



Rolls-Royce

Evidence based Requirements Management

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- Evidence based Development (EbD)
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- Conclusions

Project Overview

- Large technically challenging project
- Total project value £11–£14 billion
- 4 key industrial partners:
 - MoD (customer)
 - BAES
 - Babcock Marine
 - Rolls-Royce
- Major design activities started 2007

Product Introduction and Lifecycle Management (PILM) Stages						
0	1	2	3	4	5	6
Innovation and opportunity	Preliminary Concept Definition	Full Concept Definition	Product Realisation	Production and in-service support	Continuing in-service support	End of life disposal



Rolls-Royce

Requirements Capture and Management (RC&M) and Systems Engineering (SE) in Rolls-Royce



RC&M and SE in Rolls-Royce

- **Drivers to improve design processes:**
 - Reduce the cost of rework attributed to poor Requirements Capture and Management (RC&M)
 - Reduce engineering and project risk
 - Reduce design lead times
- **Resulting work streams:**
 - Improve our Requirements Capture process
 - Increase our understanding of how we got to our design solutions:
 - The link between the design solution and requirements
 - The link between the validation evidence and requirements
 - The flow down of higher level requirements into lower level requirements
 - Centralisation of our configured engineering data
 - Improve the robustness of our solutions

RC&M and SE in Rolls-Royce

Lesson 1 - To map requirements decomposition and link this to evidence you will need a software tool

Why we picked DOORS

- Proven Industrial Standard Tool
- Enhanced Customer Integration
- Corporately approved tool
- Corporately approved implementation guidance and templates
- Significant user experience within our organisation

RC&M and SE in Rolls-Royce

Lesson 2 - Embed SE and RC&M best practice within your generic design process / QMS

Lesson 3 - Many System Engineering tools relate directly to best practice RC&M

Typical System Engineering Techniques / Tools	
Systemic Textual Analysis	Functional Means Analysis
Viewpoint Analysis	Architectural Modelling (N ² Analysis)
Functional Modelling	Failure Mode Effect Analysis (FMEA)
Sensitivity Analysis	Reliability Modelling (RM)
QFD (House of Quality)	Fault Tree Analysis (FTA)
Simulation and Optimisation	Whole Design Evaluation (Pugh Matrix)

RC&M and SE in Rolls-Royce

Lesson 4 - Good Requirements Capture and Management is based around 3 key facts:

- Requirements need to be captured, understood, agreed and managed throughout the product life
- Requirements require evidence to show they have been achieved
- Requirements need to be broken down into lower level requirements

Other business processes are essential to RC&M:

- Design and Technical Review / Governance Process
- V&V
- Change Control
- Risk Management
- Programme Management

RC&M and SE in Rolls-Royce

The following constraints are imposed by our process:

- Evidence shall be linked to your requirement to demonstrate how it has been satisfied



A “Definition” is simply your solution or a lower level requirement you are passing to a supplier (or other part of the business) to satisfy

Or more simply:



RC&M and SE in Rolls-Royce

Requirements shall be structured and flowed down through the following hierarchical structure:

- Environment layer
- Enterprise layer
- System layer
- Cross-plant (Product/System) layer
- Sub-System layer
- Component layer

So, how did we achieved this in DOORS for our project?



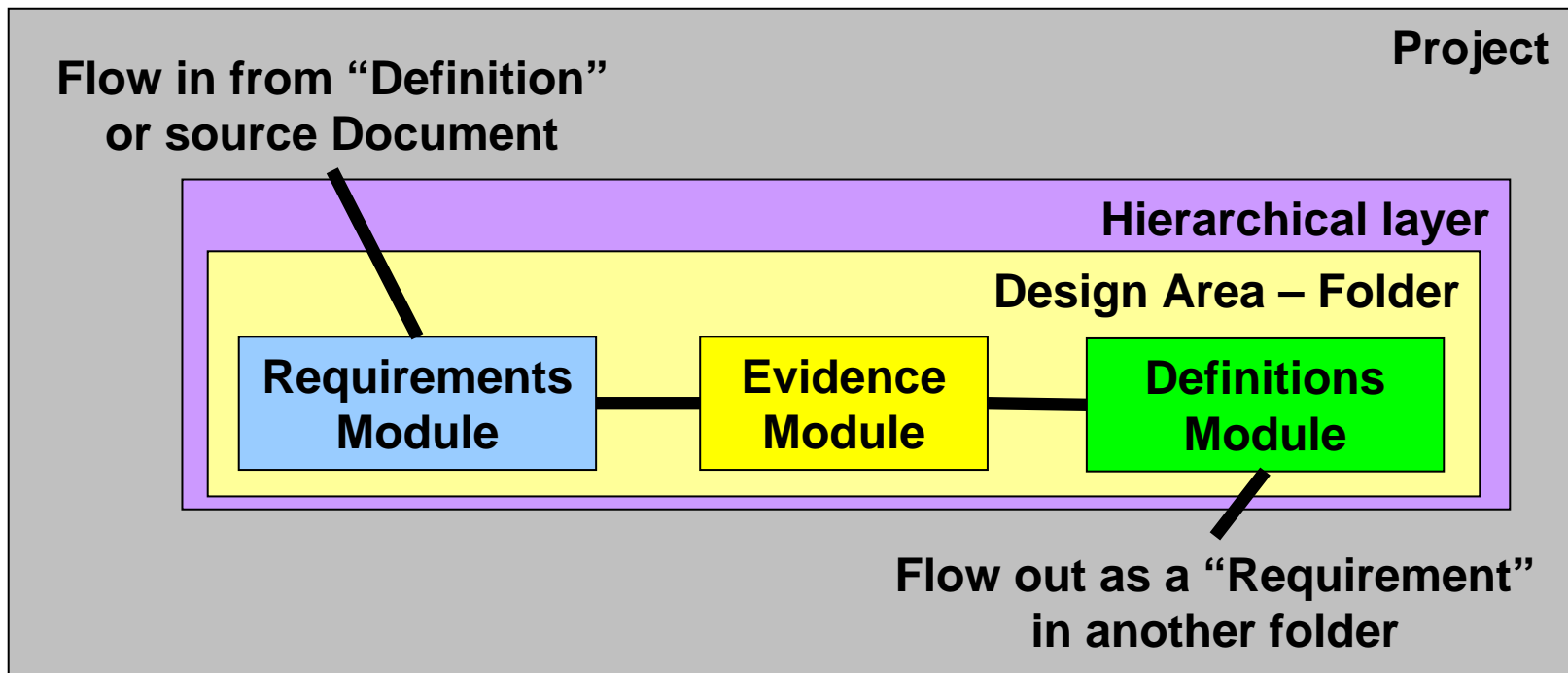
Rolls-Royce

Developing The Database Structure



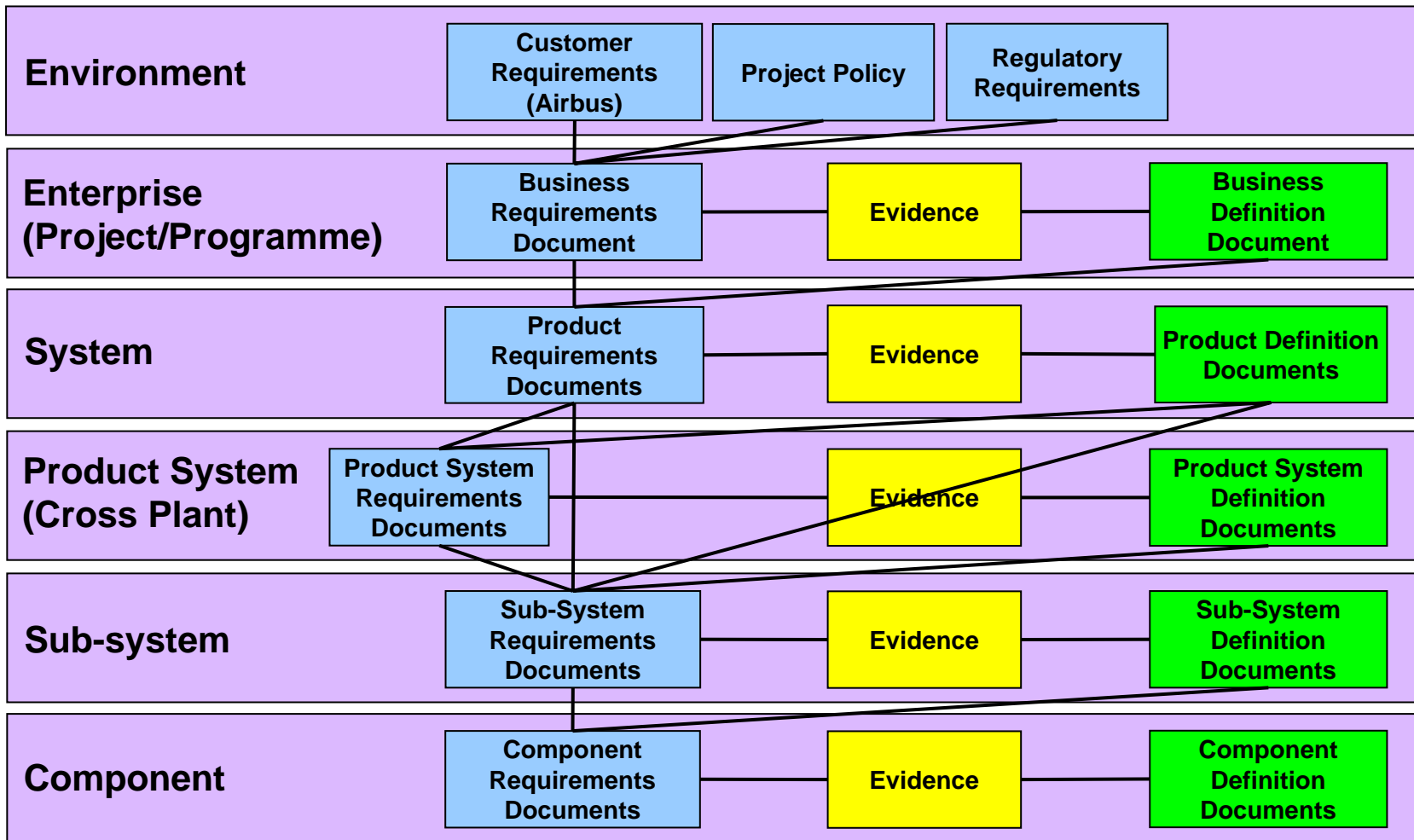
Developing The Database Structure

The basic model imposed by our process in DOORS



If you repeat this in the hierarchy imposed:

