On the Relative Importance of Modeling in CPS Development

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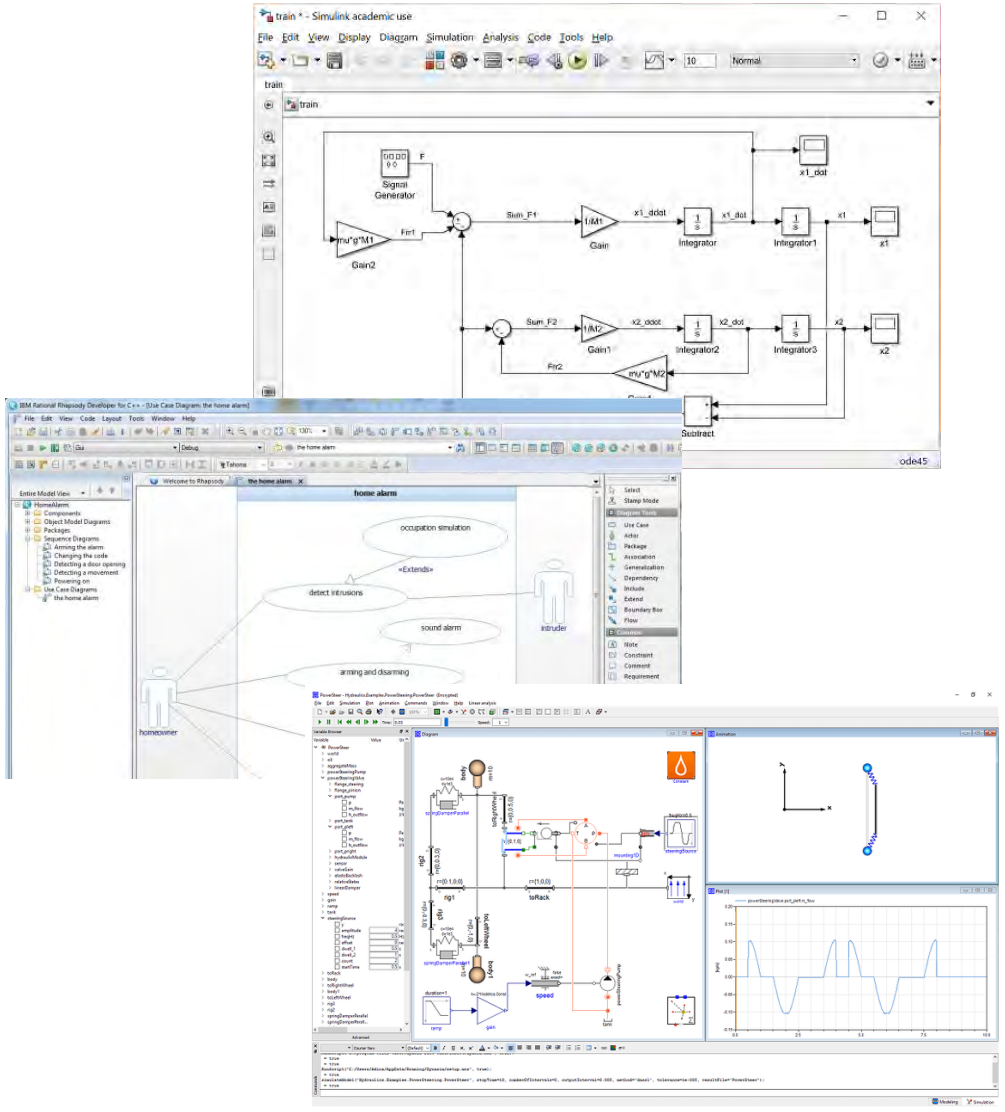
Background & rationale

- MBSE was identified as a key enabler for Gripen E development
  - Multiple papers has been written on the application of MBSE in the project
- However, there have been few analyses on the relative importance of MBSE to other essential engineering practises
- In retrospect, was the preparation for Gripen E balanced given the magnitude of the challenge?

