Digital Thread – the Missing Link

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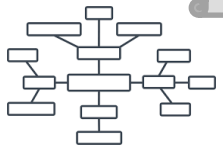
Conventional and MBSE Lifecycles

DRR

Salvage

Concept design



SRR
SDR

F

A

Deliverable: documents
+ models

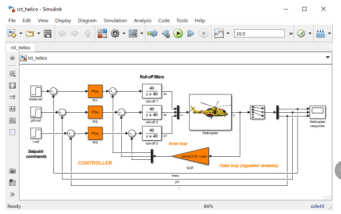
E

B

ORR

Deploy

Preliminary design



PDR

D

C

SIR
TRR

AIT

Physical design

CDR

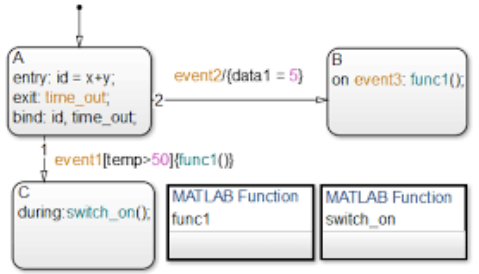
SRR - System Req. Review
SDR - System Definition Review
PDR - Prelim. Design Review
CDR - Critical Design Review
SIR - System Integration Review
TRR - Test Readiness Review
ORR - Operation Readiness Review
DRR - Disposal Readiness Review

Model Manifestations: Flight Dynamics Computer

Phase 0/A/B

Mission

- SysML Requirements
- Operation scenarios



Control Algorithm

- Functional model
- Simulink State chart

C

Improve

- Add environmental effects
- Tune algorithm

Atmospheric
Gravity
Geomagnetic

Target Hardware

- Digital Signal Processor / On-board Computer
- Convert state chart to C or VHDL

1. MATLAB HDL Coder (VHDL)
2. MATLAB Codegen (C)

D

AIT

- Hardware in the Loop
- Software in the Loop
- Flight simulator

Model Manifestations: Flight Dynamics Computer

Mission requirements

Derived requirements
System requirements

Structure

Size and volume

CAD outline

Finite element analysis

Static and dynamic load analysis

Stress margins, modal analysis, fundamental frequency, deflections

Thermal

Finite element analysis

Thermal margins

PDR

Improve CAD geometries,

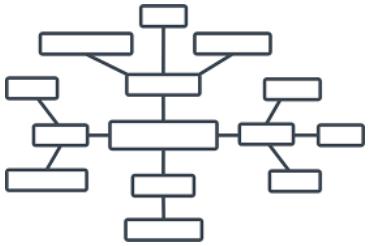
add detail / connectors, remove idealities

