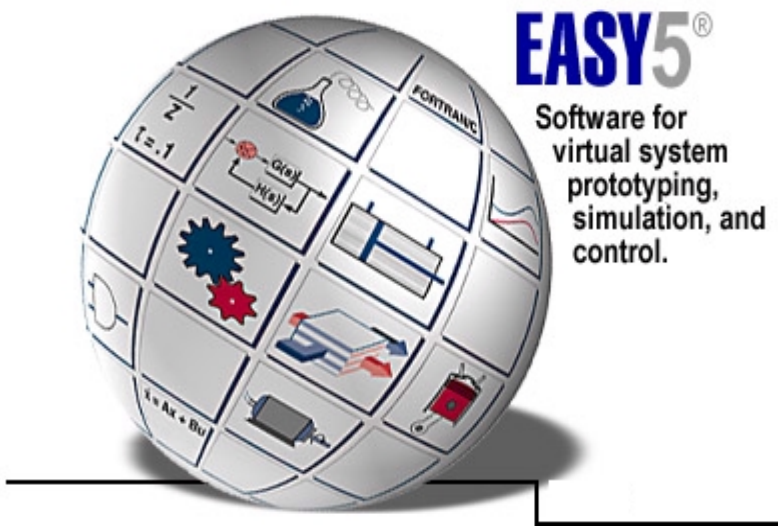


Integration of CAE Tools for Complete System Prototyping

2000 EASY5 User Conference

May, 2000

Presented by: Joel Tollefson

Presentation Focus

- **Provide a framework to support other presentations**
  - **define concepts**
  - **outline different methods for integrating CAE tools**
  - **survey current tools and practices**
- **Methods of integrating CAE tools**
  - **static data integration**
  - **co-simulation**
  - **coupled-simulation**
- **EASY5's Integration of Engineering Tools**

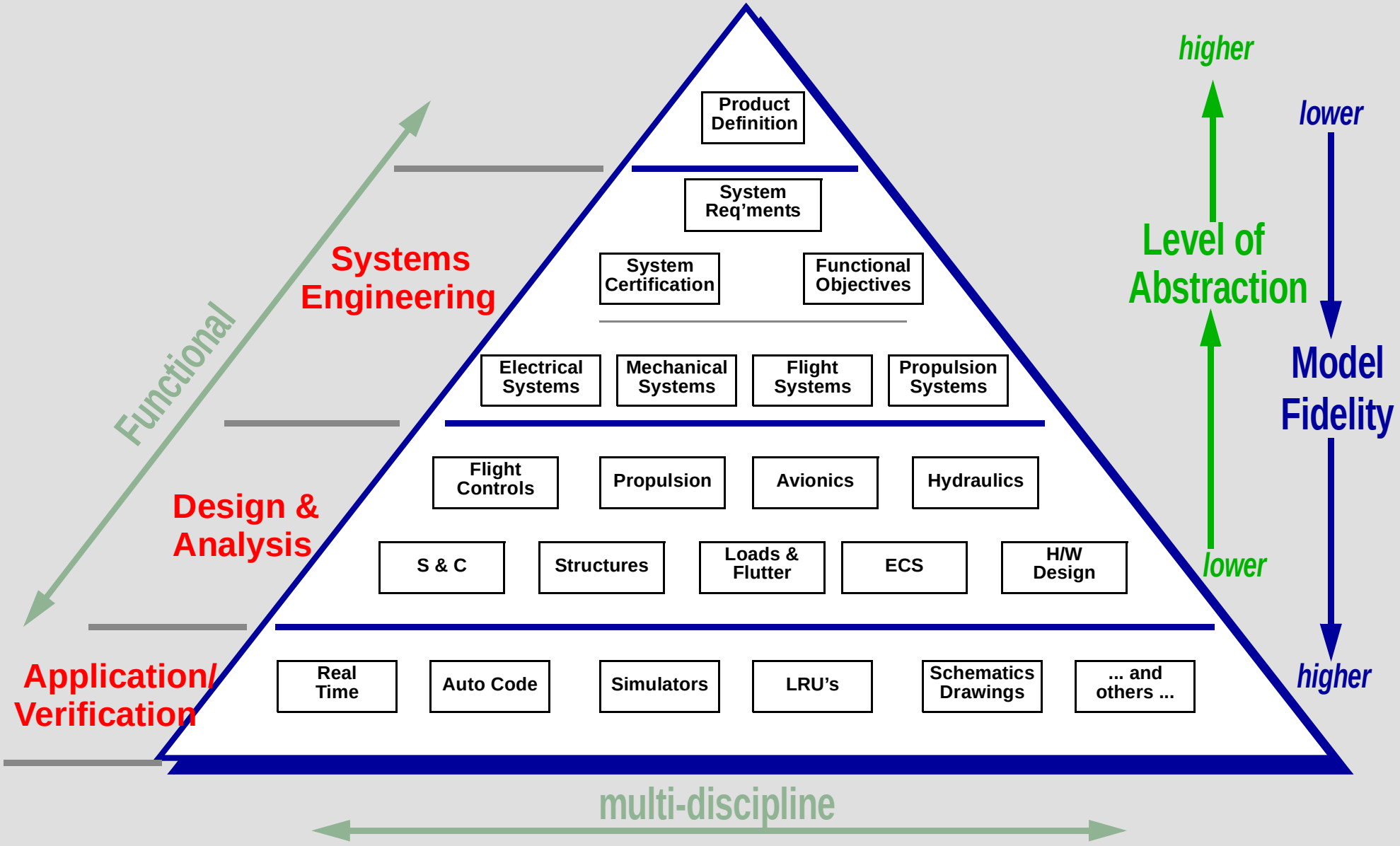
Introduction

EASY5

- **What's driving integrated systems modeling and engineering?**
  - need to be streamline engineering process: companies have many different engineering tools, methods and processes
  - goal: reduce time to market
  - promise: complete system prototyping
- **What is virtual system prototyping?**
  - modeling of entire systems, from systems level down to detailed subsystems
  - goal: produce a complete virtual system prototype - a computer model
  - use computer models to design, analyze, simulate, test entire system before "cutting metal"
  - prototype: increase design iterations, validate design, reduce h/w testing costs
- **Requirements for system prototyping**
  - ability to integrate systems modeling tools - apply broad array of computer-aided engineering (CAE) tools
  - create an integrated engineering environment

