

Intelligent Testing

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Systems Verification**

Rolls-Royce plc



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Intro

Getting on a plane...



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A passenger complained that £75 was too much. He was farmer. He had a top-line tractor.....

Jet Engine

~\$5 million

Pulls - 300 tonnes

0-175mph - 21 secs

0-2000ft - 40 secs

0-10000ft - 5 mins

Climb to - 30,000ft+

Top speed - 500 mph +

Temperature from +50 to -60 °c

18 hrs/day

Tractor

~\$0.5 million

Pulls 30 tonnes. Perhaps.

0-175 mph - No

0-2000 ft - an afternoon up a windy road

0-10000 ft N/A in Somerset

Climb to – top of the hill.

Accelerate to - 40 mph?

Temperature from +50 to -60 °c (but not
in the same day!)

18 hrs/day



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Complex environment

Complex system – Bill Gates said there is probably no development as complex as the development of a civil jet engine.

Much of the control and safety is handled by software

Safety is #1 priority

How does the testing help to achieve this?



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Total control

Control of design, implementation and testing

Testing needs to be:

- Thorough (all software tested)
- Effective (all functionality tested)
- Affordable (cannot have team of millions)
- Achievable (needs to finish before first flight)

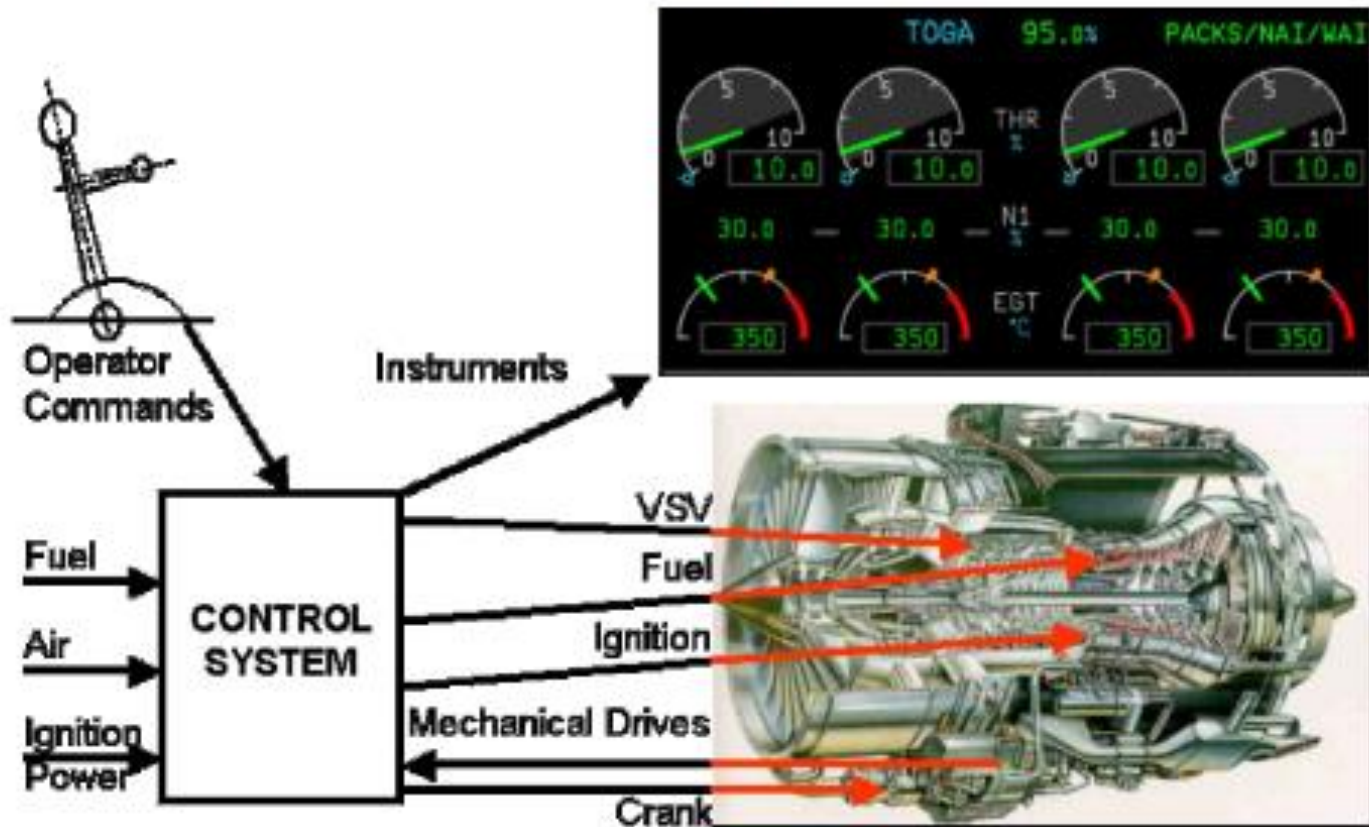
Also - we have total responsibility for suppliers and supplied components.



