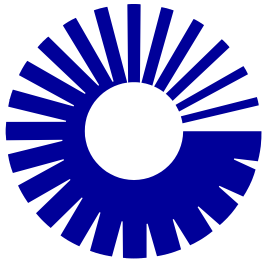

United Technologies

Systems Engineering

Status of Industrial Use, Opportunities and Needs

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TEAM

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AGENDA

System Design

Systems engineering:
(1) requirements,
(2) architecture,
(3) model based design,
(4) (design/development) process

Platform Based Design – design flows (orthogonalize concerns; hierarchy)

Opportunities & progress

System level modeling – positive on reusabality, speed…
Architecture exploration – not fully exploited - but enabled
Requirements – potential to move between formal languages (in progress for embeddded systems)
Model based development – positive on controls - MPC (and optimization), uncertainty (and use for robust design not there yet)
Process – progress on integration of tool chains; level of abstraction change (slightly) with domain (but separate into main product development cycles)

DRIVERS

System interactions (“emergent behavior”)

Requirements & acceptance testing (verification)

Safety (critical) (software intensive) systems

Reusable architectures (modularity)

Robustness (risk, lifing)

SYSTEMS ENGINEERING (DESIGN)

Process

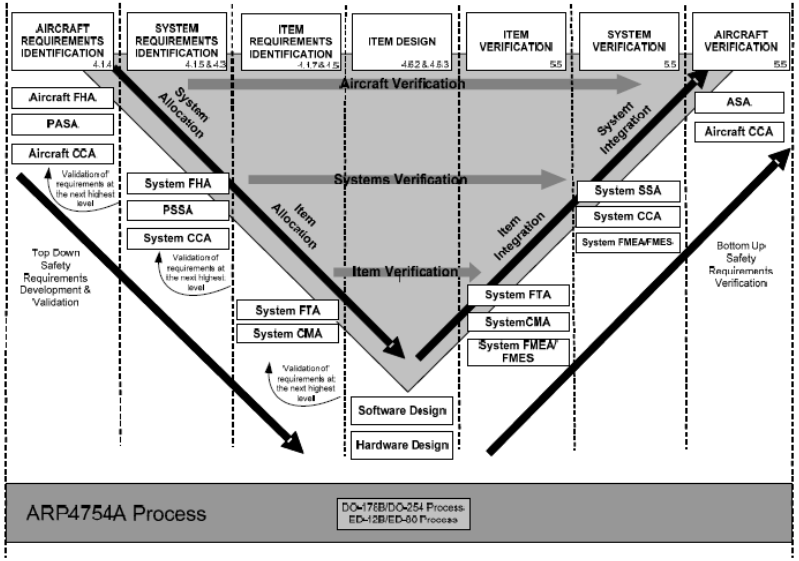
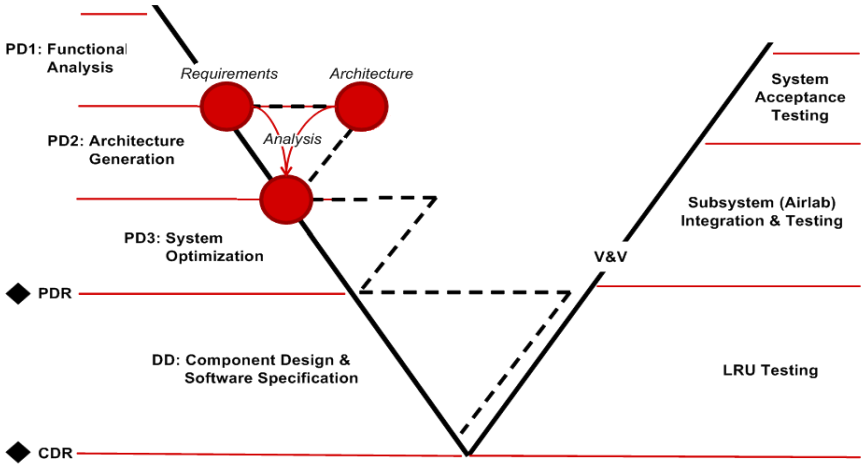


FIGURE 5 - INTERACTION BETWEEN SAFETY AND DEVELOPMENT PROCESSES



From process to analysis (model based development)

Bring forward in time the verification testing (SIL => HIL => acceptance)

Orthogonalize requirements (requested behavior) and architecture (delivering services)