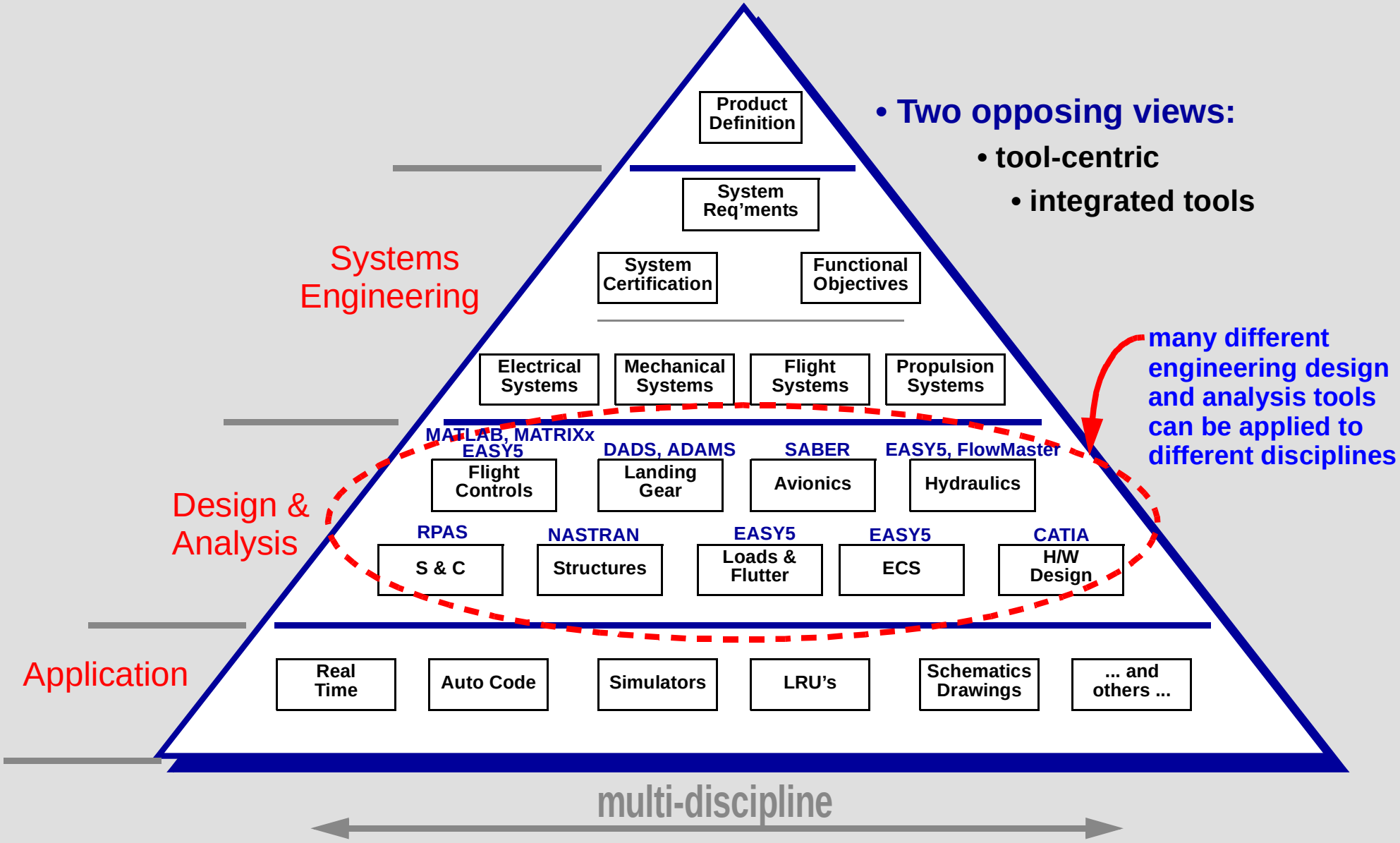
Overview of the Engineering Environment

EASY5



Selecting Design and Analysis Tools

EASY5



- **Two opposing views:**
  - tool-centric
  - integrated tools

many different engineering design and analysis tools can be applied to different disciplines