Developing The Database Structure



Developing The Database Structure

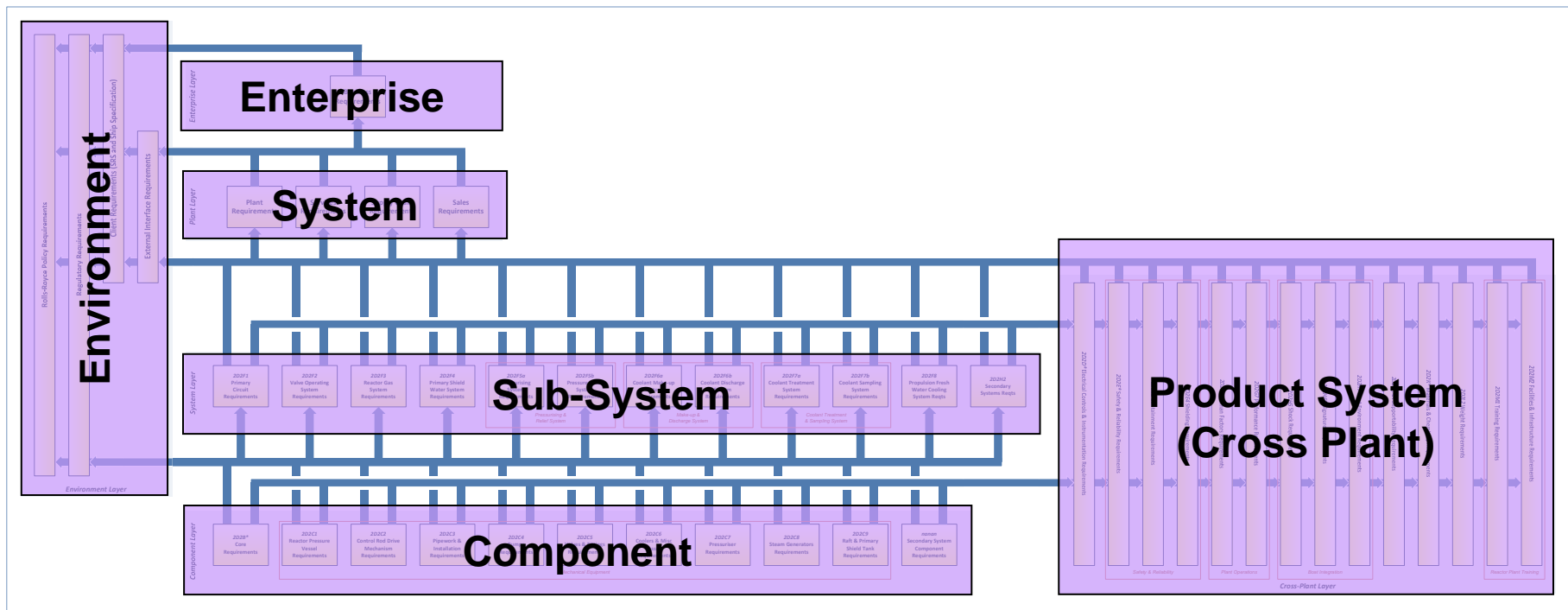
Lesson 5 – Develop a schema

Technical areas

Internal experts

Process

External consultancy



Developing The Database Structure

Lesson 6 – “Evidence” means different things to different people at different times!

- **DOORS can manage “Evidence” in different ways**
- **Several types of “Evidence” need to be managed:**

Design Decomposition Evidence

V&V Methods Evidence

V&V Results Summary

Satisfaction Evidence Summary

Test Results / Test Reports

Allocation Evidence

- **“Evidence” is time based**

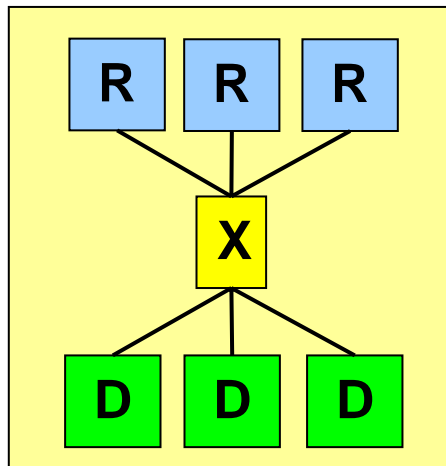
Developing The Database Structure

Managing “Evidence”

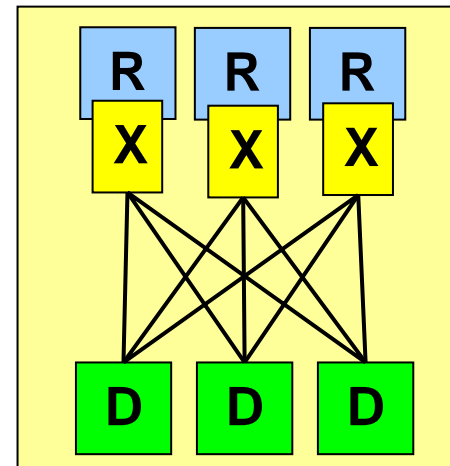
- Maximise the use of attributes to define fixed (essential) information
- Minimise the modules / folders
- Minimise the links

However, certain relationships are easier to manage with links:

“X” managed by
links = 6 links

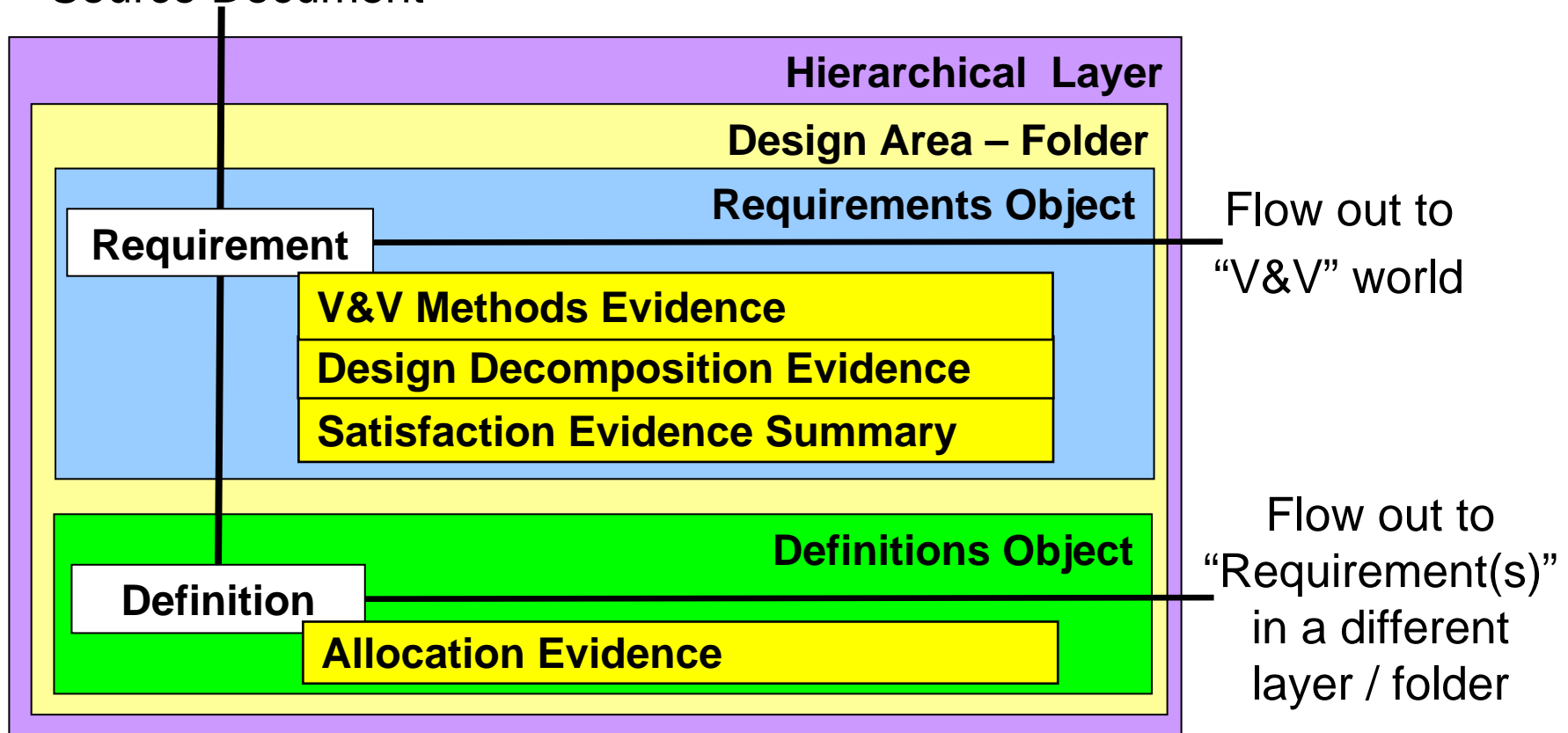


“X” managed as an
Attribute of “R” = 9 links



Developing The Database Structure

Flow in from a
“Definition(s)” or
Source Document

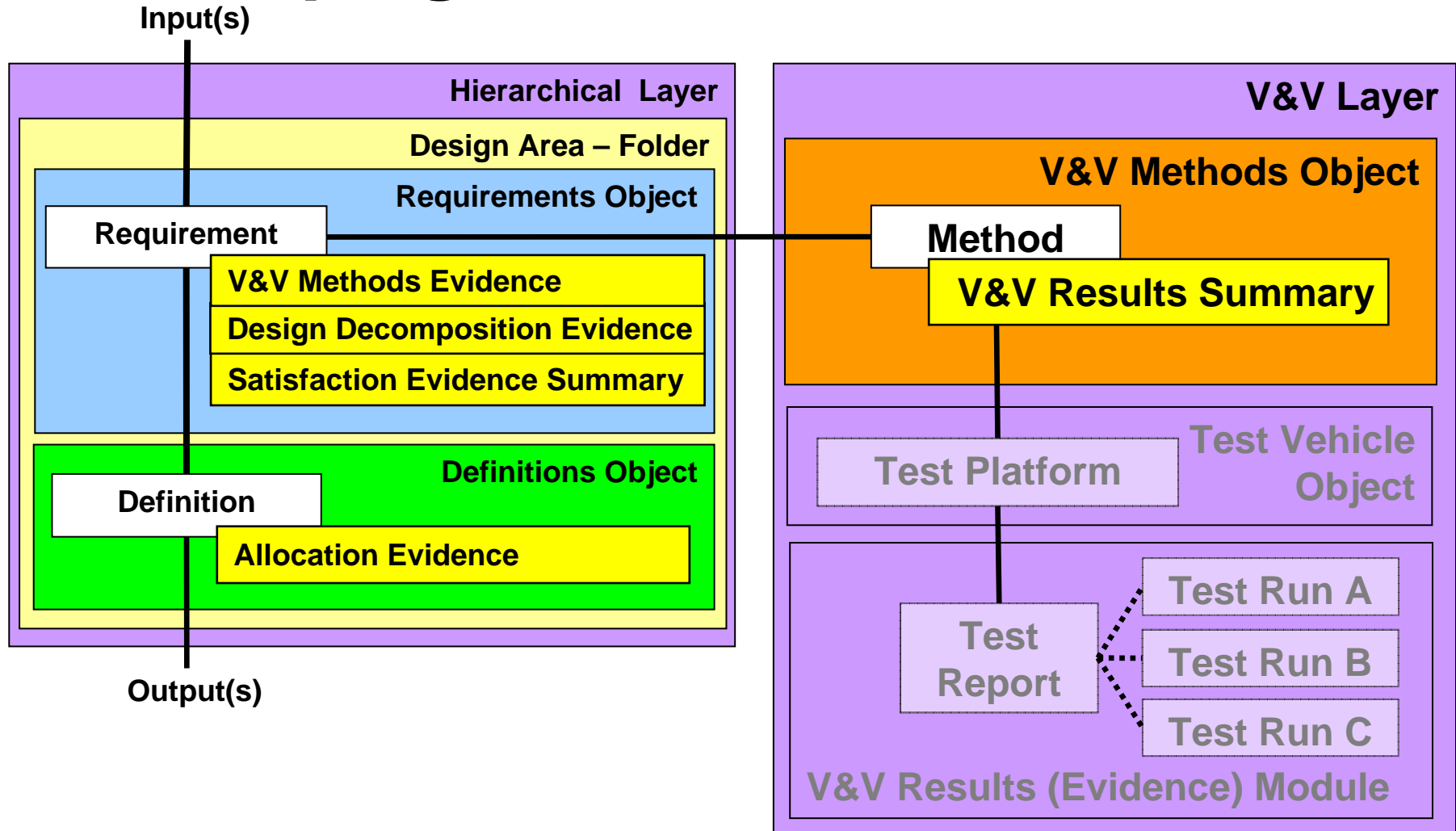


Developing The Database Structure

Lesson 7 - It was unclear how V&V is represented in the structure

- **V&V has a relationship with 2 types of “Evidence”**
 - Satisfaction
 - Decomposition
- **V&V is achieved by different methods**
- **V&V requires a different view of the world:**
 - View by Rig or test vehicle (engine)
 - View by similar methods
- **V&V methods need to be justification (Methods Evidence)**
- **V&V is time based**
- **V&V can be managed in different ways depending on the relationships**

Developing The Database Structure





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The Micro Models and Rules

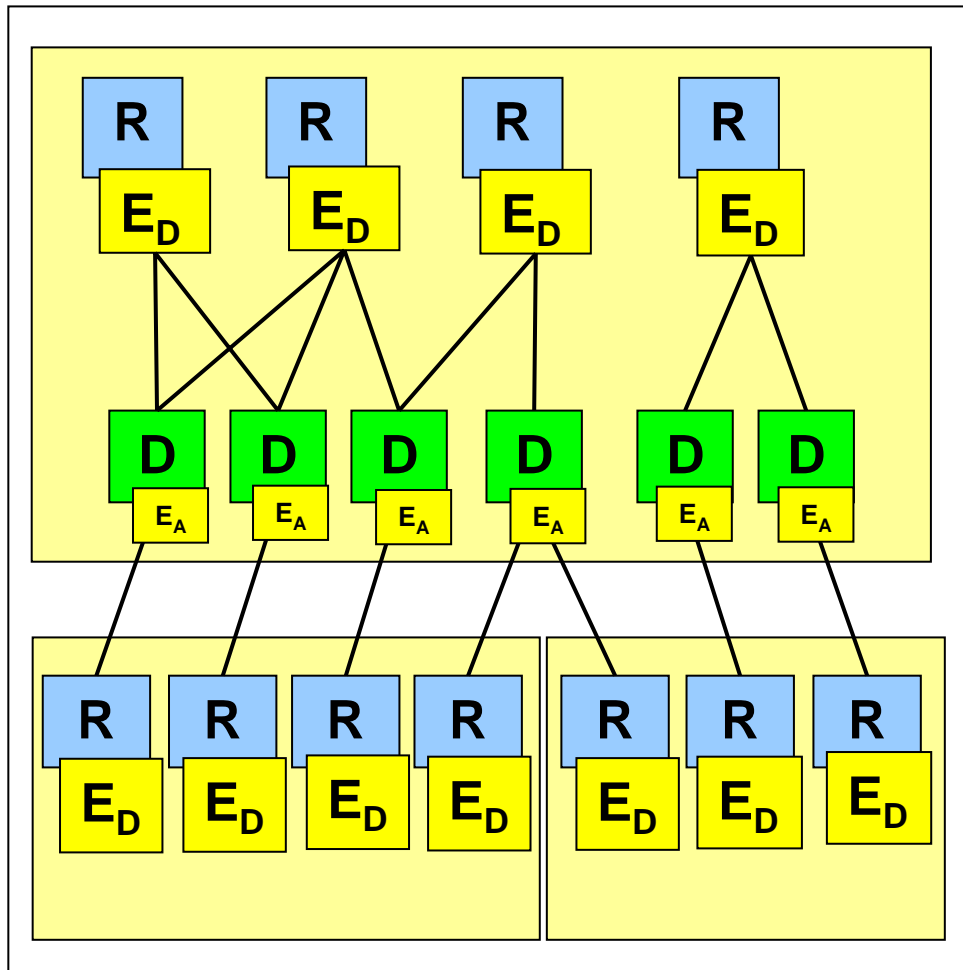


Developing Micro Models and Rules

- **Three micro-processes where identified:**
 - R-E-D } Design Decomposition
 - R-E-R } Design Decomposition
 - R-E-V - V&V planning
- **DOORS Configuration and DXL scripts used to:**
 - Enforce the models when populating the database
 - Review and report data errors (orphans, uncompleted attributes, etc)
 - Review and report statistics (users, changes, status)

Uniformity, Consistency, Familiarity

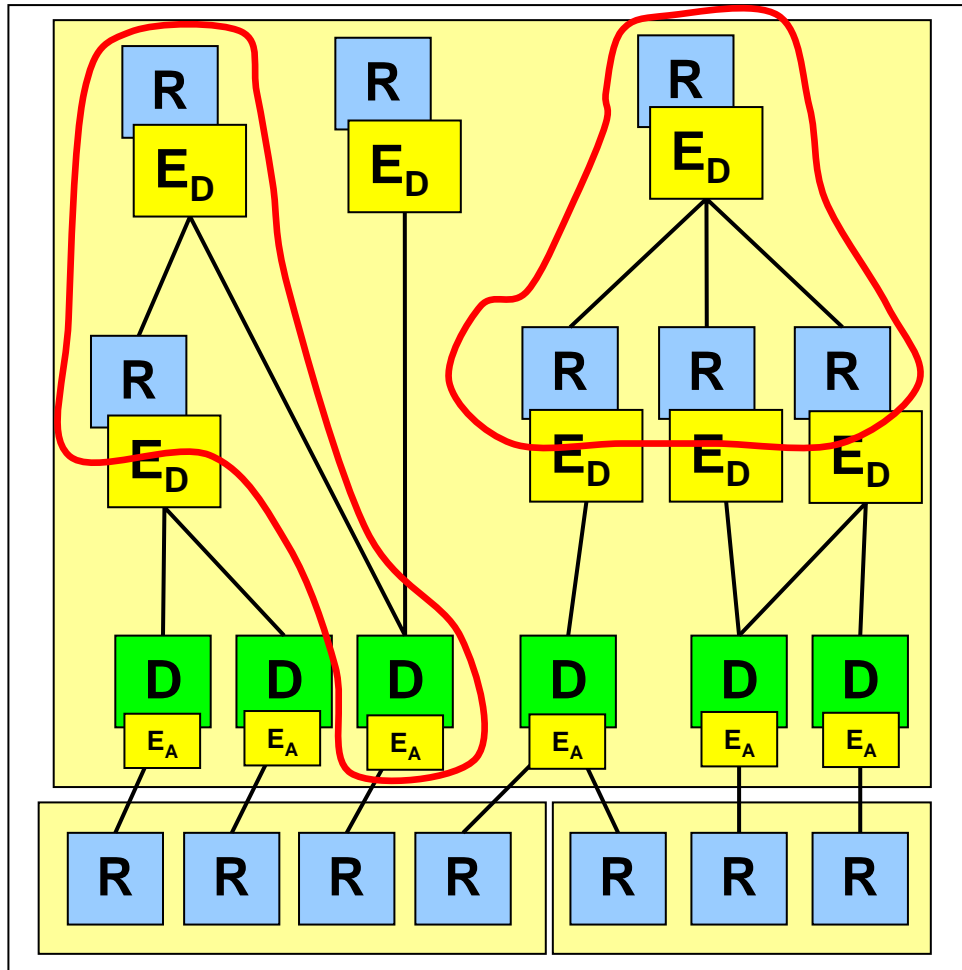
Developing Micro Models and Rules



R - E - D

- Discover your requirements (R)s
- Work out how best to decompose / deliver them
- Write it down as your Decomposition Evidence (E_D)
- Develop your lower level Definitions (D)s
- Provide allocation evidence
- Allocate these Definitions as Requirements onto your “suppliers”
- Repeat at the level below

Developing Micro Models and Rules



R - E - R

- R-E-R Links
- Mixing R-E-R and R-E-D

Rules:

All decomposition requires evidence (E_D)

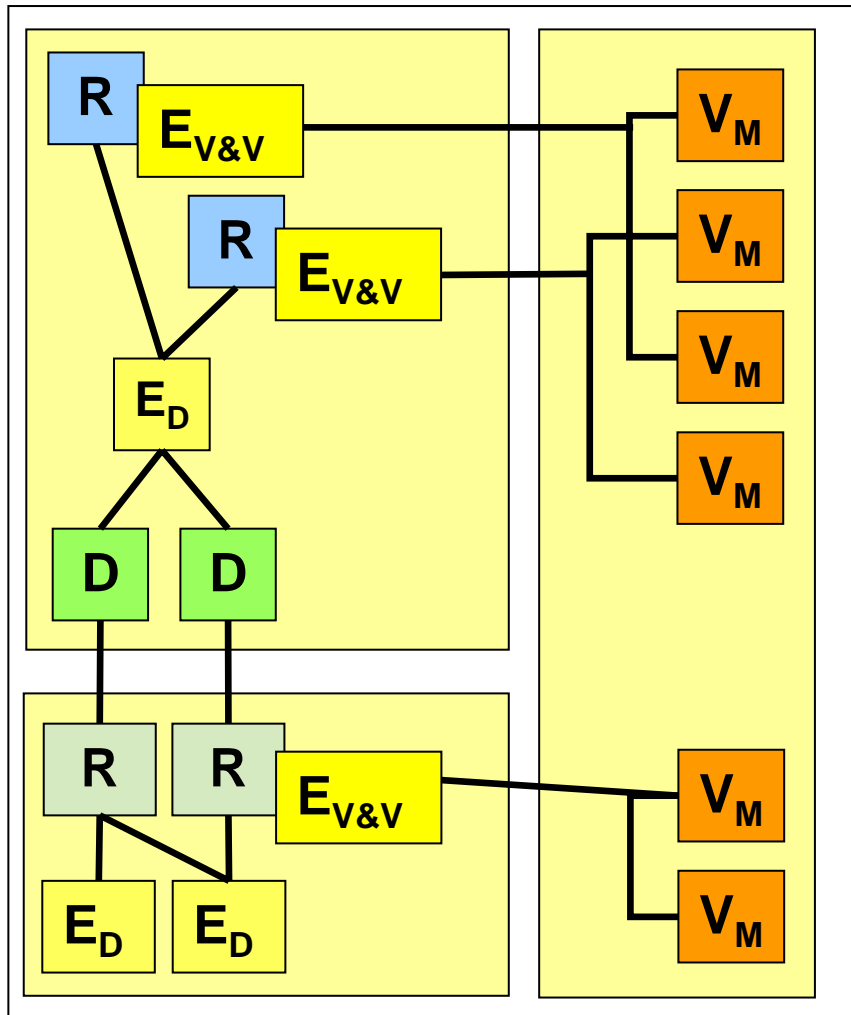
Only “D”s can flow out of a folder

Only “D”s require allocation evidence (E_A)