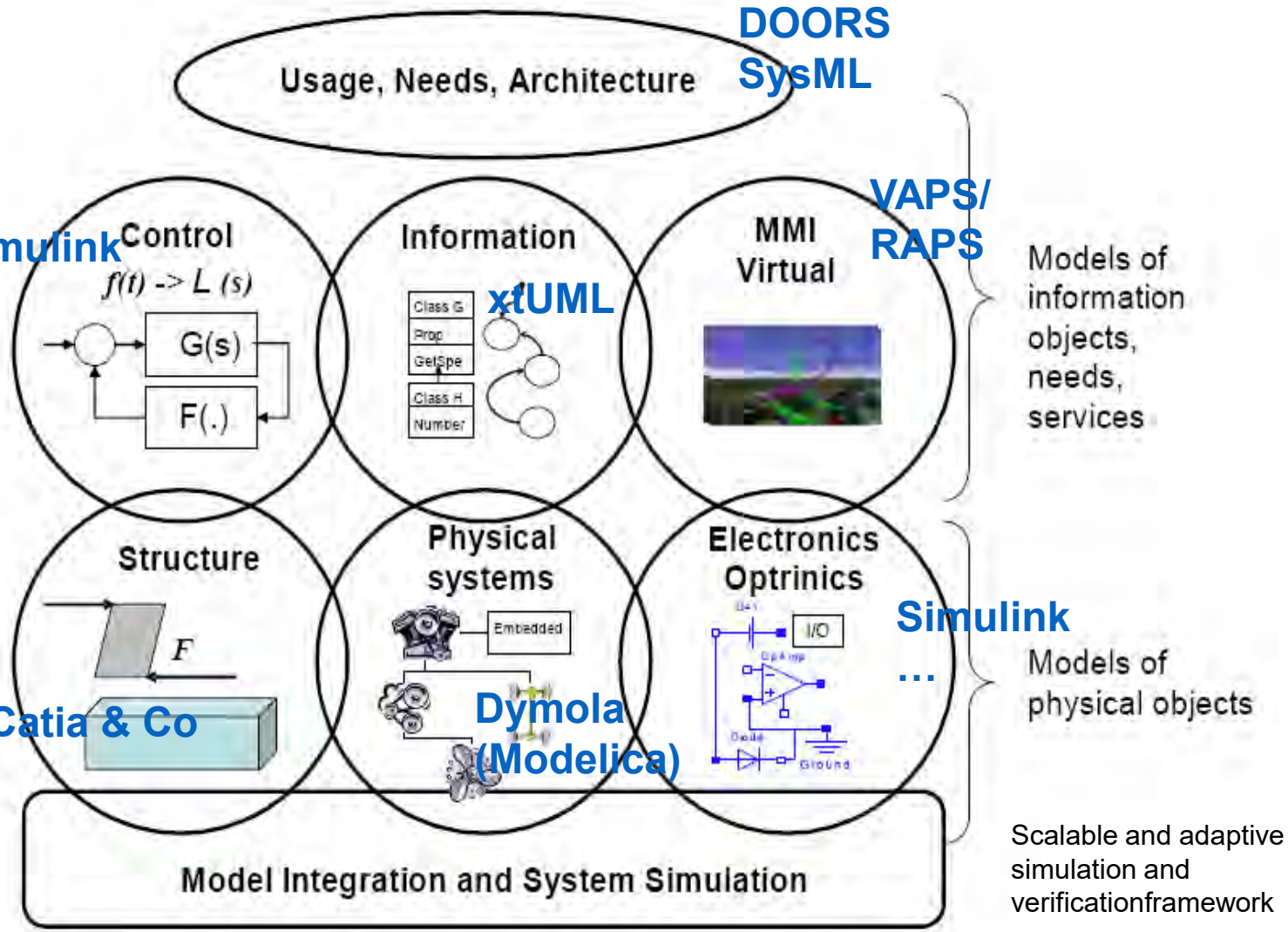
What benefits did we expect?

- Improved communication – ability to discuss design alternatives in an objective way
- Early validation – ability to simulate design concepts to increase
  - Feasibility
  - Acceptance of solution
- Improved accuracy – ability to determine and tune performance early in development
  - Fewer flight-test
- Improved quality – right the (almost) first time
- Improved efficiency – quicker turn-around