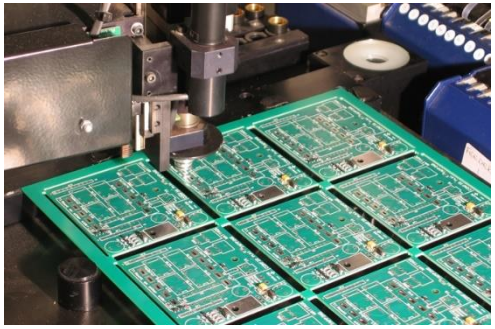
Repeat structural and thermal FEA

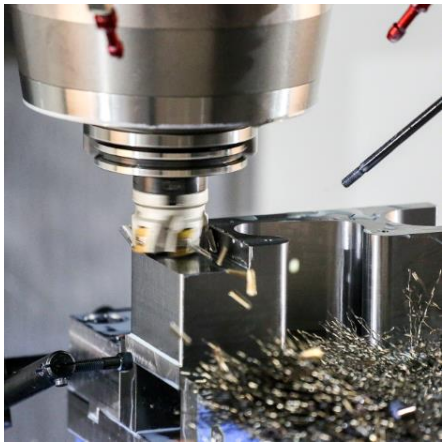
CDR

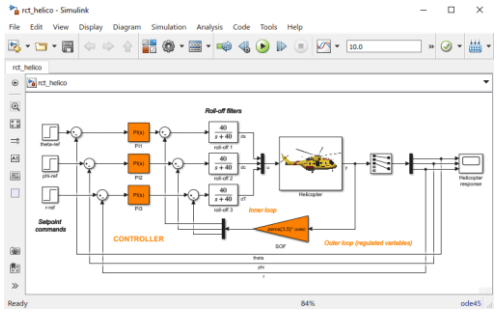
Build

CAD vs. CAM of the Flight Dynamics Computer



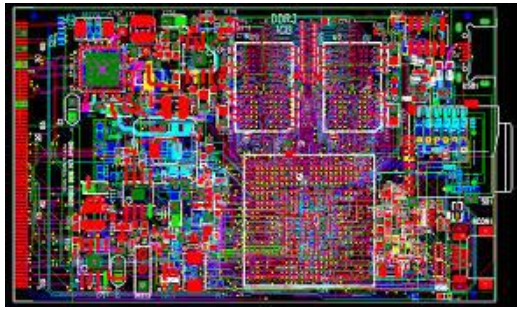






```c
#include "myMult.h"

void myMult(const double a[12], const double b[20], double c[15])
{
  int i0;
  int i1;
  int i2;
  for (i0 = 0; i0 < 3; i0++) {
    for (i1 = 0; i1 < 5; i1++) {
      c[i0 + 3 * i1] = 0.0;
      for (i2 = 0; i2 < 4; i2++) {
        c[i0 + 3 * i1] += a[i0 + 3 * i2] * b[i2 + (i1 << 2)];
      }
    }
  }
}
```

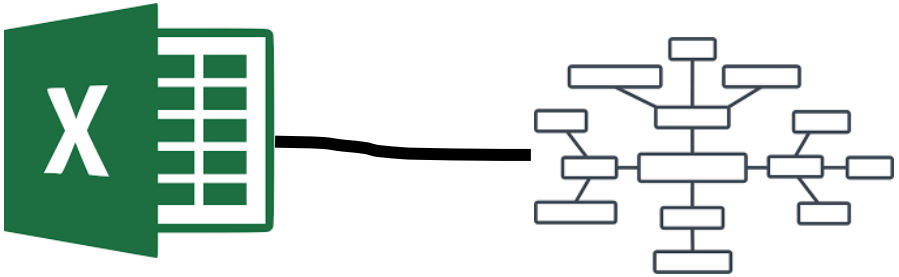


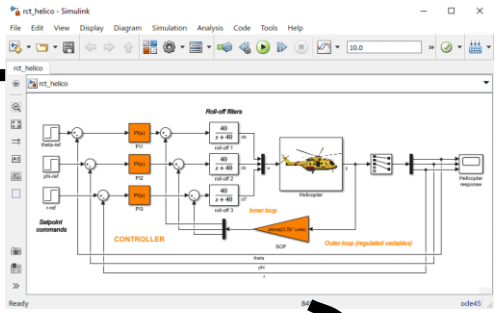
Digital Thread

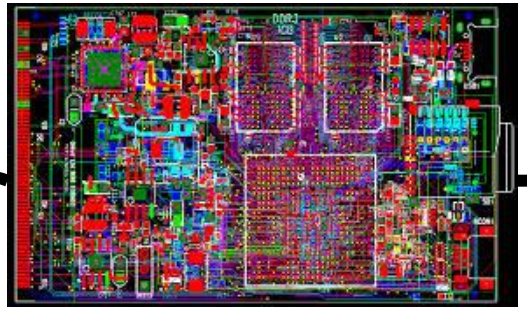
- Need a common language to read/write models across different tools e.g system models, CAD models, CAM and beyond (PLM)
- When manufacturing machines would use the same digital information “speak the same language” that we developed in the modelling, simulation and design phase, the information flow is called a digital thread