Survey of Design & Simulation Tools

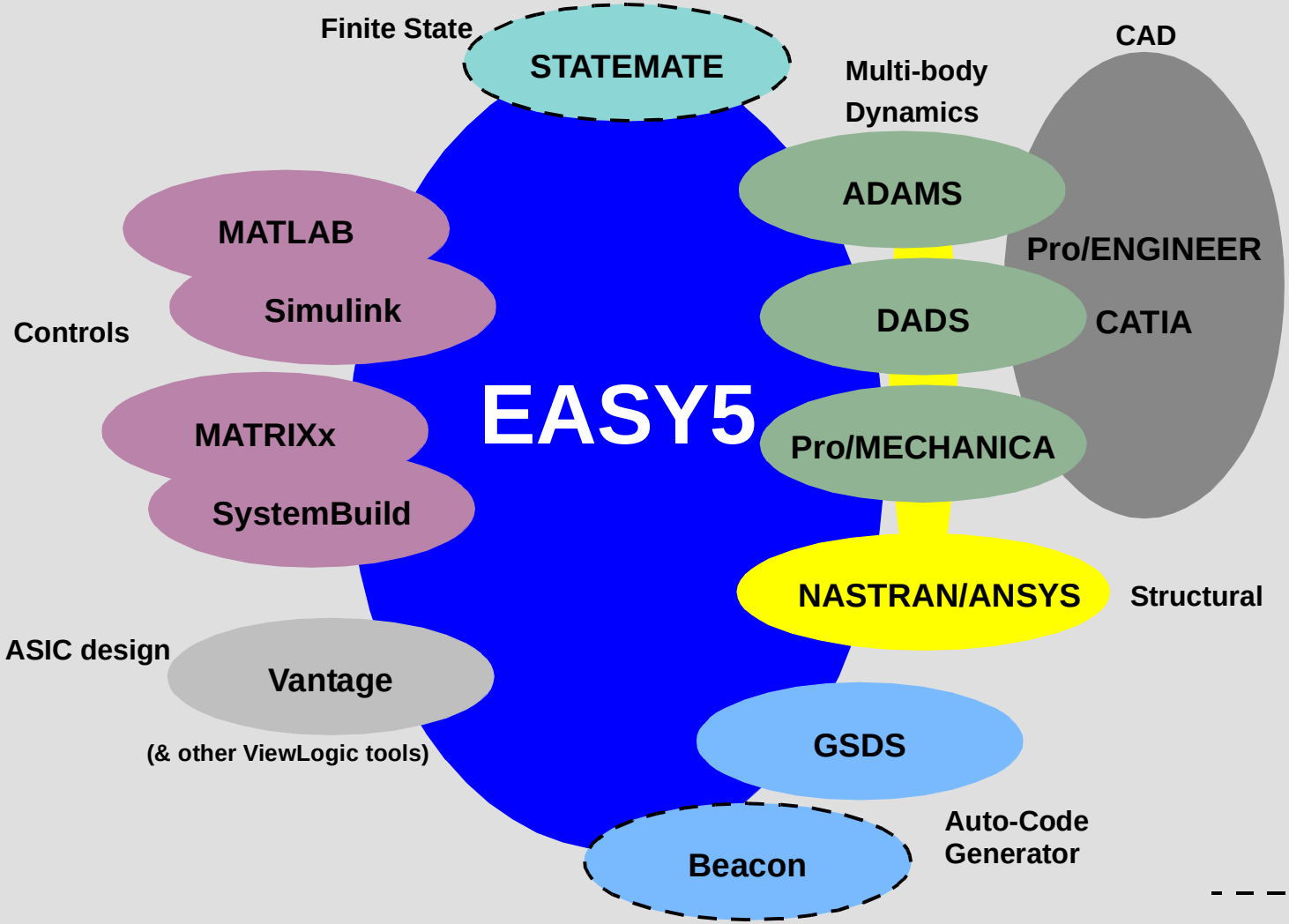
EASY5

Partial list of simulation-based tools

Engineering Disciplines	MATLAB	MATRIXx	EASY5	SABER	FlowMaster	ADAMS, DADS Pro/Mechanica	VANTAGE	STATEMATE
Controls								
Finite State	StateFlow	BetterState						
Mechanical								
Electric Circuits								
Integrated Circuits								
Electric Machinery								
Pneumatics								
Powertrain								
Hydraulics								
Auto-Code								
Real Time								

EASY5 Chose the Integrated Tools Approach

- Over 6 years of experience integrating CAE tools with EASY5.
- Tools are integrated using our “Extensions” feature.

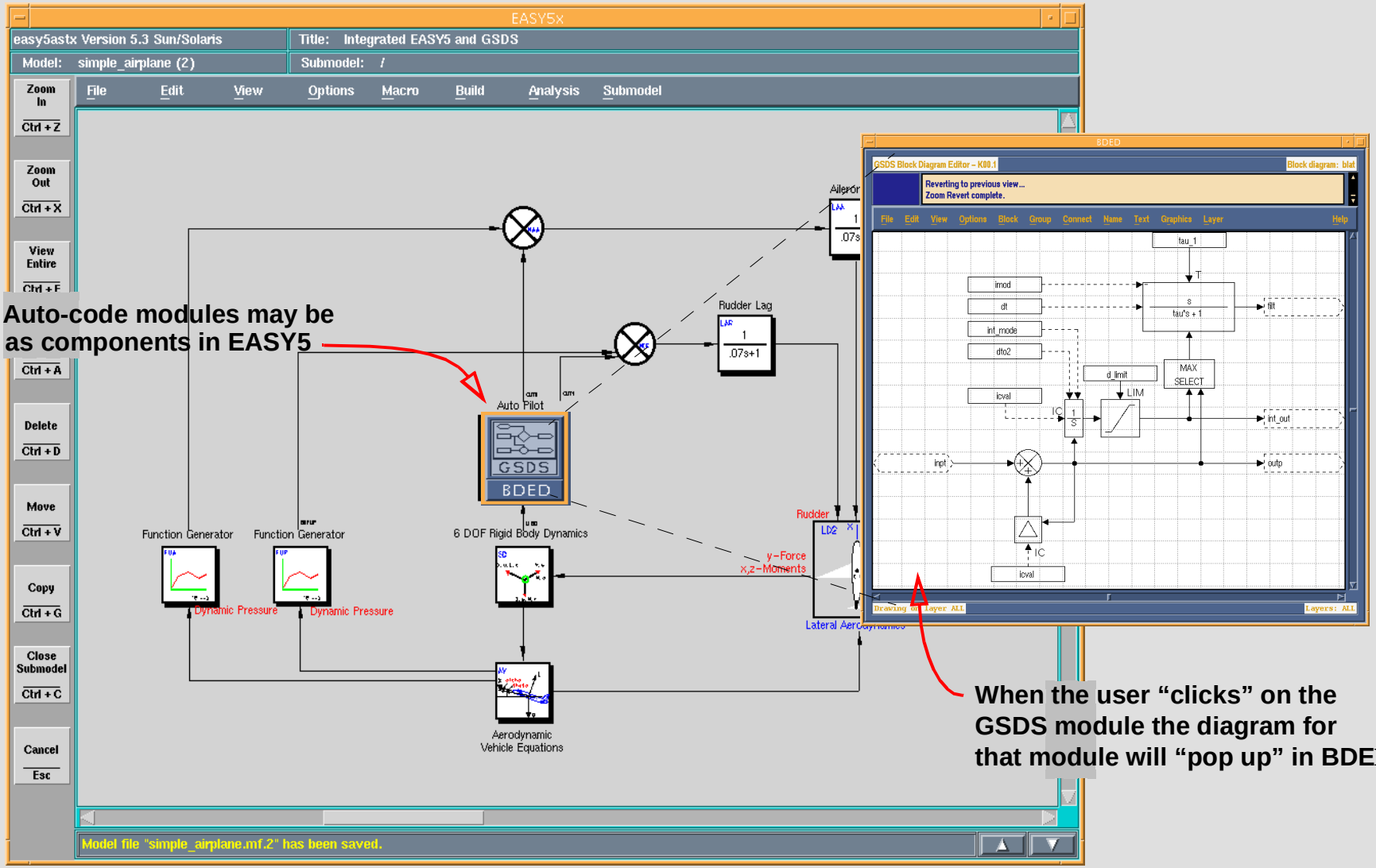


EASY5's Extension

- What is the EASY5 "Extension" ?
  - a special component that provides the "s/w hooks" for other CAE tools to integrate with EASY5
  - from user's point-of-view it provides a seamless integration of tools
- Provides an open architecture and published API for integrating other tools with EASY5.