Use of modelling tools

Objective is to optimise this loop



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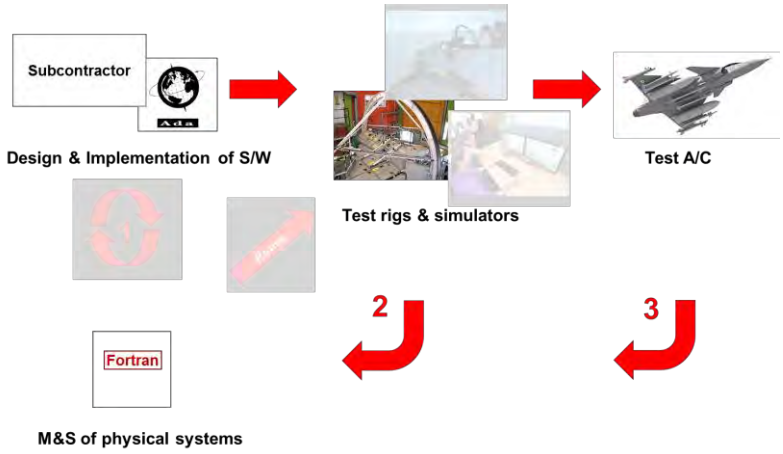
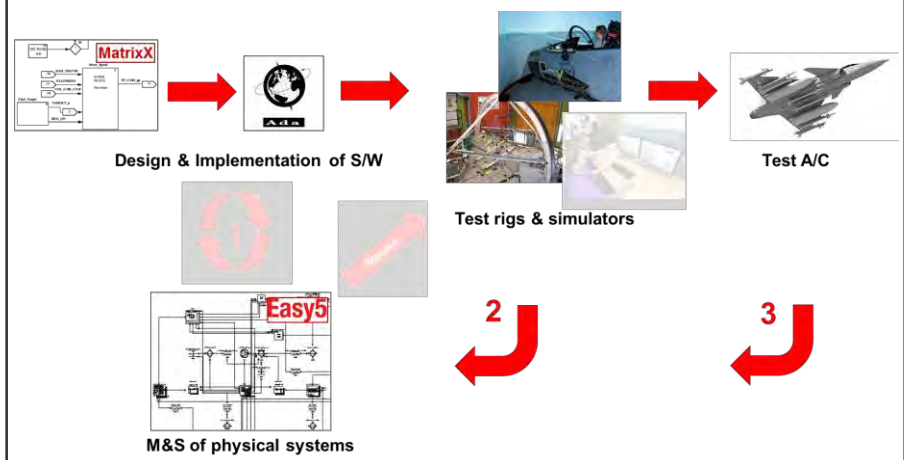
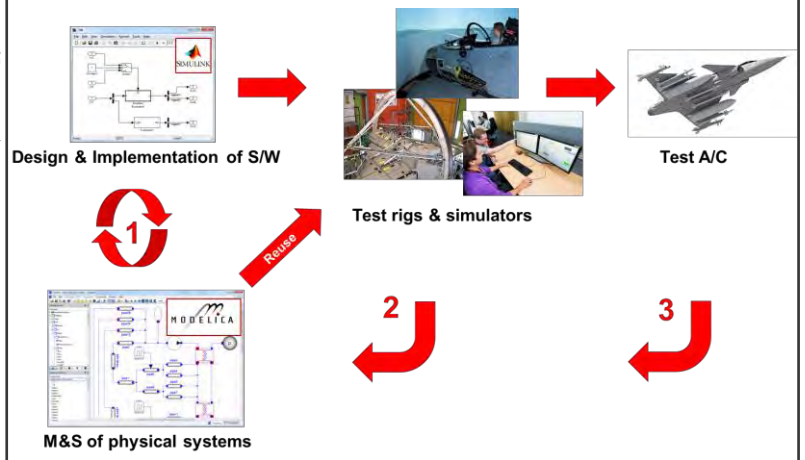
MODEL-Based Development of aircraft vehicle systems

Gripen A/B	Gripen C/D	Gripen E
		
S/W design tools	✓	✓
S/W code generation		✓
M&S tools	✓	✓
Closed loop simulation		✓
Subsystem test rigs ✓	✓	✓
Model reuse in simulators		✓
Soft integration simulators		✓
HIL integration simulators	✓	✓

Has MBSE made Gripen E more mature quicker?

Did we get the expected benefits?

