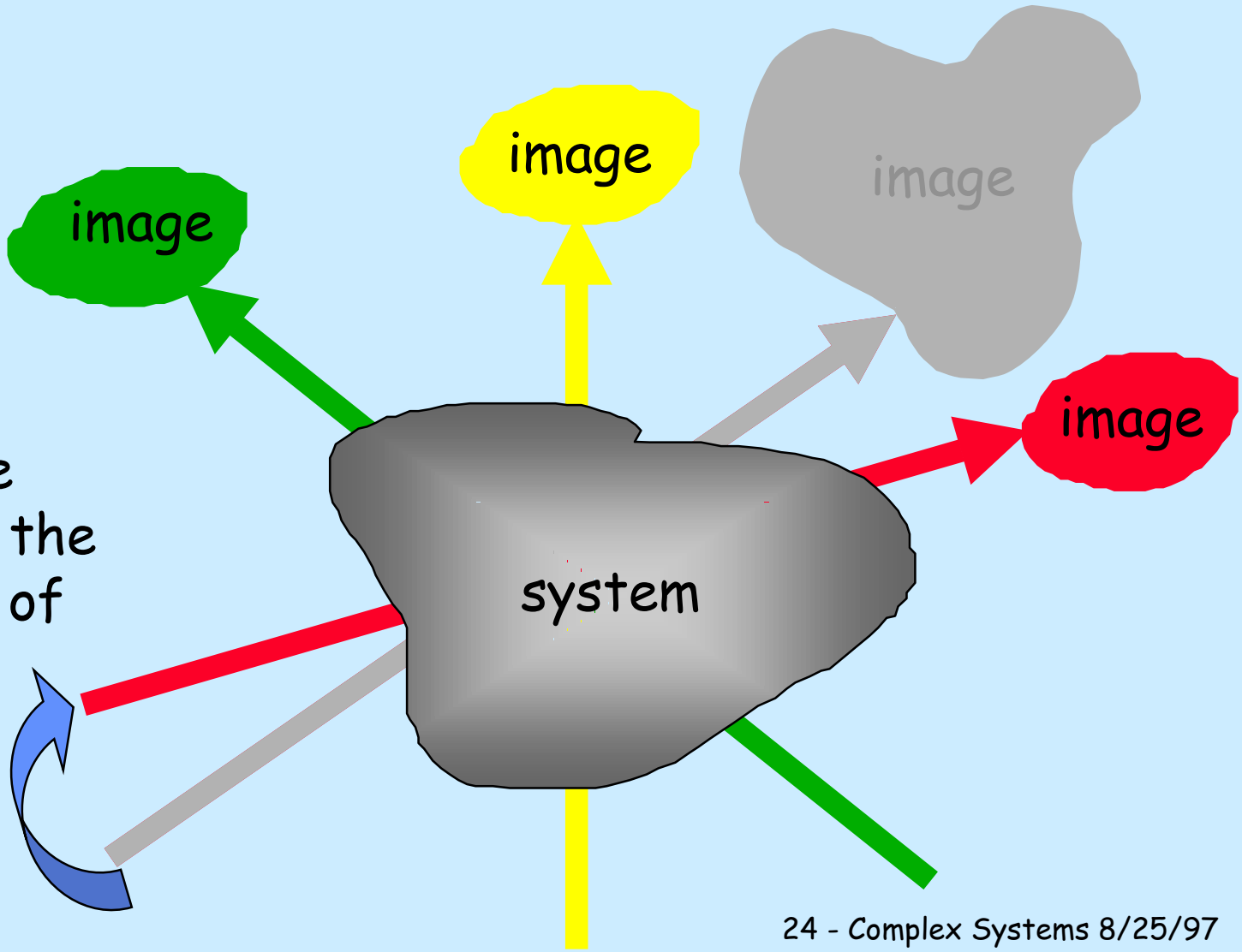


Abstraction



Choosing Perspectives

Shift in perspective can reduce the complexity of an image



Framework Benefits

- **Rapid, ongoing system integration**
  - Incremental design
  - More analysis, less prototyping & experimentation
- **Design for robustness & stability**
  - Choose perspectives that minimize interdependencies
  - Use framework to understand implications of remaining interdependencies
- **Design for adaptability**
  - Base design on perspectives that are relatively unchanging (fixed points), leaving others in which adaptation will take place

Why Now?

We Have Guideposts

- **Emerging frameworks**
  - Multi-paradigm modeling languages (e.g. UML)
  - Interface-based design (e.g. Felix)
  - Heterogeneous simulation environments (e.g. Ptolemy)
  - Spreadsheet design (e.g., power implication frameworks)
  - Hybrid systems environments (e.g. HyTech)
  - Geometric integration environments (e.g. CATIA)
- **Architectures based on conscious choice of fixed points**
  - Virtual machines
  - ASIPs, ORBs, MPEG4

Why Now?

- Industry culture sustains isolated design perspectives
- Lack of theory and technology (standards, reusable tools, composition theories) perpetuates *ad hoc* design
- "Grand Unified Language"-s will make frameworks rigid and absolute instead of flexible