Example of Extensions: Integration of EASY5 and GSDS

EASY5



GSDS Auto-code modules may be added as components in EASY5

When the user "clicks" on the GSDS module the diagram for that module will "pop up" in BDED

- **Presentation on EASY5 and GSDS integration to be given by Mike Bingle.**

Extensions Expands EASY5's Application Domain

EASY5

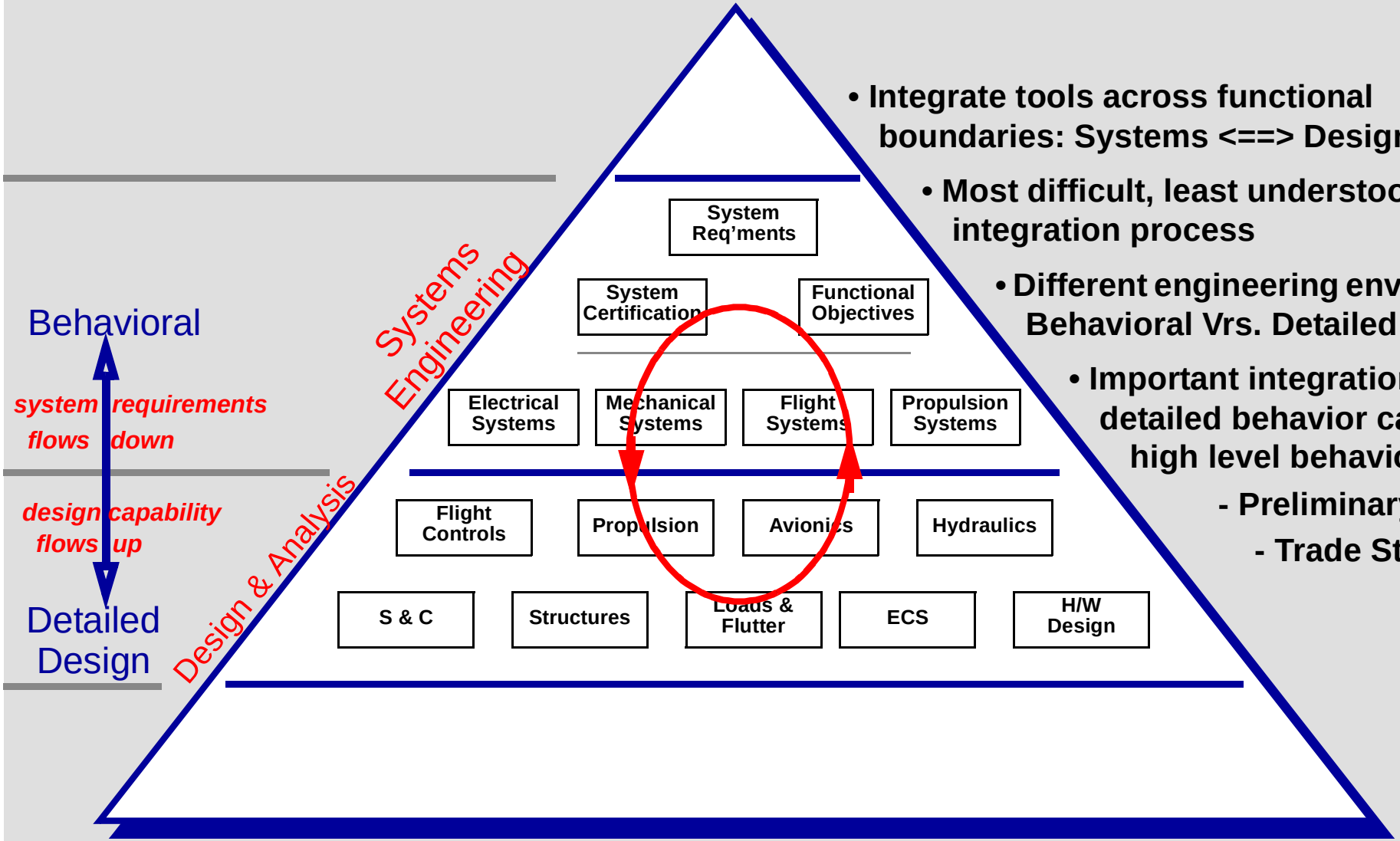
	MATLAB	MATRIXx	EASY5	SABER	FlowMaster	ADAMS, DADS Pro/Mechanica	VANTAGE	STATEMATE
Controls								
Finite State	**StateFlow**	BetterState	**Statemate**					
Mechanical	(1)	(1)	(2)					
Electric Circuits								
Integrated Circuits			**VANTAGE**					
Electric Machinery								
Pneumatics								
Powertrain								
Hydraulics								
Auto-Code			**GSDS**					
Real Time								

(1) linked with DADS, ADAMS, Pro/Mechanica (2) integrated with DADS, ADAMS, Pro/Mechanica