- Improved communication – ability to discuss design alternatives in an objective way
- Early validation – ability to simulate design concepts to increase
  - Feasibility
  - Acceptance of solution
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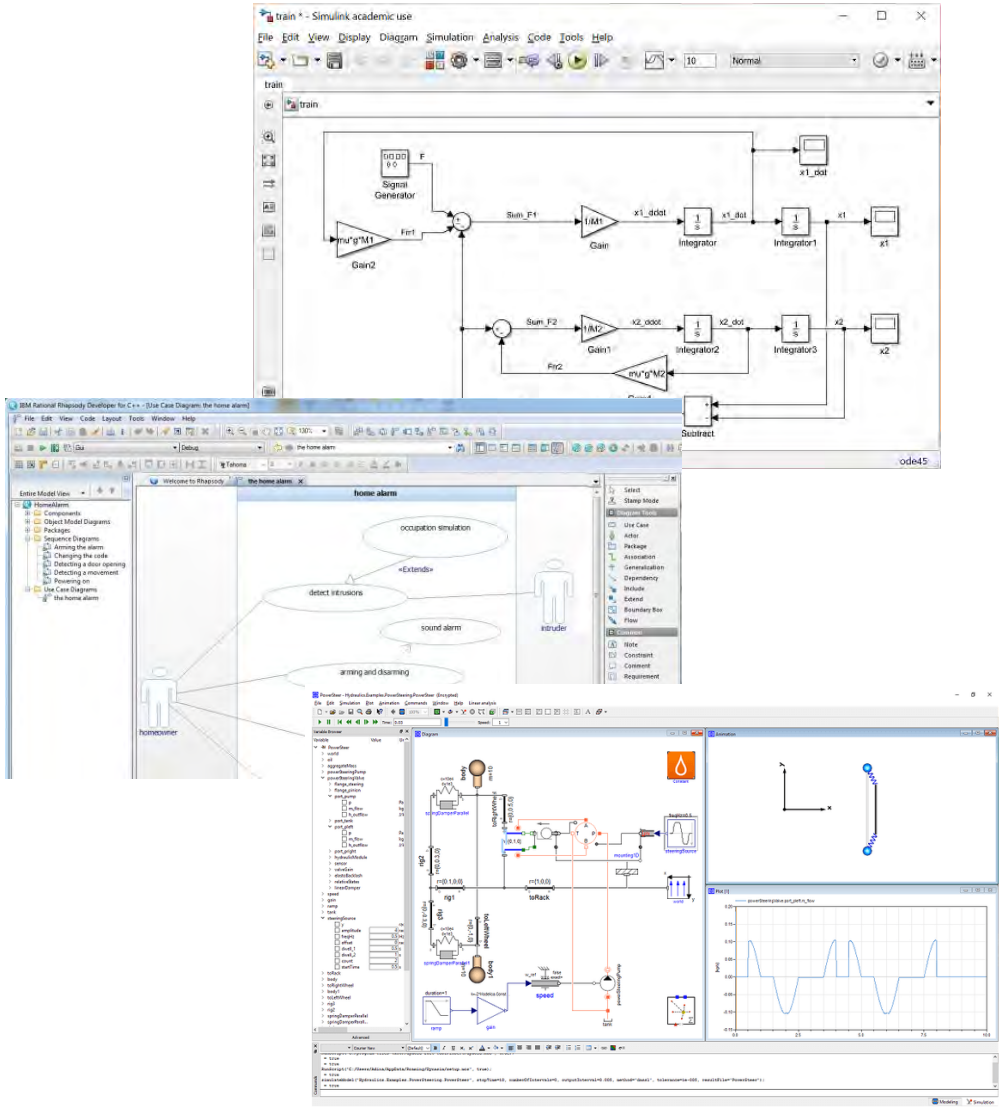
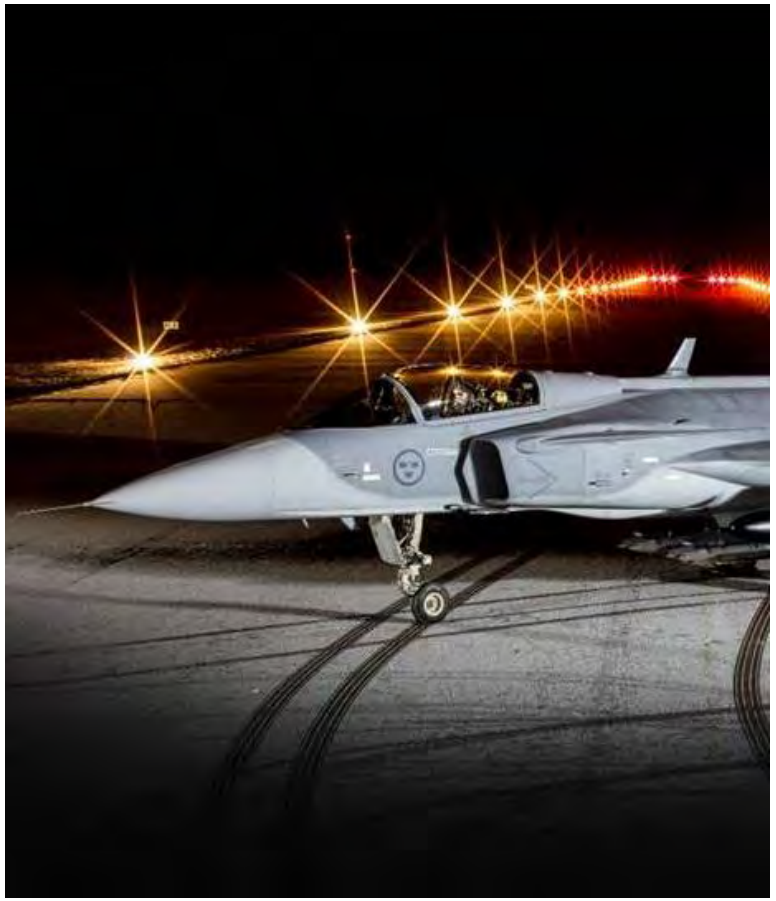