“R” must be identical to linked “D”

“R” to “R” links within a module

Developing Micro Models and Rules



R - E - V

- Using your requirements (R)s
- Define the Method(s) you need to provide satisfaction or support your design decomposition (V_m)
- Capture the logic / reasons the methods are appropriate ($E_{v\&v}$)
- Repeat at the level below

Rules:

All V&V methods require evidence
 All V&V methods must link to a requirement



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Implementation / Conclusions



Implementation / Conclusions

- **Training**

- **Key user training:**

- Foundation (1 Day)
 - Practitioner (1 Day)

- **User training:**

- Rolls-Royce Basics (0.5 Day)

- **All users project specific training**

- **Super-users / mentoring**

- **Improving visualisation - TraceLine**

- **Process documentation**

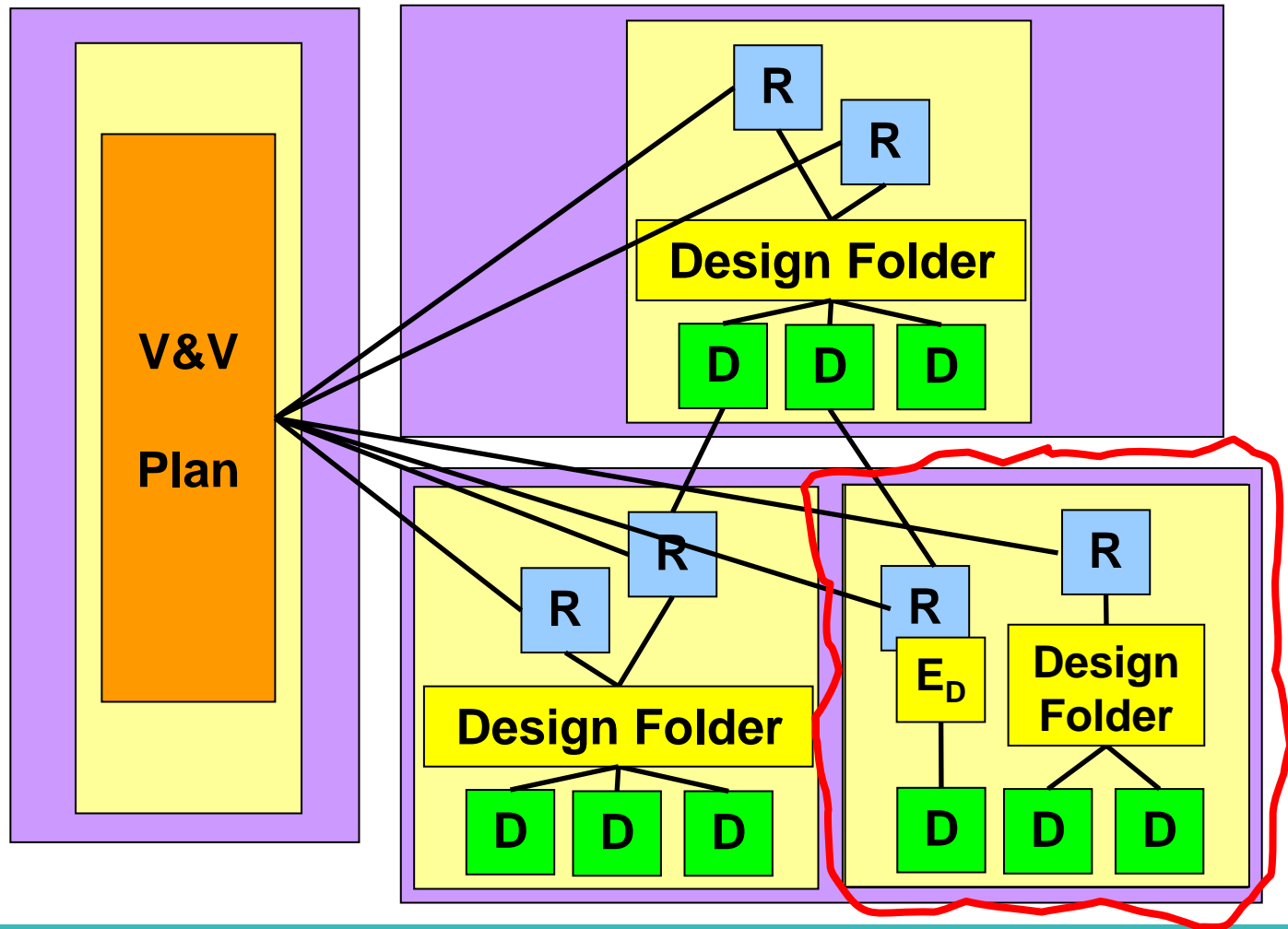
Implementation / Conclusions

- Don't underestimate the impact of implementing explicit (rich) traceability
- Implementation timing is important:
 - Information needs managing as soon as economical
 - Start top down, add structure as solution develop
 - Manage and plan your V&V

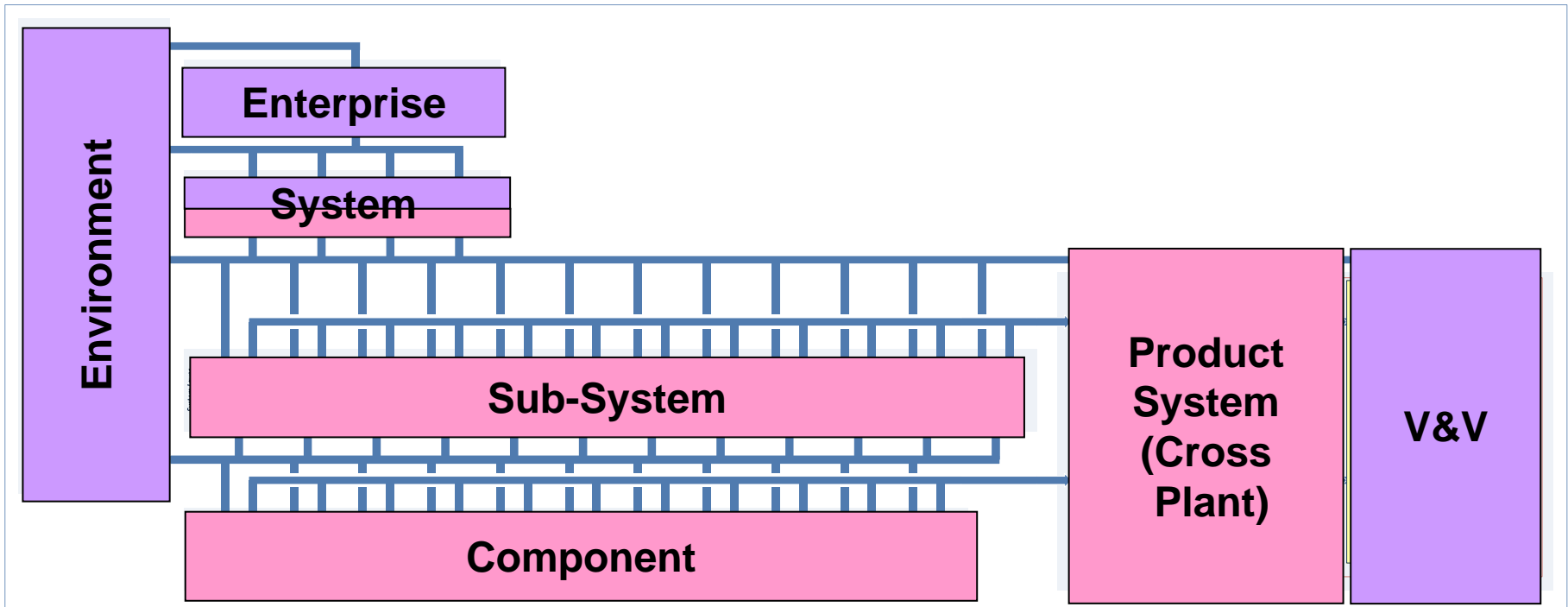
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- Implementation success
- Be pragmatic and keep an open approach

Implementation / Conclusions



Implementation / Conclusions



Full Explicit Traceability

Area by Area Flow Down Traceability



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Part 2 - Lessons Learnt From Consultancy