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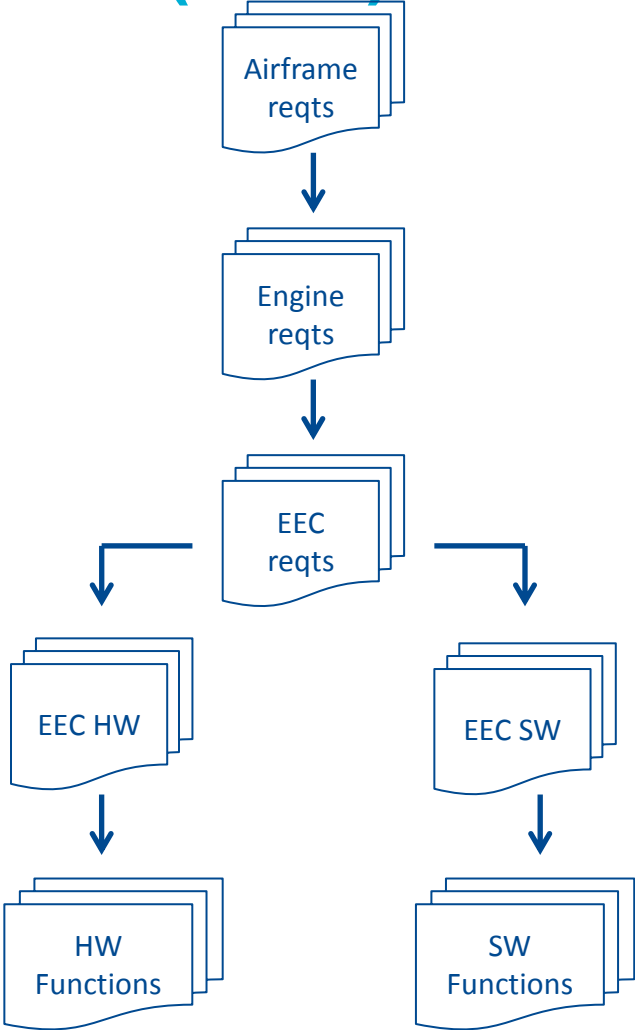
Electronic Engine Controller (EEC)



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Design Structure (ideal)