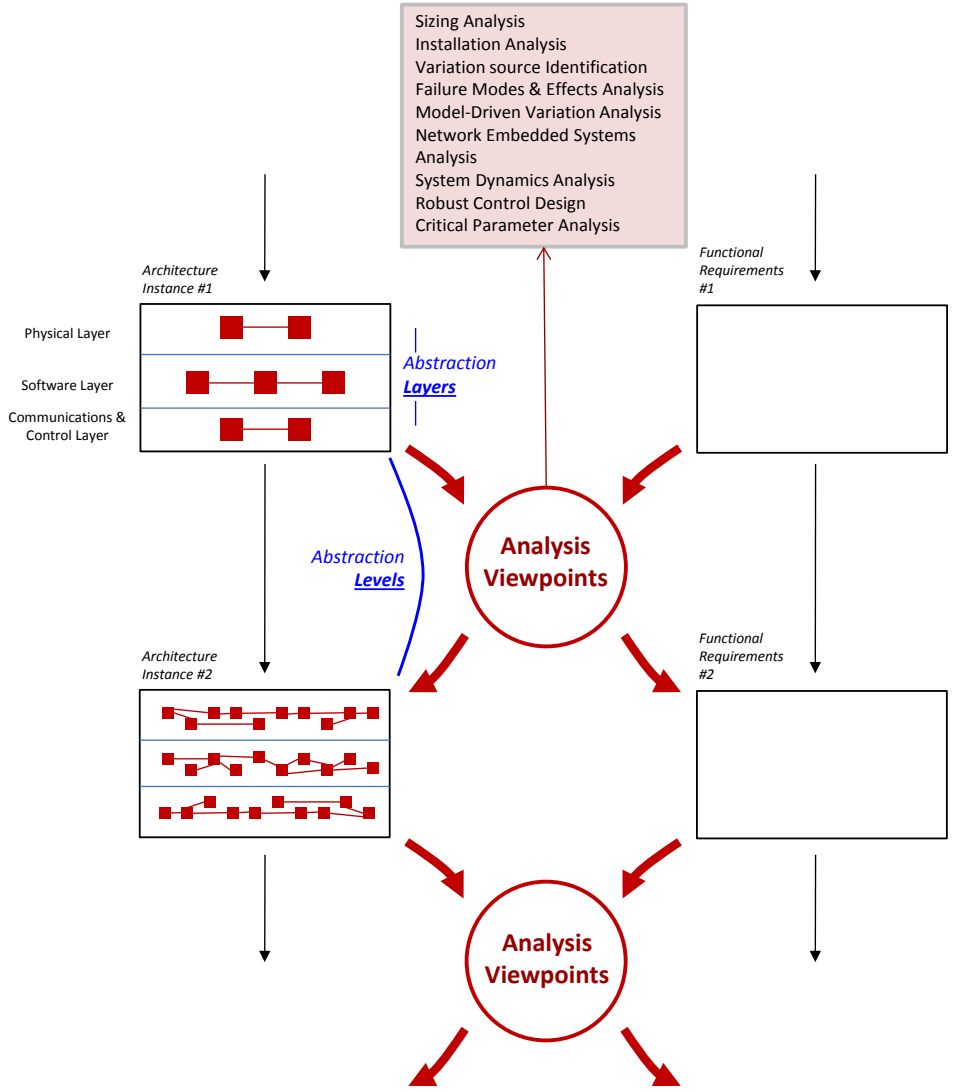
DESIGN PROCESS

Status & Opportunities

Range of analyses (views)

Hierarchy (refinement)

Separation of concerns (requirements, architecture, analysis)



SYSTEMS ENGINEERING (DESIGN)