Evidence Based Development



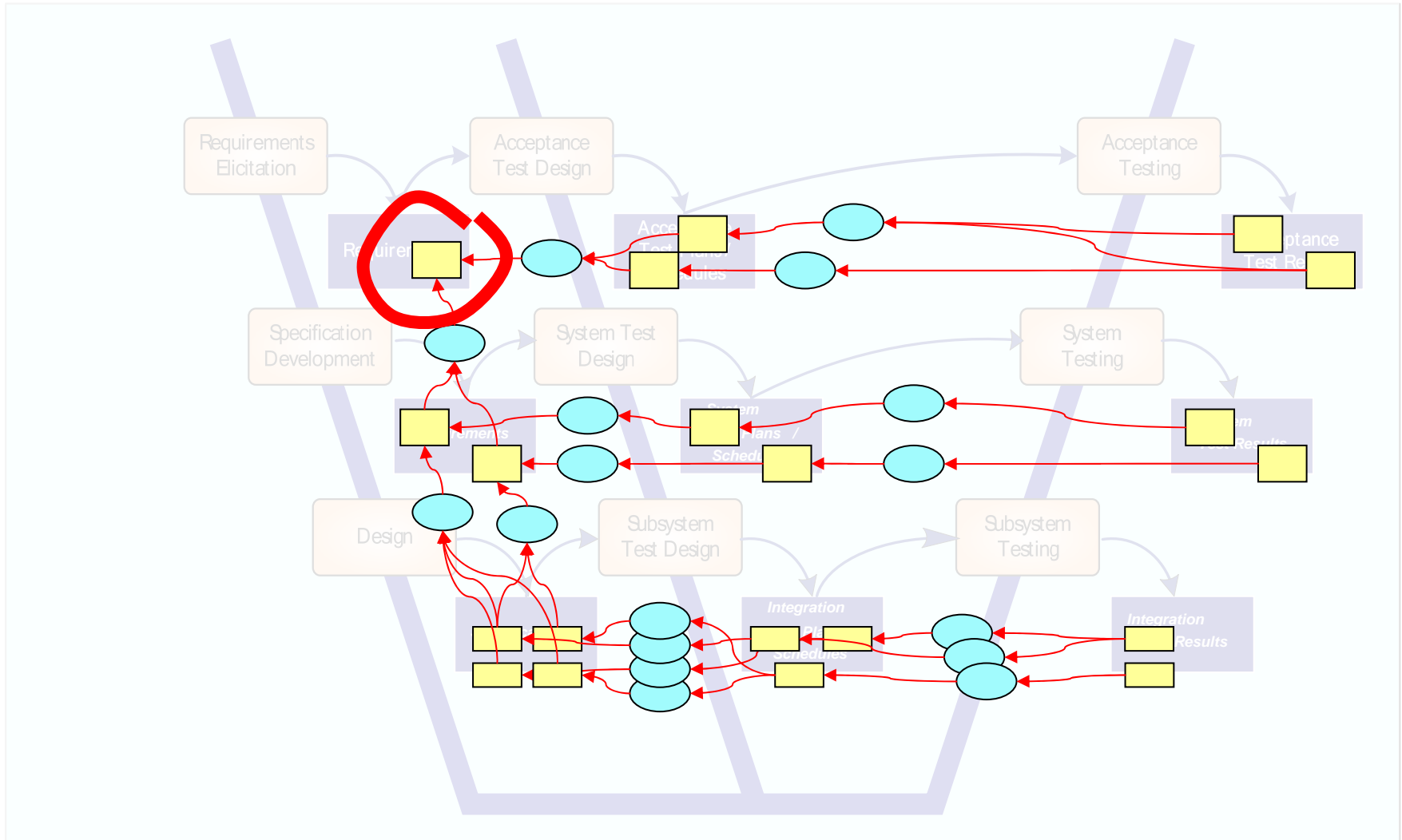
Evidence-based Development™

- **Rolls-Royce corporate process has much in common with integrate's “Evidence-based Development”**
 - Collection of evidence around “rich tracing”
 - Evidential backbone
 - everything hangs off it
 - Incremental assurance

EbD[®] - Benefits

- **Progressive assurance**
 - Growing body of evidence for fitness-for-purpose
- **Allows evidence to evolve over time**
 - Intention and fulfilment
 - Broad range of analysis techniques
- **Uniform approach**
- **Improve integrity and cost-effectiveness of certification**

EbD[®] - Collection of Evidence





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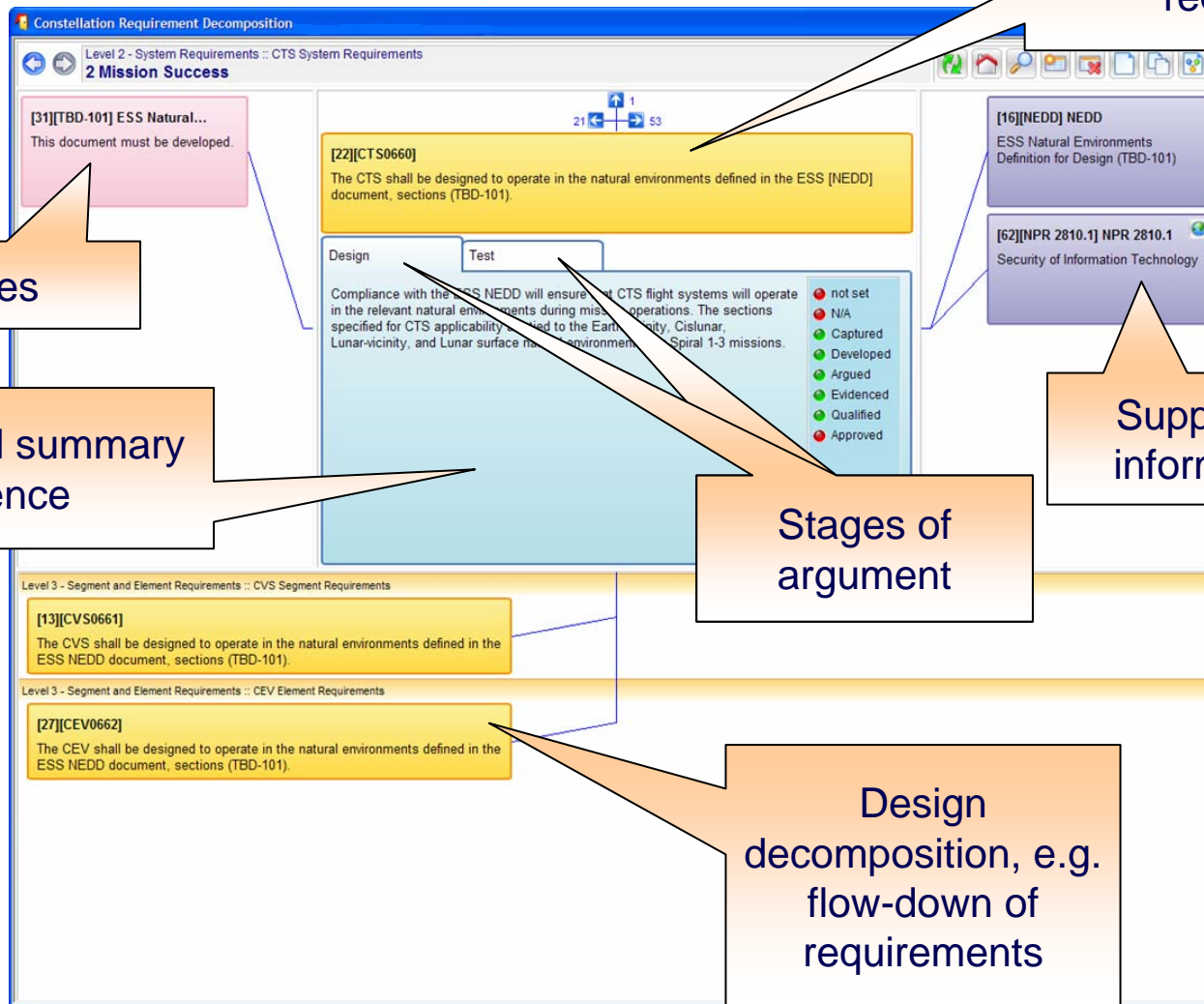
TraceLine for DOORS



TraceLine for DOORS

- **Tool extension that supports Evidence-based Development**
- **Alternative interface**
 - Graphical
 - Intuitive, browser-style
- **Supports collection of evidence around a requirement**
 - Multi-dimensional, e.g.
 - decomposition, verification

TraceLine for DOORS





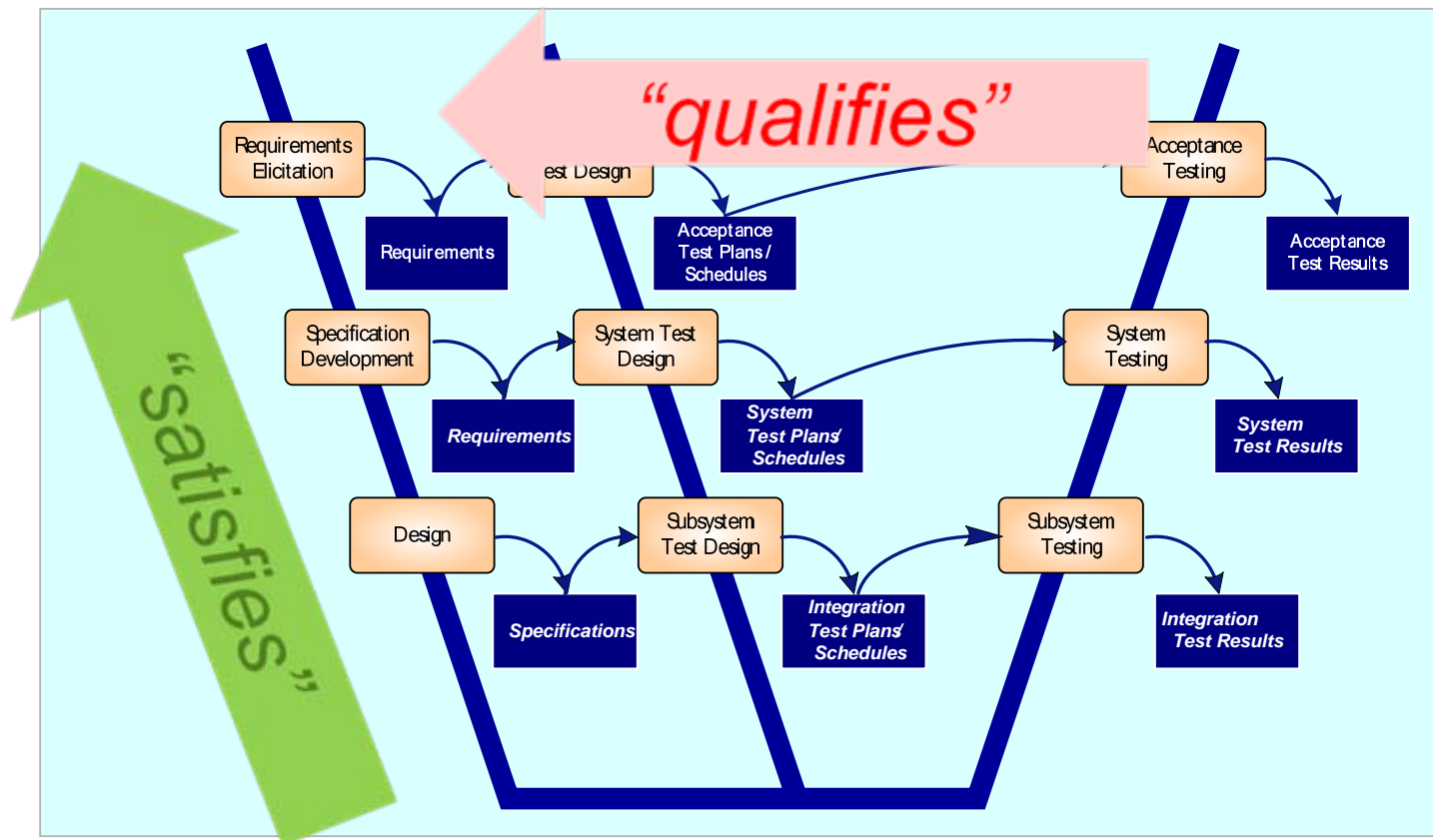
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Terminology