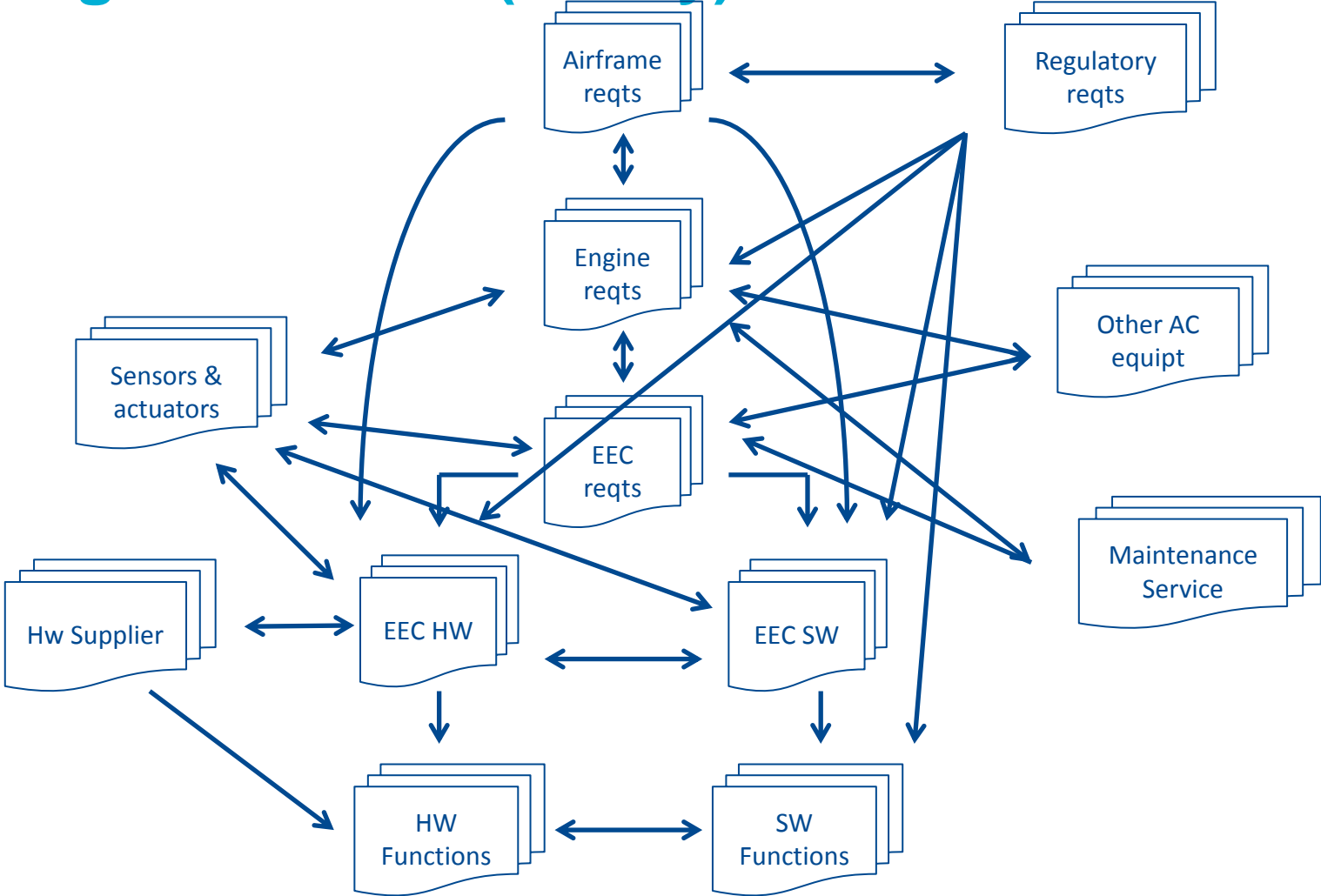
EEC – Electronic Engine Controller



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Design Structure (reality)



EEC – Electronic Engine Controller



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Constraints

- Aircraft first flight date is committed
- Fuel consumption must be >5% better than previous generations, therefore tolerances probably tighter and more functions than before
- Cost is committed



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Testing

Software testing crosses several boundaries:

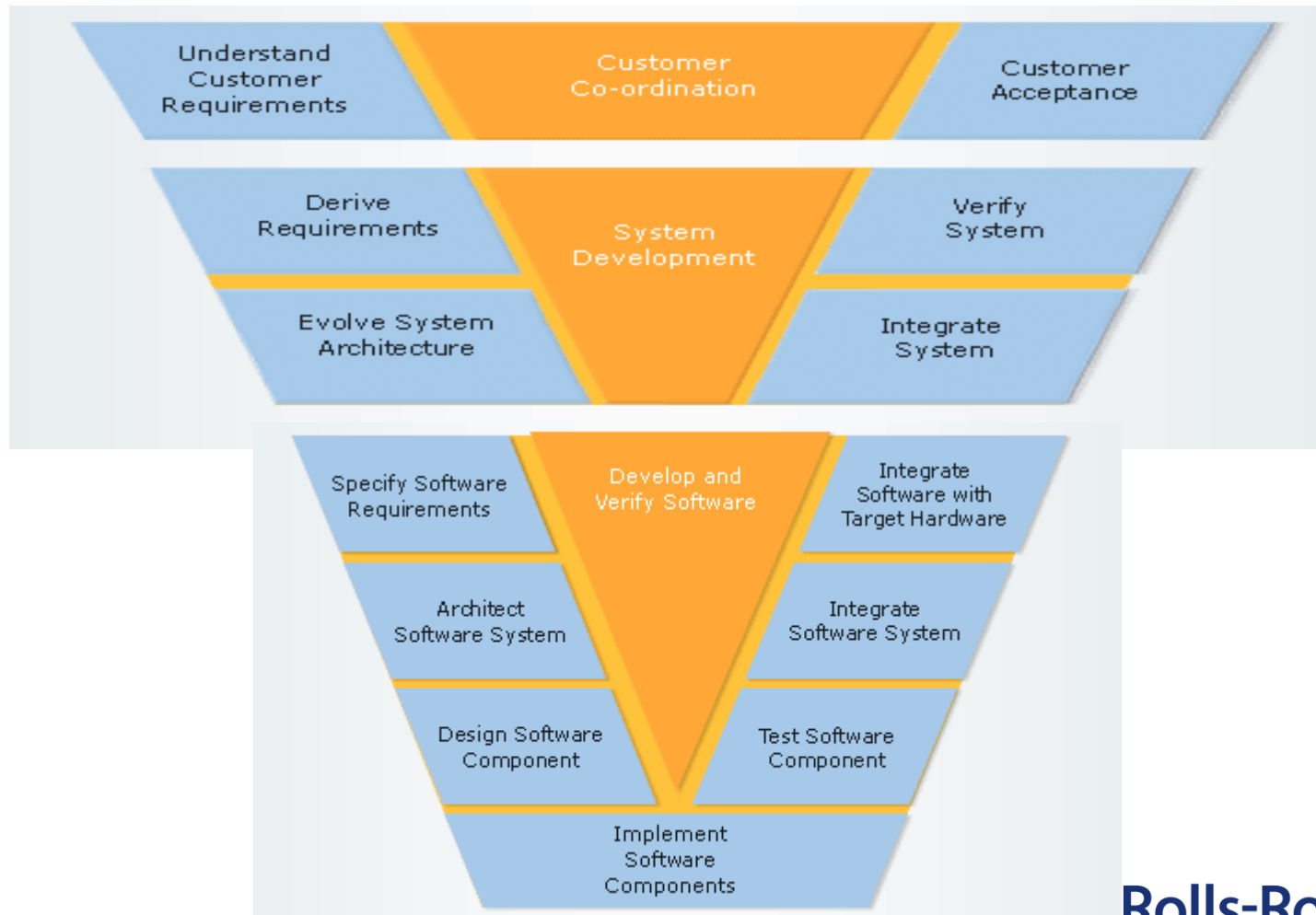
- Hardware testing
- System testing
- Engine testing
- Flight testing