embedded tool =	
linked/integrated with external tool =	

Cross-Functional Integration of Tools
Bridging the Gap Between Systems & Design

EASY5



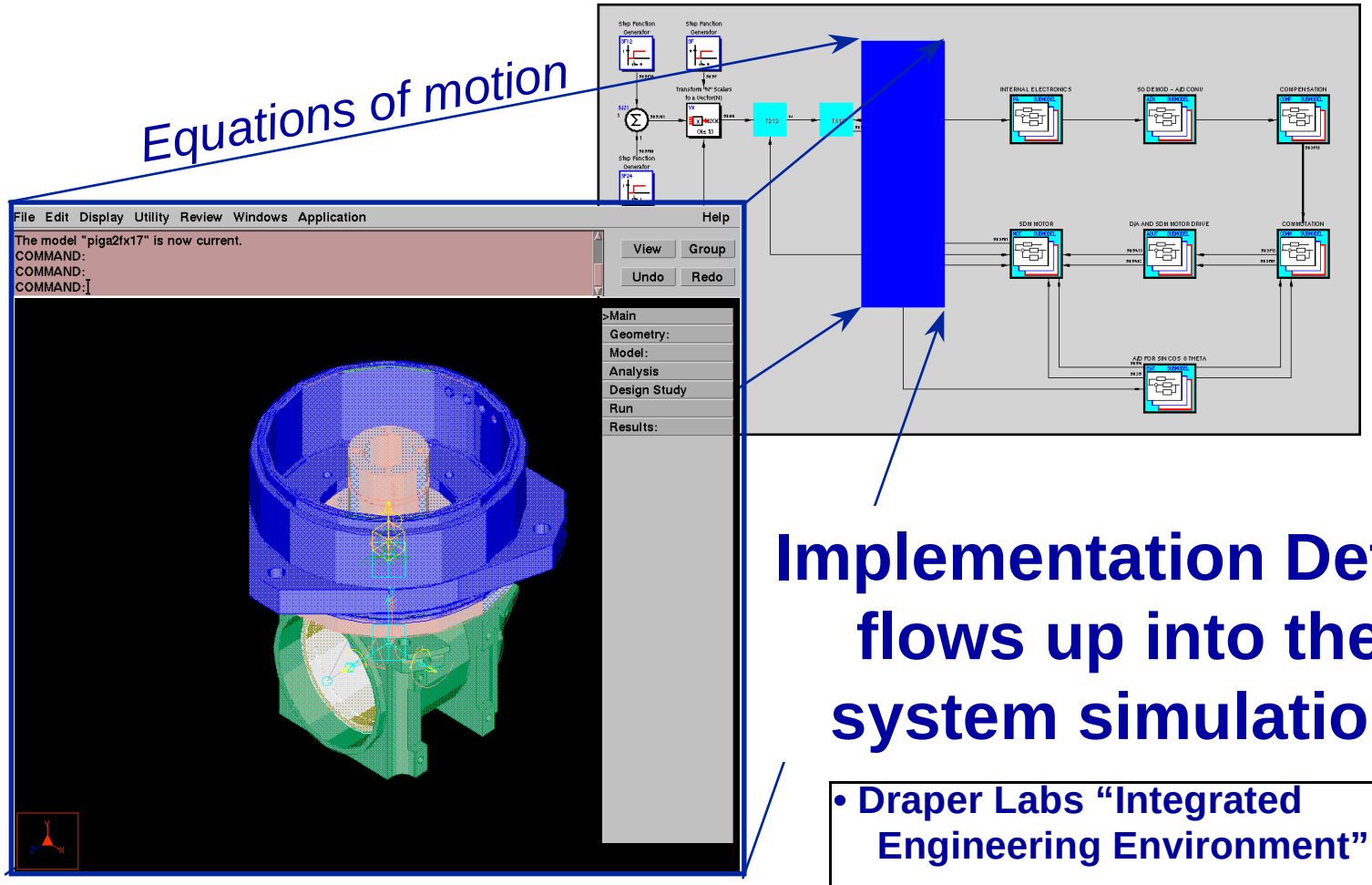
- Integrate tools across functional boundaries: Systems <==> Design
- Most difficult, least understood integration process
- Different engineering environment: Behavioral Vrs. Detailed Design
- Important integration - detailed behavior can affect high level behavior
  - Preliminary Design
  - Trade Studies

Example of Cross-Functional Integration
Draper Labs IEE Program

EASY5

Precision Instrument Simulation

Equations of motion



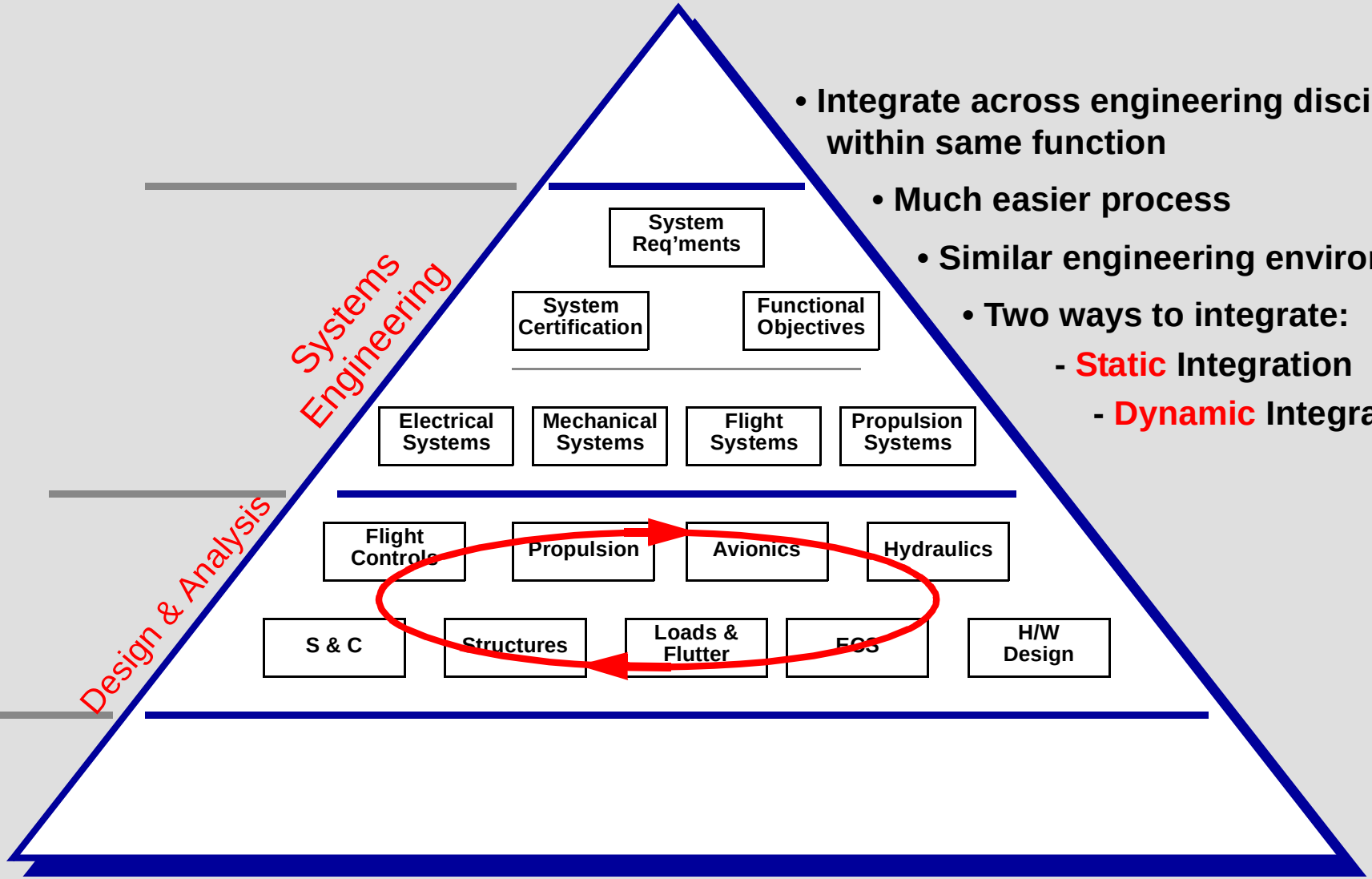
Implementation Detail flows up into the system simulation

Behavioral Description of a Detailed Mechanical Design

- Draper Labs "Integrated Engineering Environment"
- Build a "systems level" model
- Integrate detailed design model as needed.