Digital Thread

- Stitching all model abstractions and manifestations







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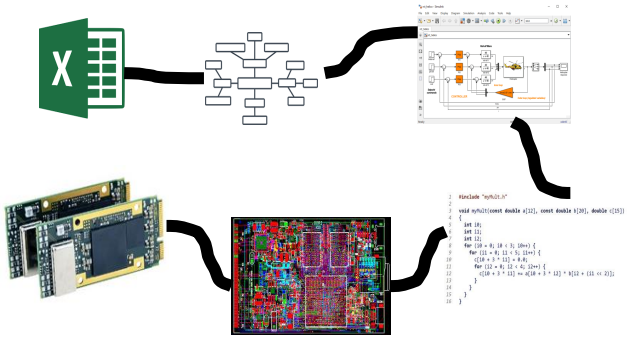
}
```

Digital Thread

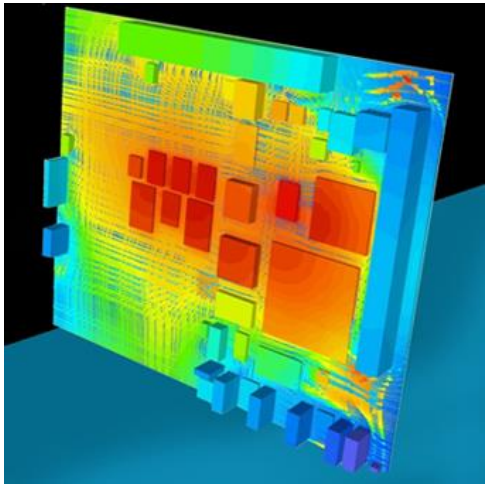
- Enable or hide model manifestations

or “physical behavioural views”

- Leads to traceability, V&V, digital twin

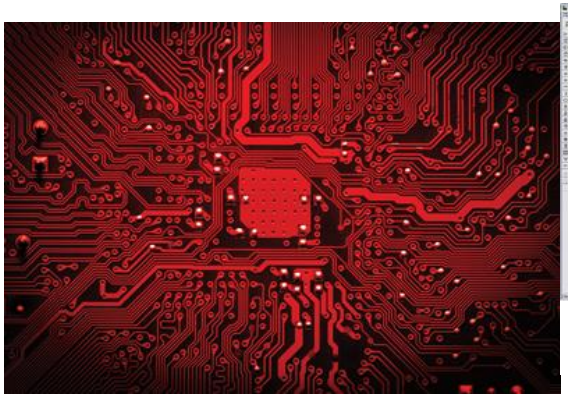


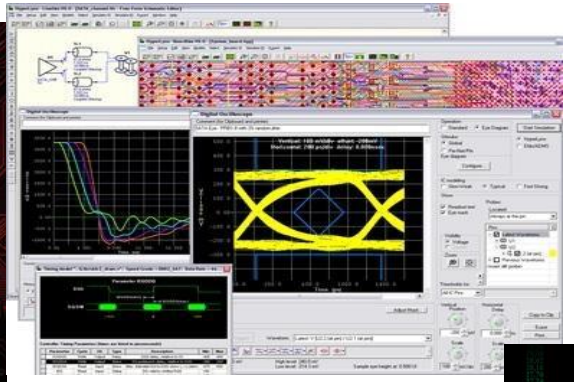
Thermal analysis



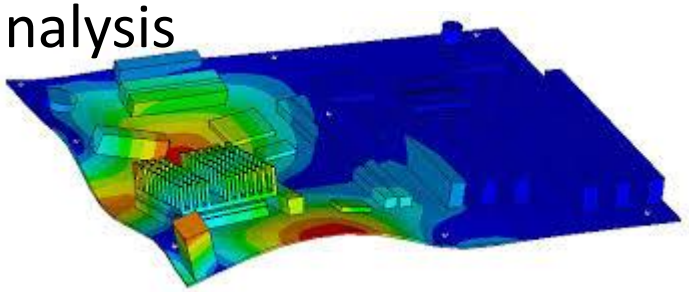
Electromagnetic emission

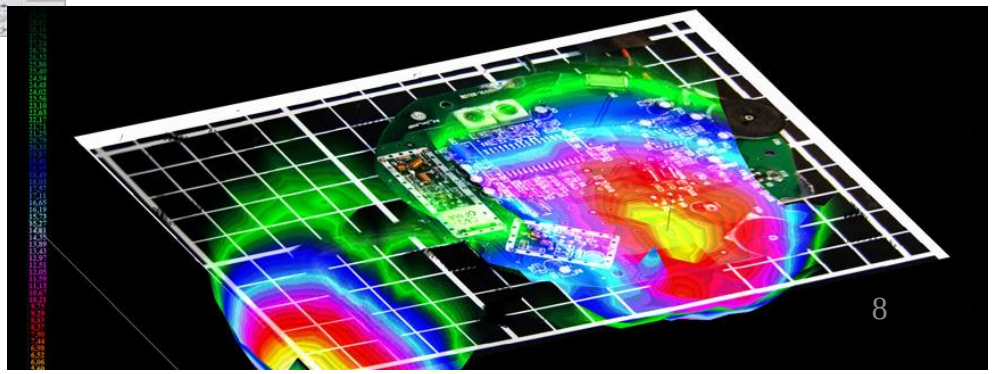
Signal integrity analysis





Structural analysis



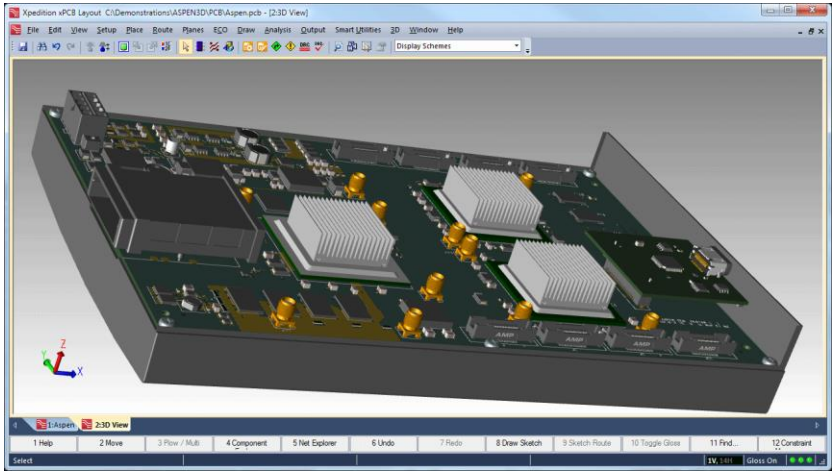


Digital Thread

- A digital record of all “states” of a manufactured system over time from conception to disposal
- INCOSE working definition: *A Digital Thread contains digital artifacts which are a combination of authoritative professional data, information, knowledge, and wisdom addressing stakeholders’ unique perspective in a digital viewpoint that can be digitally represented in a view within an enterprise data-information-knowledge system/s of a materiel system*

Digital Thread

- Clickable retrieval of the product's engineering data
- SysML (requirements)
  - Simulink model (functionality)
  - C code (DO-178C compliance)
  - Circuit schematic and PCB layout
  - Hardware logic (DO-254 compliance)
  - Parts tolerances
  - Structural, thermal, emissions, signal integrity profile
  - Manufacturing and test requirements
  - Product BOM and cost - Wire harness and routing
  - Parts delivery times - Placement/Configuration in system



The Status of the Thread

Phase A

Phase B

Phase C

Phase D

Phase F

MDENet Project - Digital Twinning

- Project with CIMPA PLM Services a Sopra Steria company
- Define factory layout across CAD/CAM and virtual environment
- Lightweight file format e.g JT
- Digital Twins Definition Language (DTDL) for IoT/Cloud