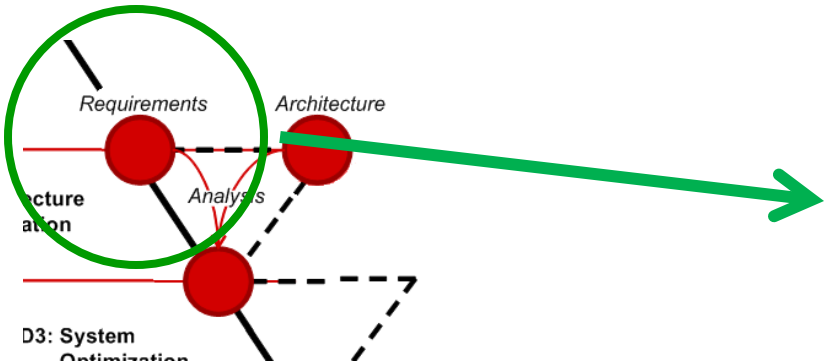
Definition

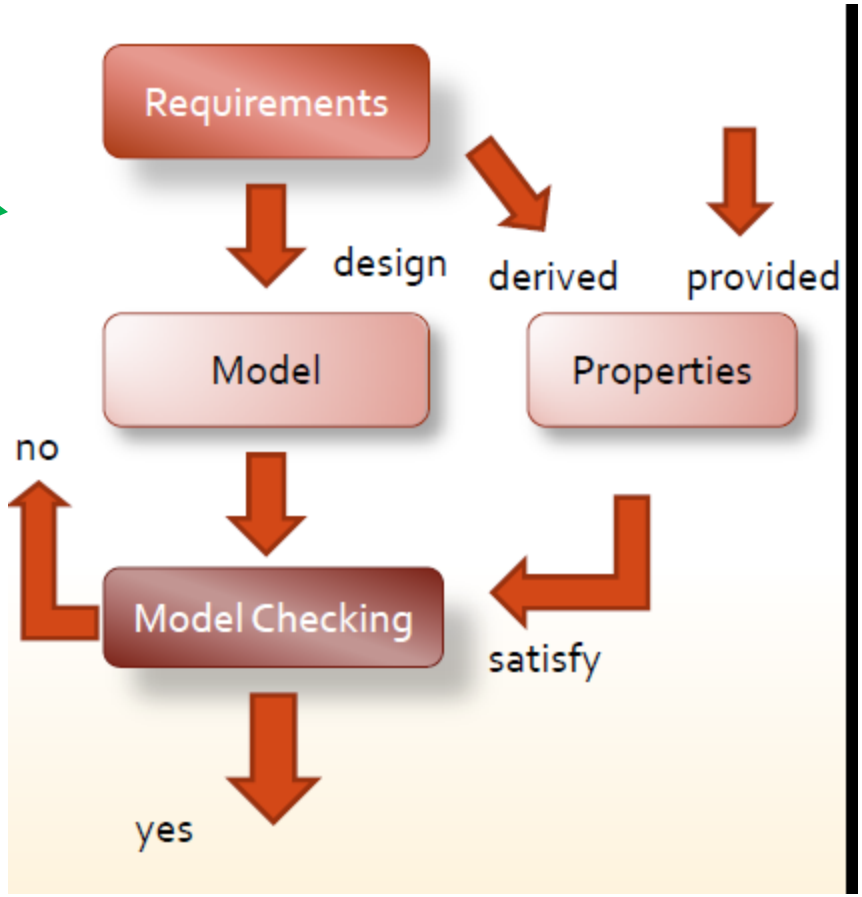
Systems engineering is a methodology for product system level design, optimization and verification that:

1. Provides guarantees of performance and reliability against customer **requirements** while achieving business cost and time-to-market objectives;
2. Produces modular, extensible **architectures** for products incorporating mechanical components, embedded systems and application software;
3. Exploits **model-based analytical tools and techniques** to determine design choices and ensure robust system performance despite variations caused by product manufacturing, integration with other products and customer operation; and
4. achieves these objectives through the coordinated execution of a prescriptive, repeatable and measurable **process.**

REQUIREMENTS

Status & Opportunities





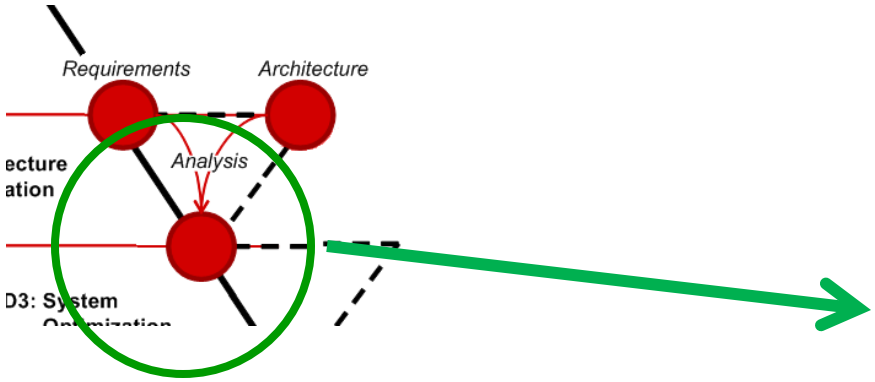
Enabler – formal language (not just equation based language)