Bridging the Gap Between Engineering Disciplines

EASY5



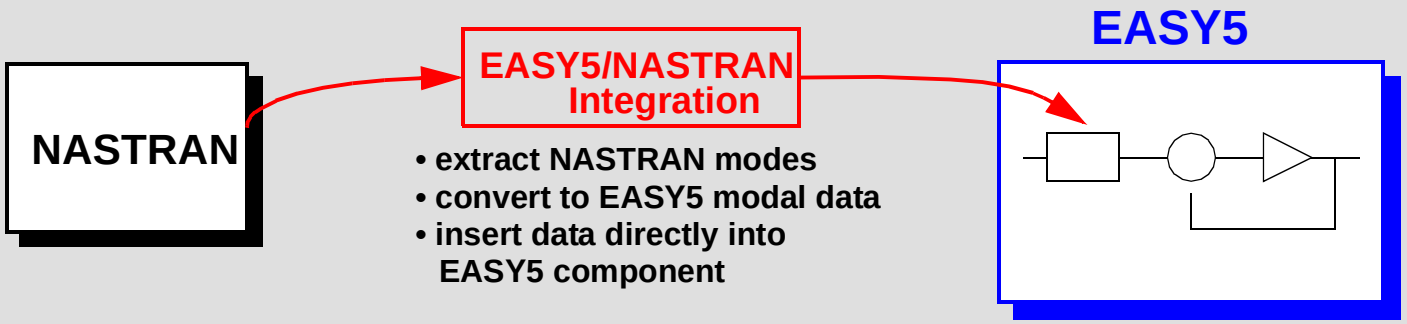
- Integrate across engineering disciplines, within same function
- Much easier process
- Similar engineering environment
- Two ways to integrate:
  - Static Integration
  - Dynamic Integration

multi-disciplines

Static Integration of CAE Tools

EASY5

- "Static" Integration: geometric or parametric data is shared between programs
  - simple - implementation is usually straight forward
  - commonly used to integrate different types of application tools; example: geometric-based modeling with simulation-based tool
  - example: CATIA and DADS integration - shares geometric data
  - example: NASTRAN <==> EASY5 integration

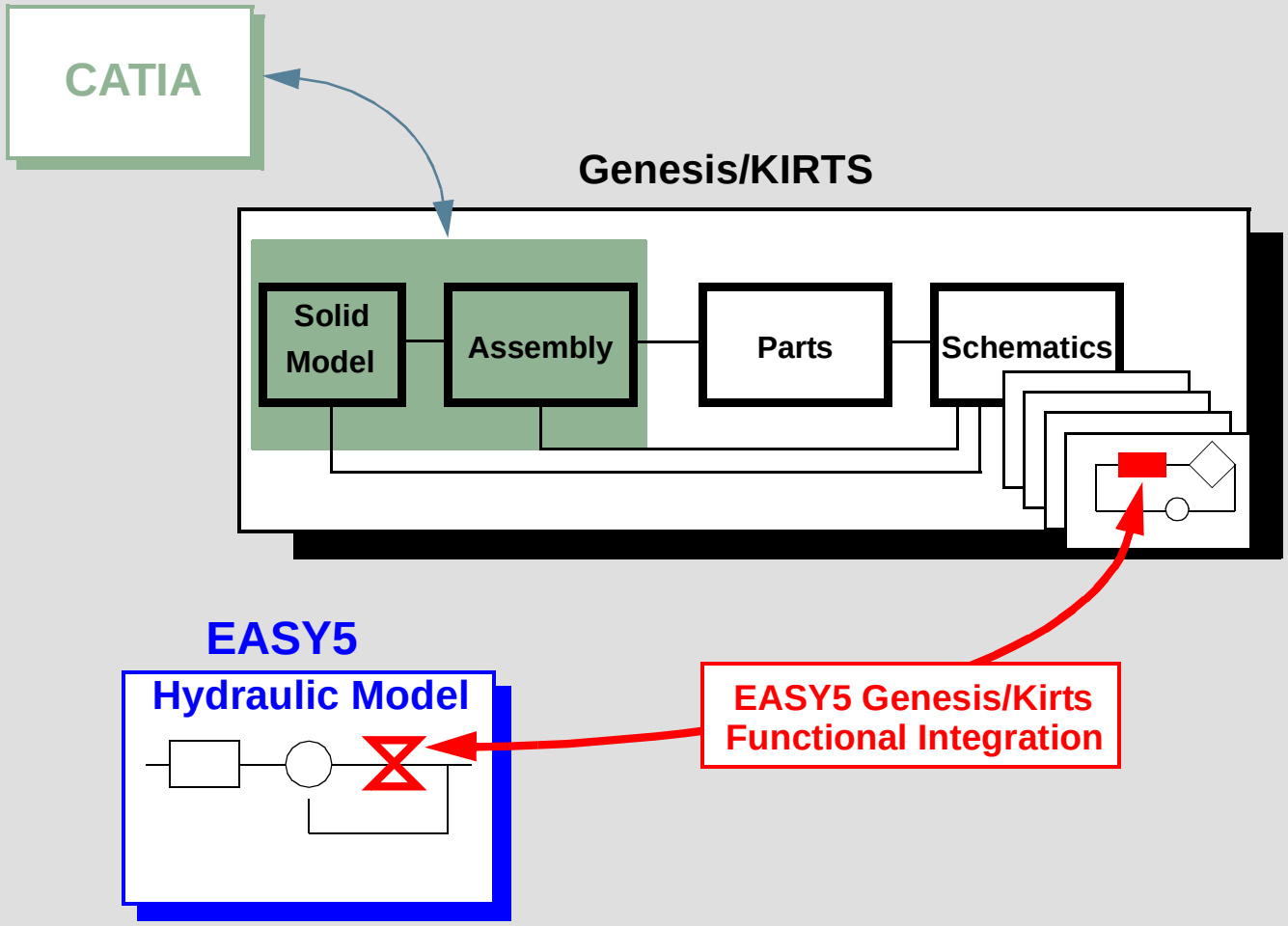


- EASY5/NASTRAN integration is implemented using an "Extension" component.