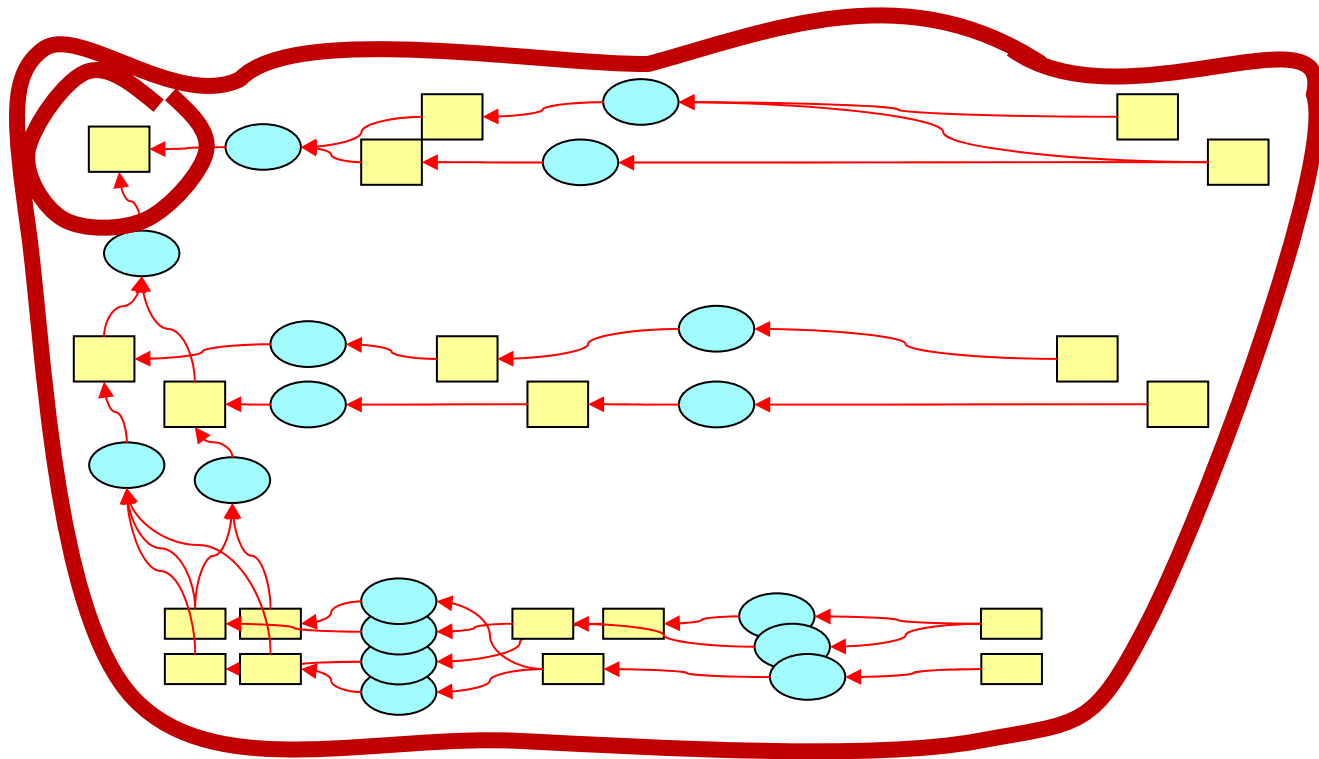


Terminology - What We Learnt

- Traditional terminology:

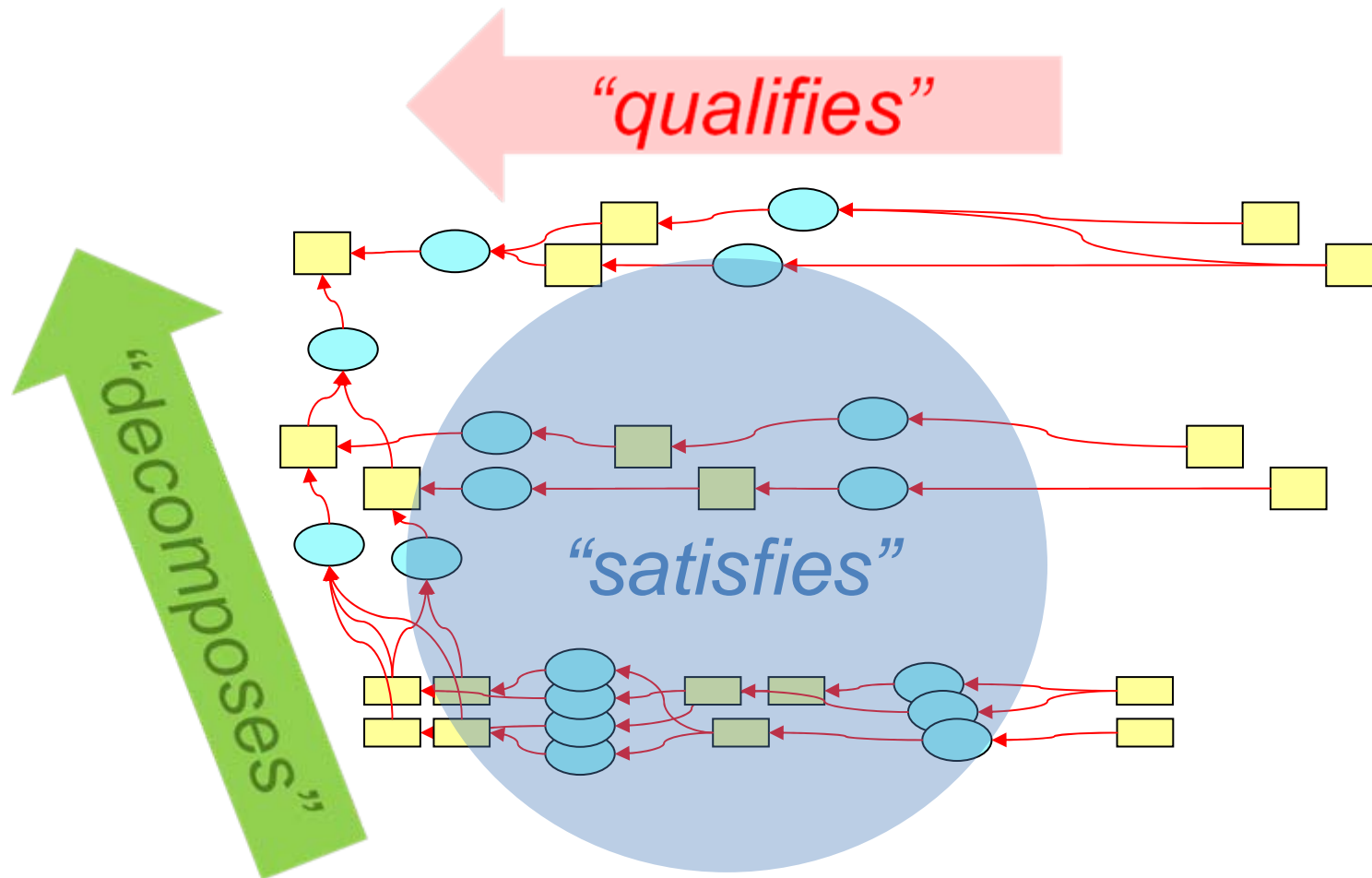


Terminology - Assessing Satisfaction?



All this supports satisfaction

Terminology - Adjustments





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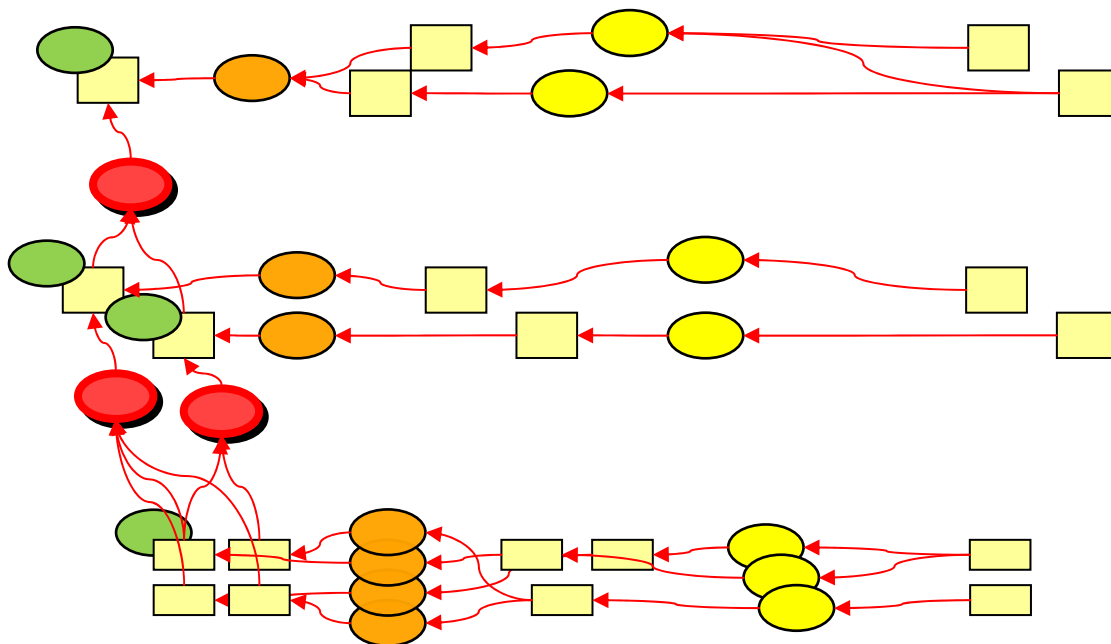
Kinds of Evidence



Kinds of Evidence

- **Decomposition argument**

- Why is the set of decomposed requirements right?
- Argues for correctness of the intended design

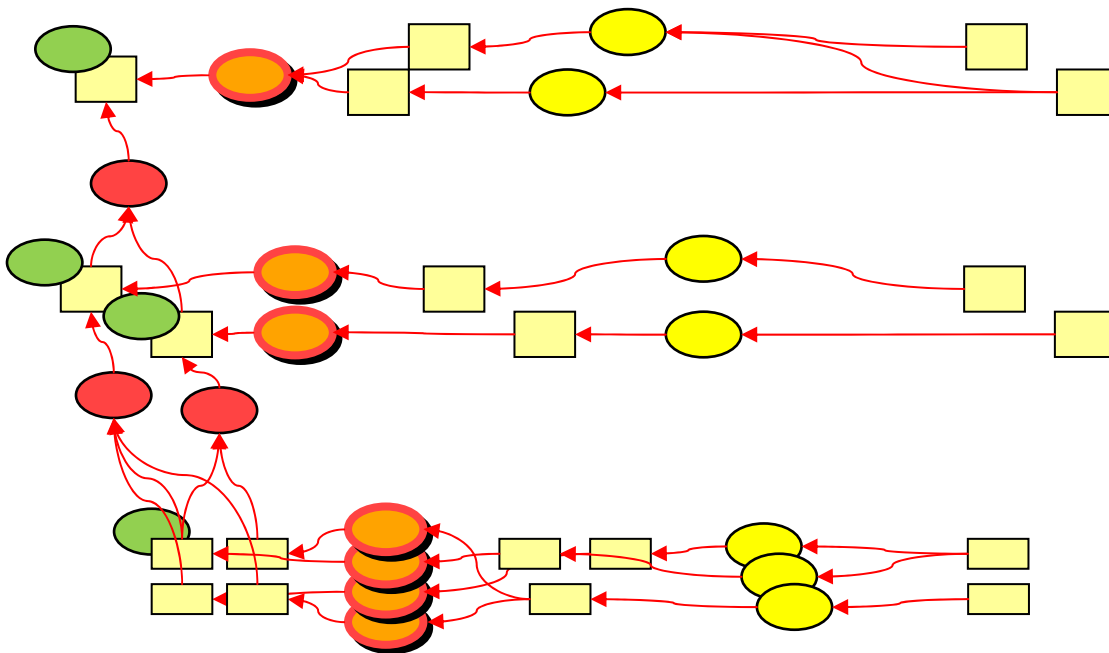


legend



 decomposition evidence

Kinds of Evidence

- **Qualification planning argument**
 - Why is the set of qualification actions right?
 - Argues for the intended qualification plan