MBSE did make us better, but was our focus appropriate?

Aerospace challenges

- Systems
  - Complex
  - Multi-disciplinary
  - Expert operated and maintained
- Systems with very long development cycles
  - We don’t start over very often – every 30 years or so…
  - Do we remember how to start over?
- Large and heterogeneous development organisation
- Unusual acquirer/supplier relationship
- Starting over is a once in every 30 years opportunity to reform work in engineering disciplines



Factors influencing efficiency

- Process
- Methods
- Tools

- Complexity
- Heterogeneity
- Brown/Green field development

- Competencies
- Experience
- Leadership

Challenges when transitioning from Brownfield to Greenfield development

PROCESS AND MEASUREMENTS

Brownfield

Process has been executed multiple times

Few synchronisation points

Experienced teams and small solutions spaces

- Limited risks

Delegation is key to efficiency

Inherently known performance

- Value of process measurements is limited

Greenfield

First time execution

Multitude of synchronisation points

Inexperienced teams in the new envirnment

- Large risks

Centralisation is key to efficiency and understanding of progress

Development performance is difficult to asses

- Explicit measurement key to assessing progress

ARCHITECTURE AND ARCHITECTS

Brownfield

Architecture is set – for and for bad

- Merits and constraints are known

Little need for an indenpendent architecture function

- Architectural decisions can be delegated to development teams

Most probable the architecture is broken

- But everyone has to live with it!

Greenfield

Need to set the architecture and make every team conform to it

Need to constantly evaluate progress and performance

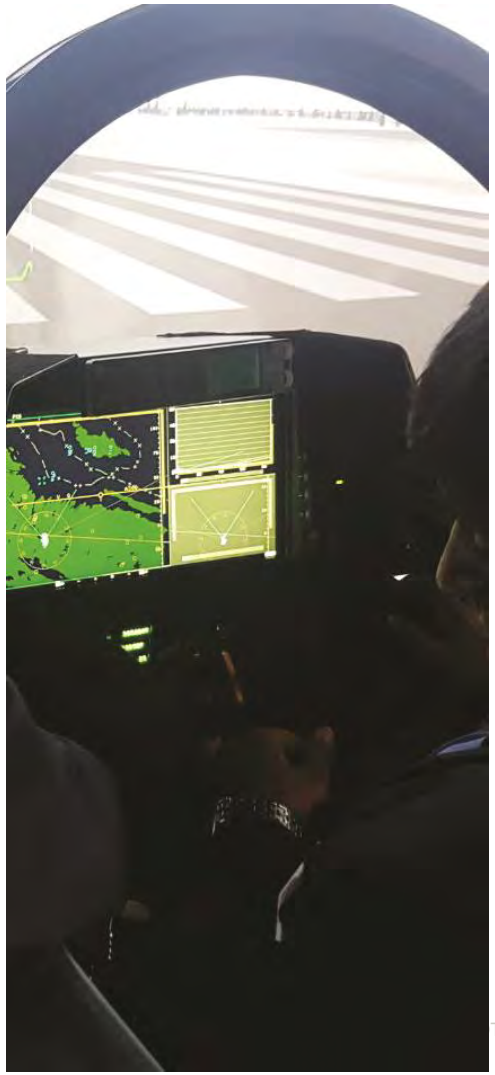
- And take necessary corrective actions

Architecting is a central element in development

Unproven architecture – risk for ugly surprises

- But it is not broken yet

INTEGRATION



Brownfield

New functionality added are largely independent of other concurrent development efforts