Beyond Static Integration

EASY5

- **Example: Genesis/KIRTS functional integration with EASY5**
  - **Genesis/KIRTS: generates functional dynamic models from CAD definitions of hydraulic and ECS systems**
  - **Presentation will be given by Raju.**



Dynamic Integration of CAE Tools

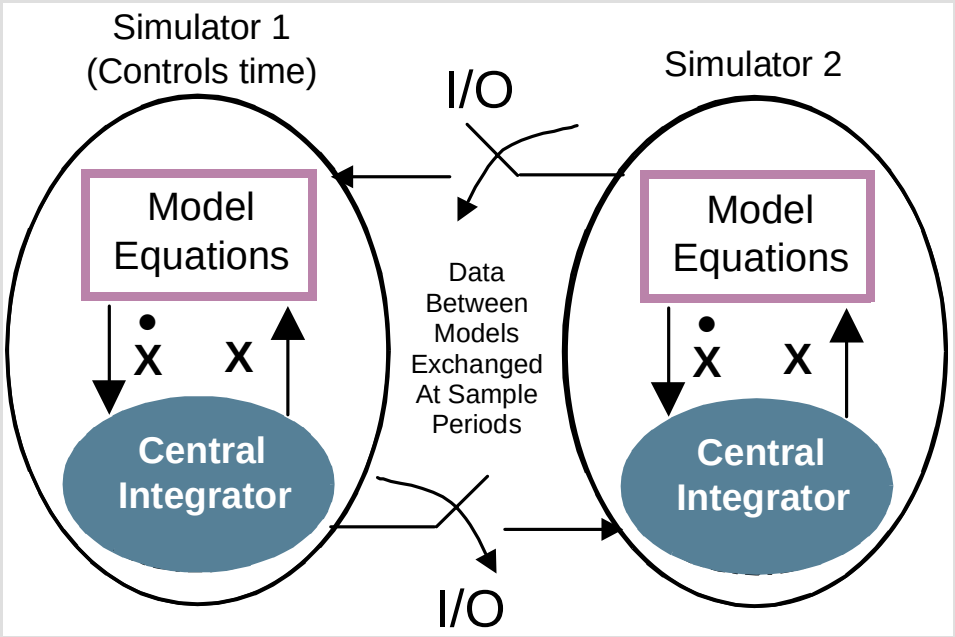
EASY5

- Involves “dynamic integration” of data and/or code.
- Much more complex and difficult to implement
- geared to “simulation-based” tools
- 2 methods
  - co-simulation integration
  - coupled-simulation integration

CAE Integration Using Co-Simulation

EASY5

- **Co-Simulation**
  - two simulation programs run simultaneously
  - each solves its own differential equations - each controls its own Time
  - data is shared between programs at predetermined time intervals

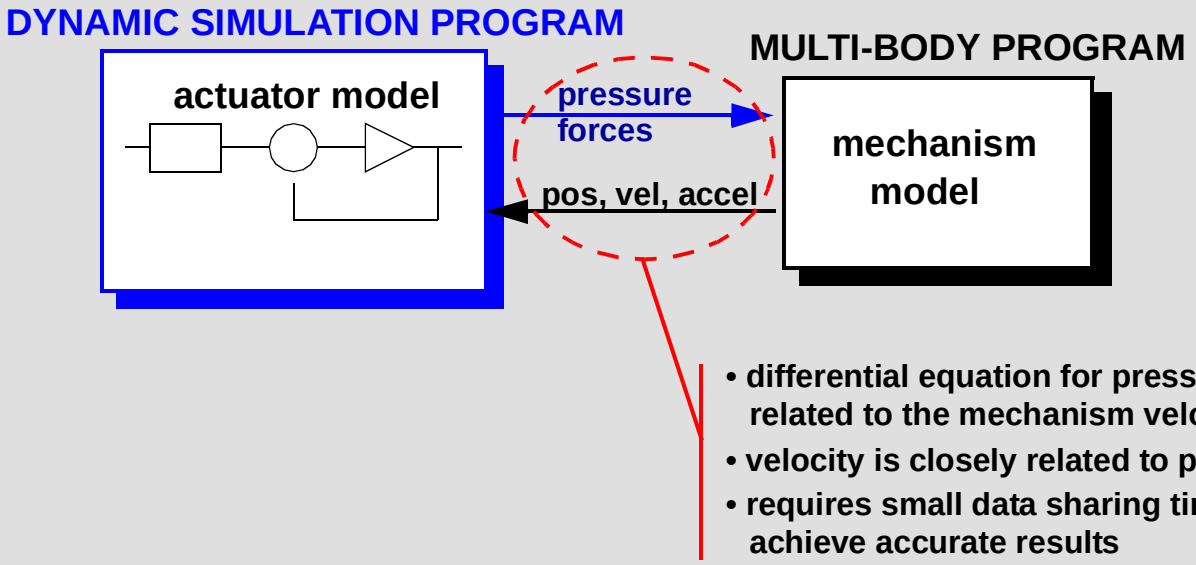


- **Examples of co-simulation**
  - EASY5's co-simulation with SystemBuild and Simulink