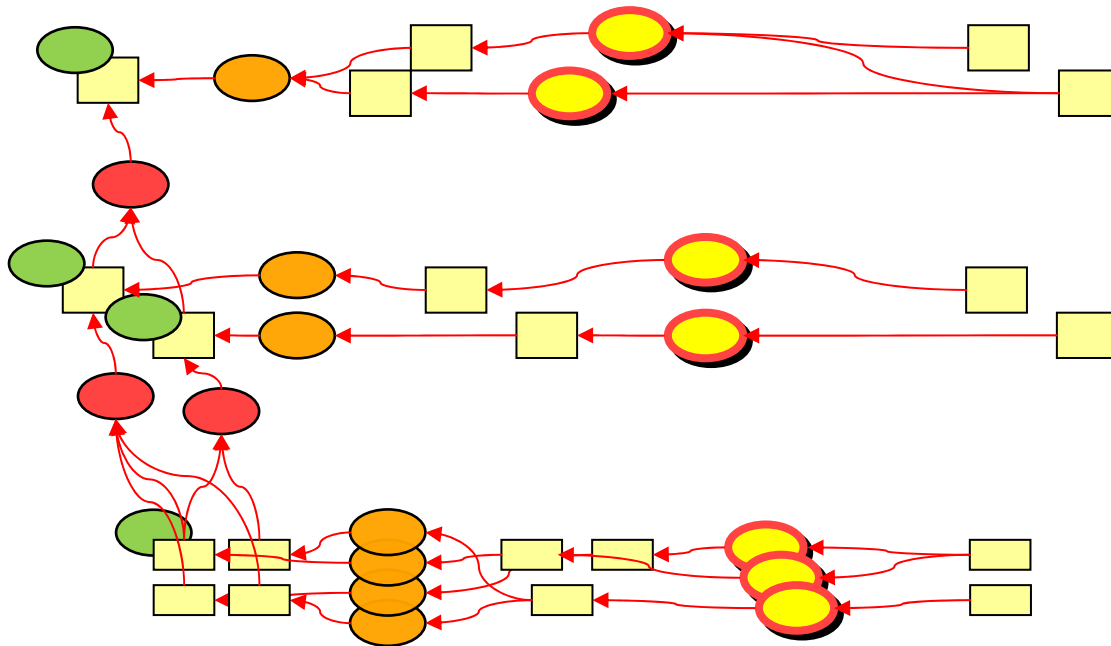


legend




-  decomposition evidence
-  qualification evidence

Kinds of Evidence

- **Qualification outcome argument**
 - Summarises evidence for correct outcome
 - Records fulfilment of test results



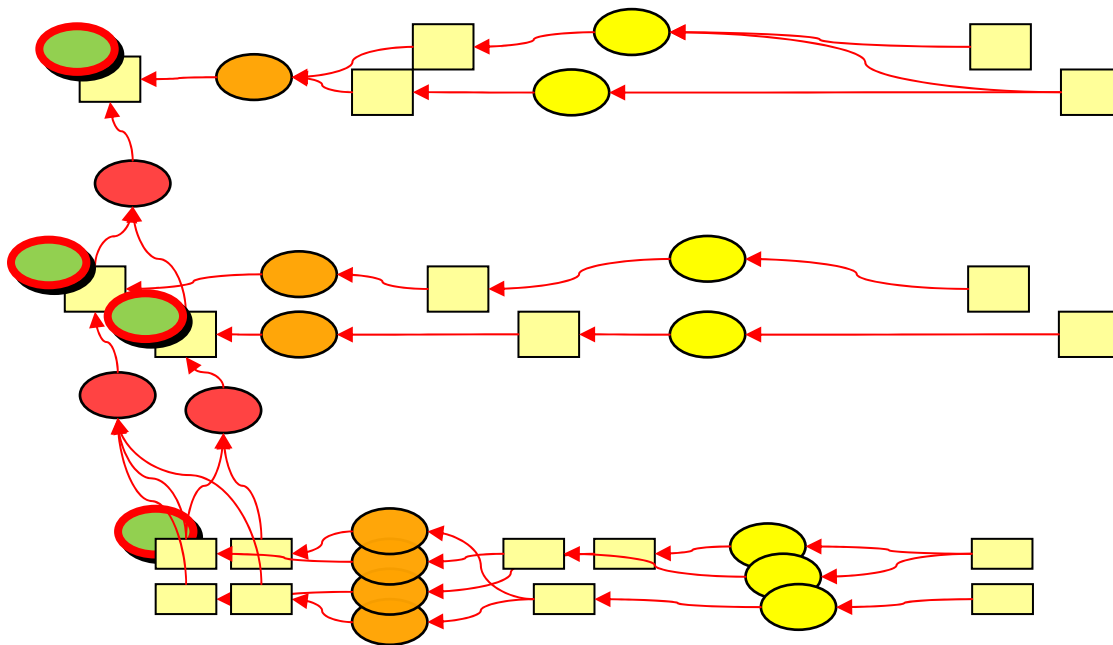
legend

-  decomposition evidence
-  qualification evidence
-  results evidence

Kinds of Evidence

- **Satisfaction argument**

- Summarises evidence for satisfaction or requirement
- Culmination of verification and validation



legend

- decomposition evidence
- qualification evidence
- results evidence
- satisfaction evidence



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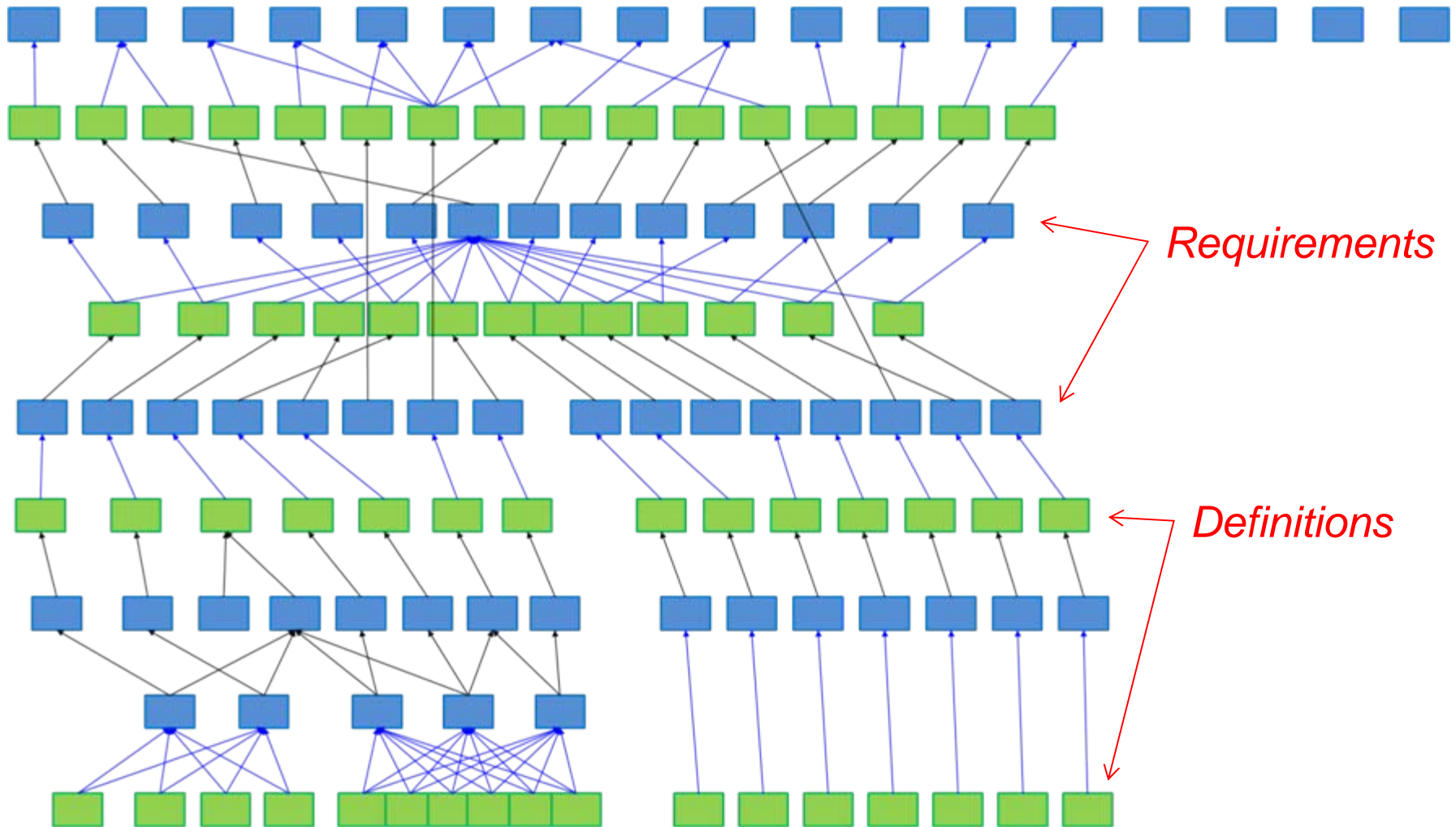
Flow down



What We Learnt – Flow down

- **How do requirements flow down?**
- **Working with real data has provided insights**