Status – strong for embedded systems; weak for continuous time (non-simulation based verification)

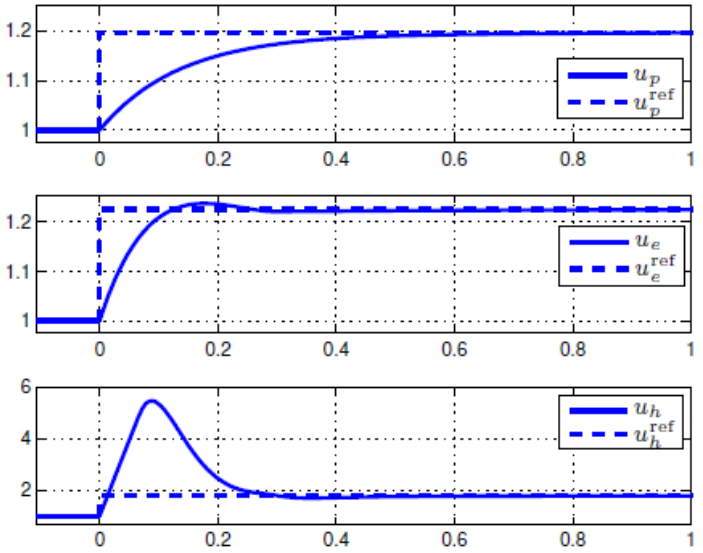
Opportunity – robust design/uncertainty

MODEL BASED DEVELOPMENT

Status & Opportunities




```
optimization VDP_Opt(objective=cost(finalTime),
      startTime=0,
      finalTime(free=true, initialGuess=1))
   VDP vdp(u(free=true,initialGuess=0.0));
    Real cost (start=0);
equation
    der(cost) = 1;
constraint
    vdp.x1(finalTime) = 0;
    vdp.x2(finalTime) = 0;
    vdp.u >= -1; vdp.u <= 1;
end VDP_Opt;
```