Co-Simulation Disadvantage

EASY5

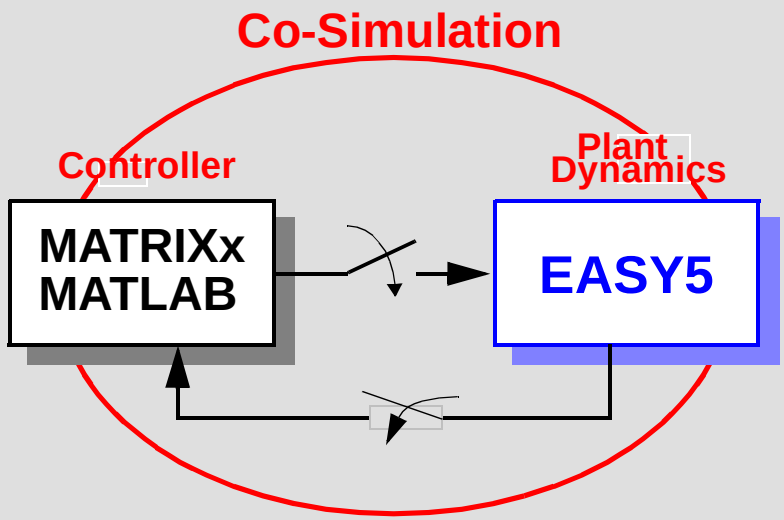
- **Not a design and analysis tool -- only a simulation tool**
  - not possible to generate a linear model of complete system
  - can not perform controls design and analysis, steady state, etc.
- **Excessive run times for models with “coupled dynamics”**
  - small data sharing time intervals may be required - constrains numerical integration and results in unacceptable simulation run-times
  - MATRIXx/DADS co-simulation is a good example of this problem: f



- **Co-simulation works best on systems that are not tightly coupled .**

EASY5 Interface to MATRIXx/MATLAB

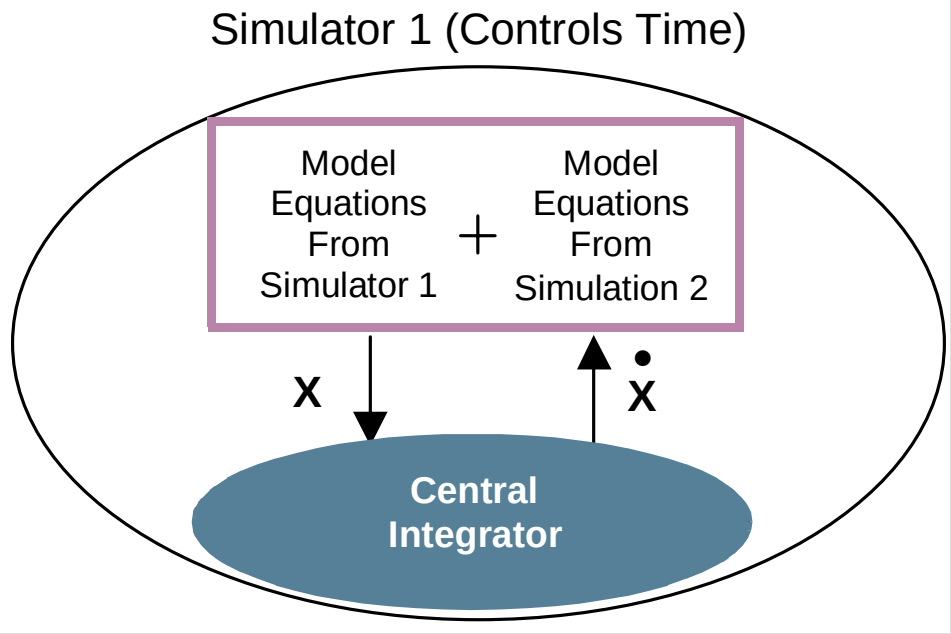
- **Purpose**
  - To simulate any EASY5 model from within MATRIXx (SystemBuild) or MATLAB (Simulink) models.
- **Advantage**
  - you can use EASY5 to build large, complex highly nonlinear plant models - difficult to do with MATLAB/ MATRIXx
  - use EASY5 Switch states and special integrators
  - use EASY5 application libraries - hc, hv, ec, pt, en, etc.
  - use other tool's strength - controller design and analysis



CAE Integration Using Coupled-Simulation

EASY5

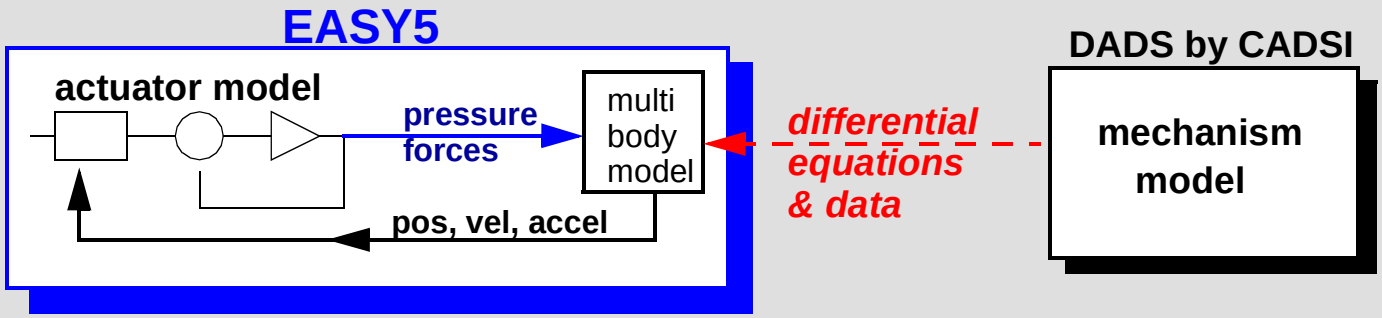
- **Coupled-Simulation approach**
  - **equations (differential, difference, algebraic) from different CAE tools are combined (coupled) into one set of equations, inserted into one of the CAE programs**
  - **solved by a central numerical integrator in the simulator that controls time**
  - **required when equations in different tools are tightly coupled - such that only a central numerical integrator can produce more accurate results within a reasonable amount of time**



Advantages/Disadvantages of Coupled-Simulation

EASY5

- **Advantages**
  - reduced simulation time
  - true design and analysis tool
  - allows engineer to apply all analyses: simulation, steady-state, linear analysis, control systems design
  - integration is more “seamless” from users point of view
- **Disadvantages**
  - much more difficult to integrate CAE tools using coupled-equations approach
- **Example of coupled-simulation integration:**
  - EASY5 integration with DADS, ADAMS, and ProE/Mechanica



- **Coupled-simulation of CAE tools easily done with “Extensions”.**

Summary

EASY5

- Integration of CAE tools is necessary for complete system prototyping.
- Integration of CAE tools is central to EASY5 - being developed as a core competency
- EASY5 “Extensions” feature provides a mechanism for integrating CAE tools - makes the integration appear seamless to the user.