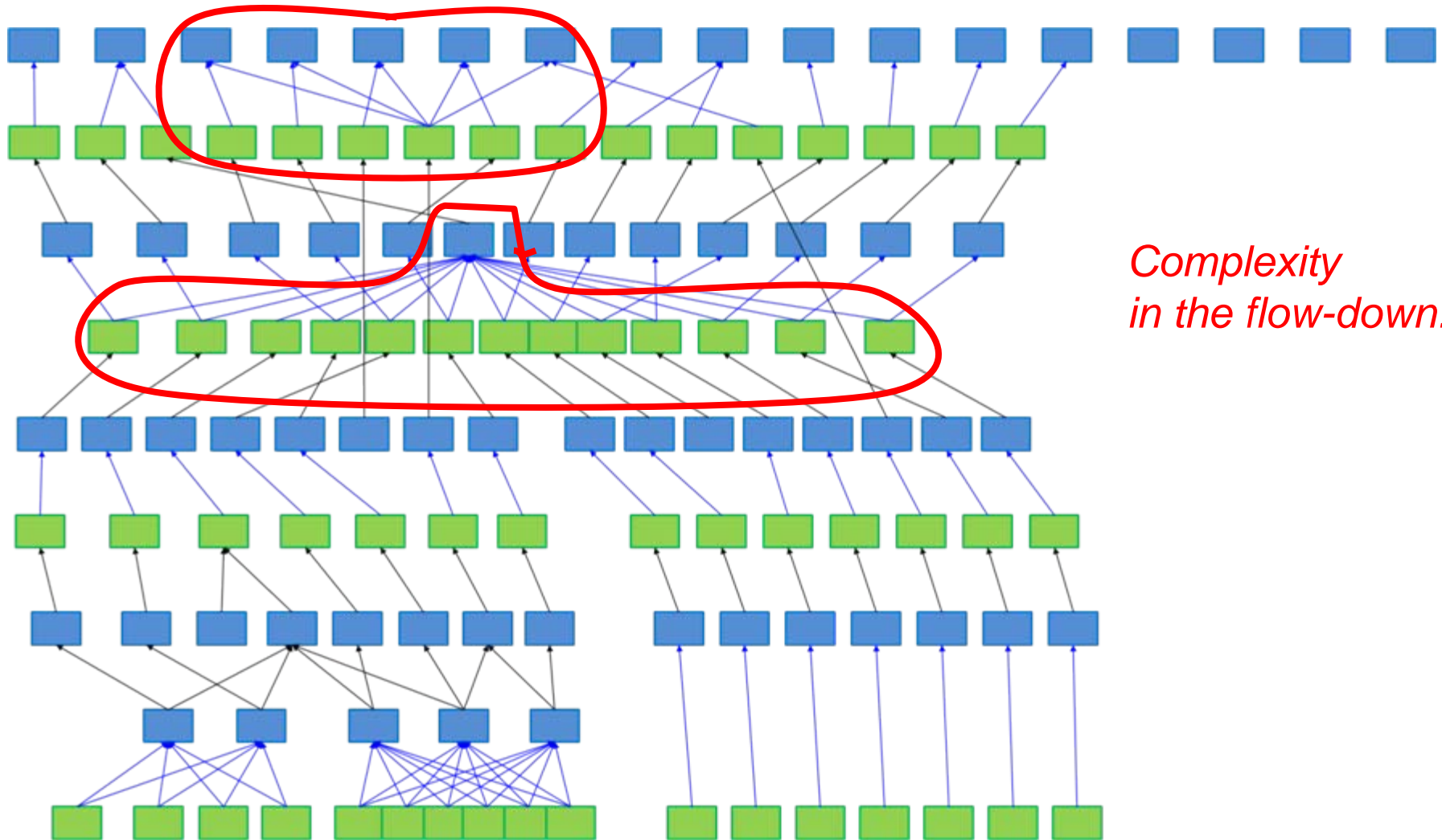
Flow down Example



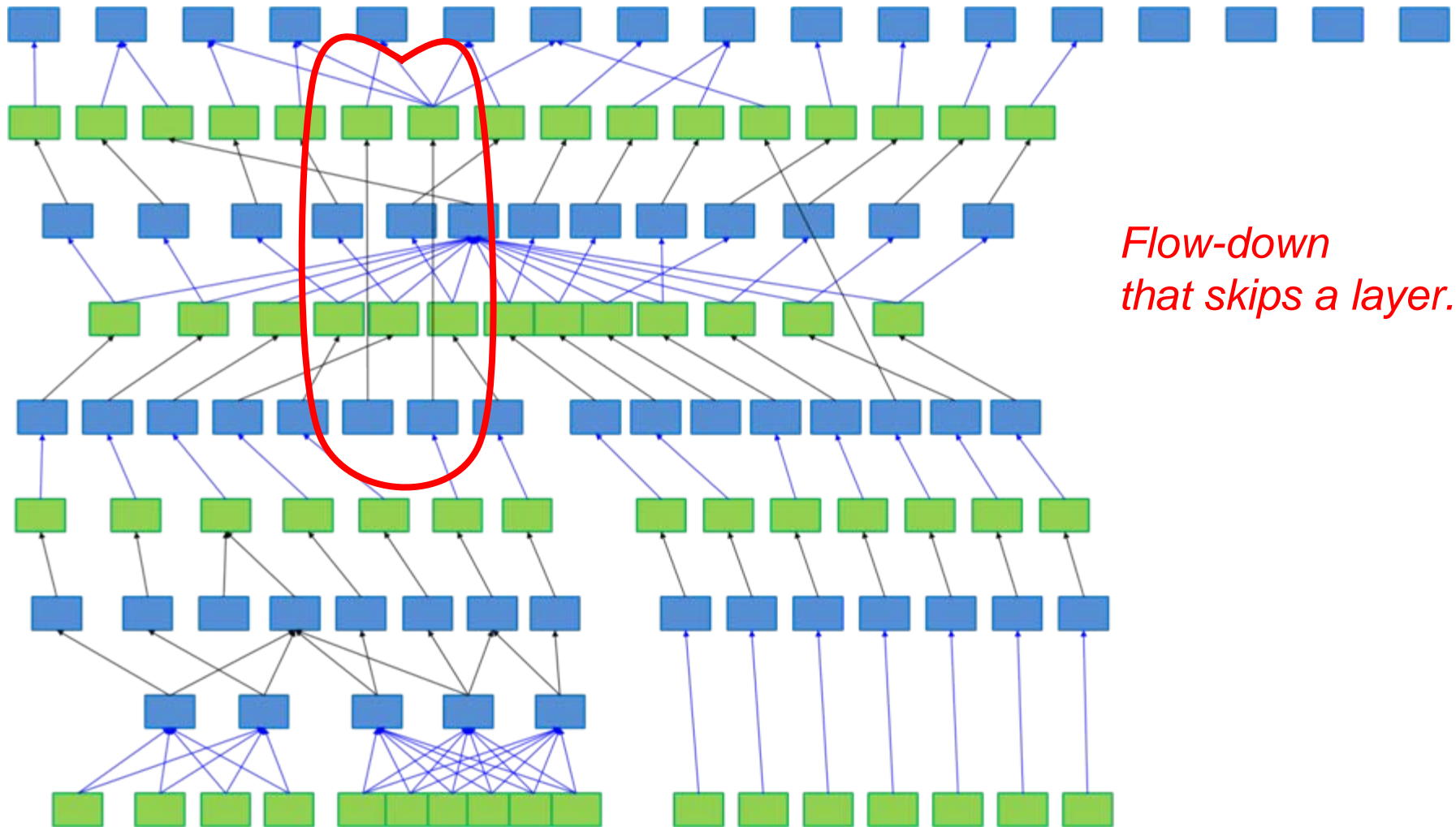
Flow down Example



Flow down Example

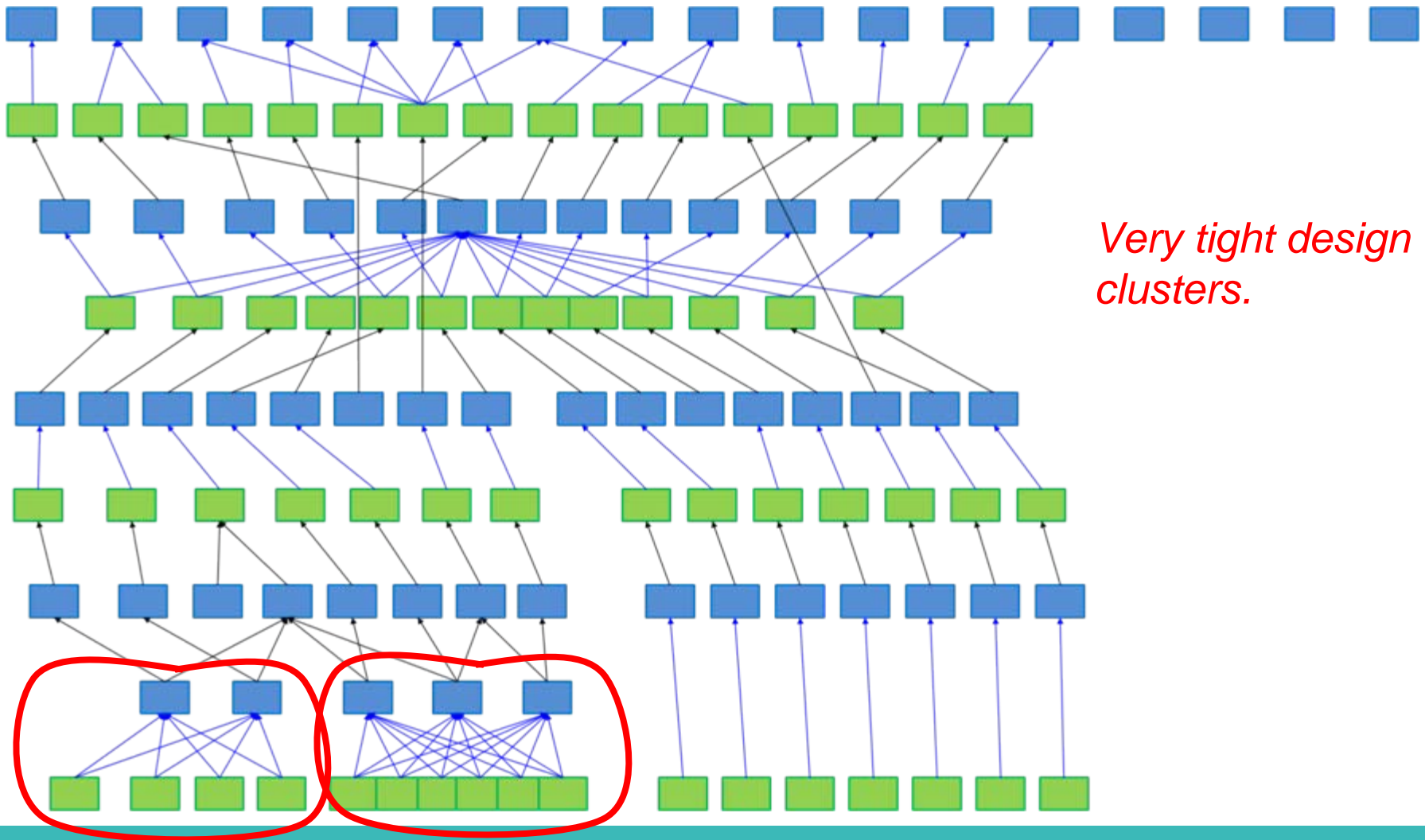


Flow down Example



*Flow-down
that skips a layer.*

Flow down Example





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Conclusions



Conclusions

- **The Rolls-Royce project demonstrates a major implementation of Evidence based Development**
- **Applying this approach in a real project environment is providing lessons**
 - Getting the terminology right
 - Learning about requirements flow down



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Thank you – Any questions?