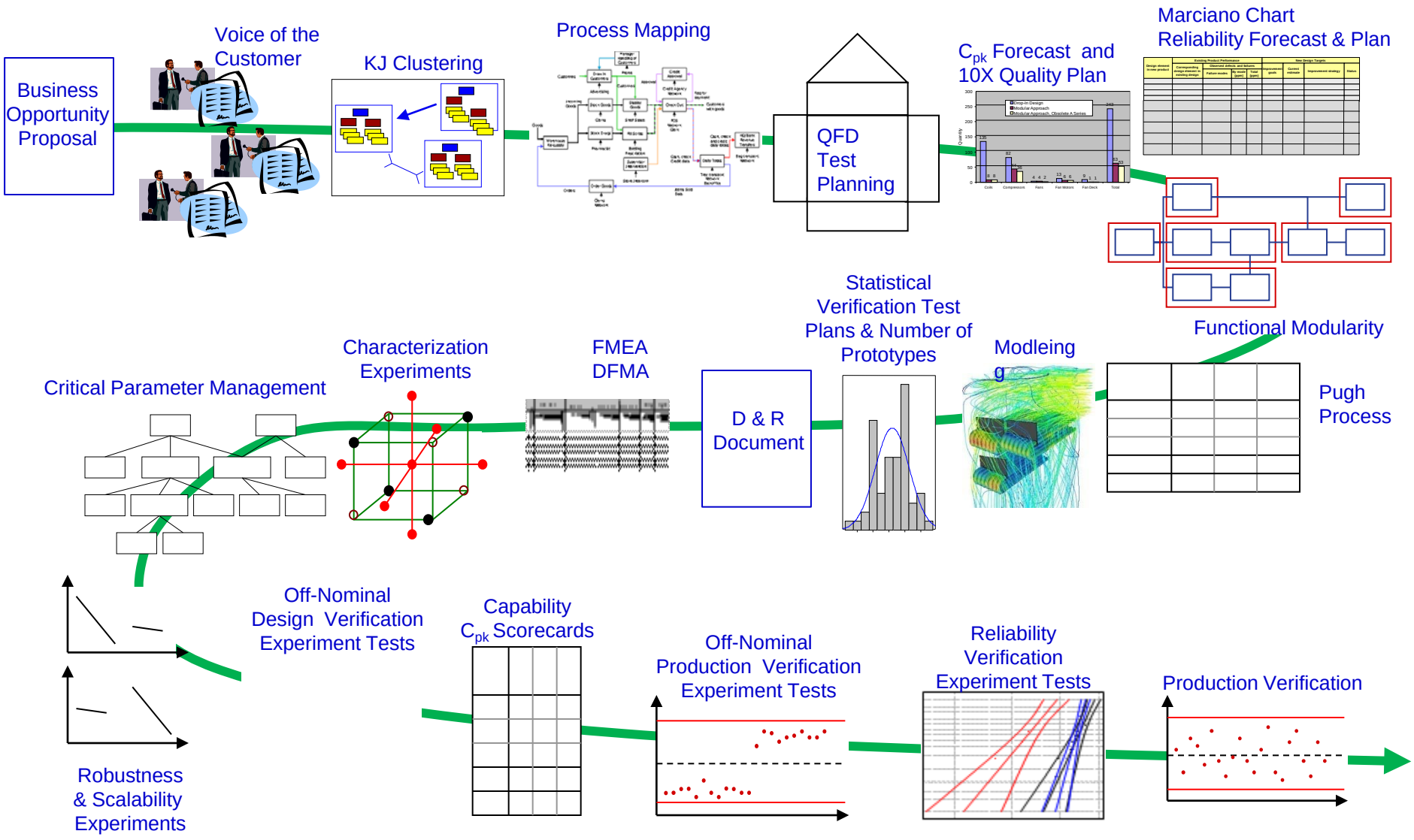


Enabler – equations; interconnection structure

Status of use of equation based language – strong for optimization (MPC; Akesson-Optimica) ; not exploited for robust design; weak for architecture exploration

Opportunity – robust design/uncertainty

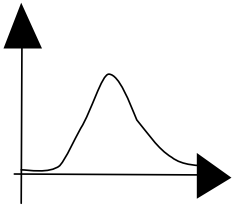
ROBUST DESIGN

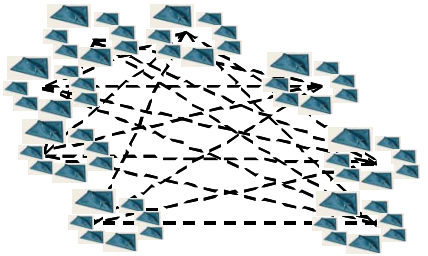


ROBUST DESIGN & UNCERTAINTY

Status & Opportunities: Exploit Structure

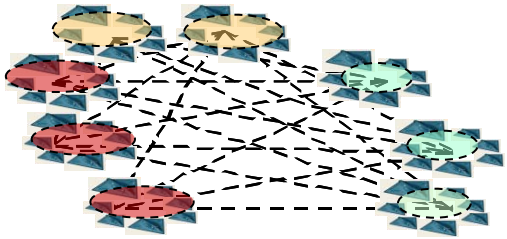
Probability Distribution of input parameters



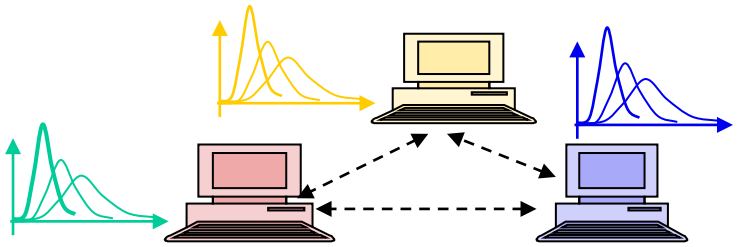


Utilize interconnection structure to tear system into strong & weak connections; propagate uncertainty (Meyn-Mathew (and others) DARPA RUM 2008)

Find Weak Interaction



Exploit Weak Interaction



SUMMARY

System Design

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Process – progress on integration of tool chains; level of abstraction change (slightly) with domain (but separate into main product development cycles)

Summary

Big needs on uncertainty/robust design (much wider view of product development);
Opportunity for realizing potential of tool integration (FMI) and with PLM (data management)

KEY POINTS

System Design

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Summary

Big needs on uncertainty/robust design;
Opportunity for realizing potential of integration (FMI) with tool chain and PLM