- Large stable core

Little or no need for a centralised integration strategies

Little emphasis on a centralised integration planning

Greenfield

No, or little core, lots of interdependencies

Integration planning and sequencing is essential

- Anatomies or similar essential for understanding relationships

Centralised integration planning

TACIT KNOWLEDGE AND TRAINING

Brownfield

Gradual adjustment of development methodology

Knowledge is in the wall

Training is only for the newbies

Greenfield

Disruption in development methodology

There is no wall

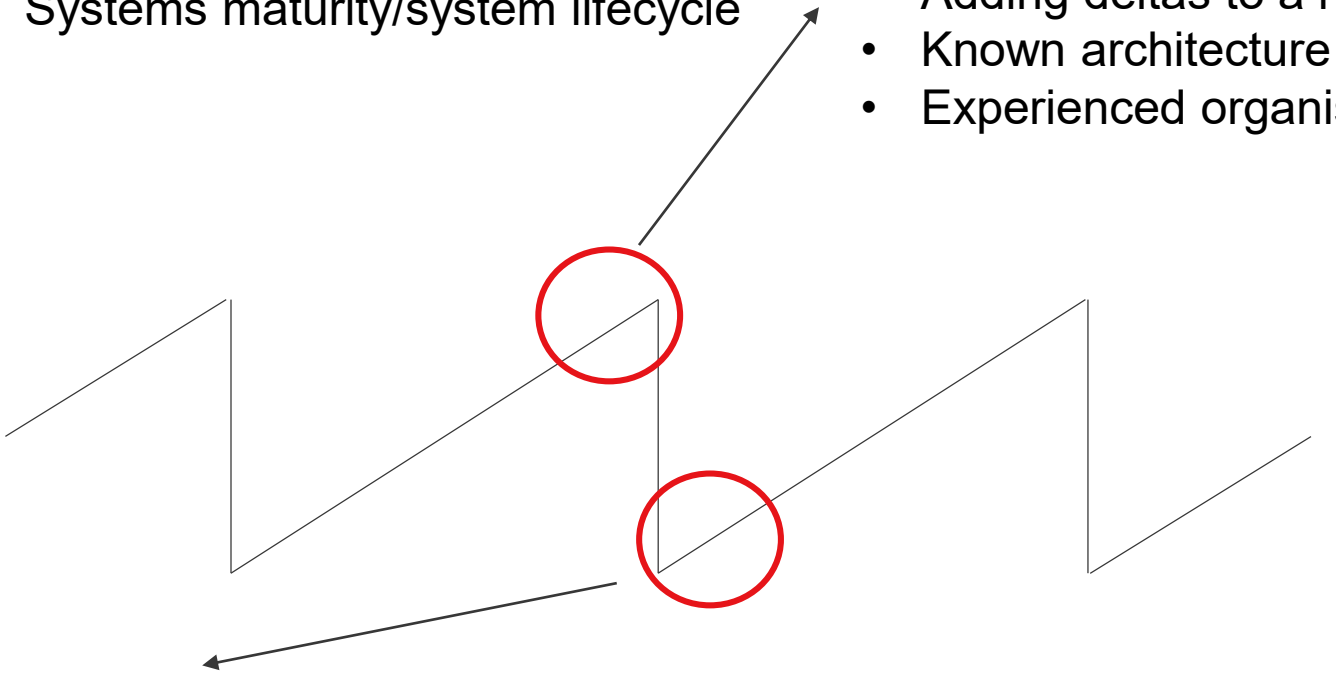
Training is a mechanism to build the new consensus

Mandatory for all roles

What was the real problem?

Transition from brown to greenfield

Systems maturity/system lifecycle



- Adding deltas to a highly mature system
- Known architecture and constraints
- Experienced organisation – in terms of brownfield development

- No baseline system available
- New architecture, constraints are not known
- Inexperienced organisation - in terms of greenfield development

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Take aways for engineering education

- It is the large scale and heterogeneity that makes difficult to develop CPS
- It is not about a tool or two
- Engineers need to be able to collaborate in inter-disciplinary teams
  - T-shaped engineering leaders
- The importance of communication
- Process and methodology over tools

- Life long learning – focus on strengthening technical leadership/ Systems Engineering related competencies