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Validation V – testing at various levels



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Divide and conquer:

- Test requirements at suitable level, but also have ability to pass up or down
- Testing at higher levels costs more, and occurs later in the programme, so emphasis on testing early and low, (and repeating with lower risk at higher level)
- Need to track results passed up or down
- Need to track results tested across multiple vehicles
- Do requirements need to be tested at every level?



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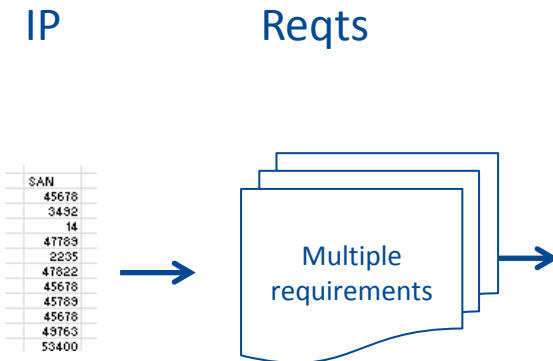
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Structured testing

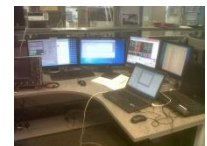
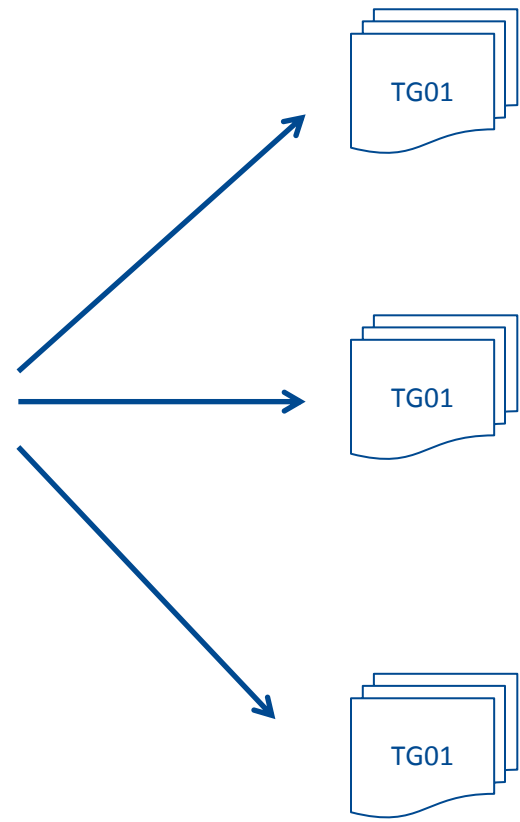
Tags

Tests

Vehicles



Doc	reqt	version	SAN
DNS824538	DNS824538/345	3	45678
DNS824539	DNS824538/346	5	3432
DNS824600	DNS824538/347	2	14
DNS824601	DNS824538/348	3	41783
DNS824602	DNS824538/349	12	2235
DNS824603	DNS824538/350	4	41922
DNS824604	DNS824538/351	7	45678
DNS824605	DNS824538/352	2	45783
DNS824606	DNS824538/353	3	45678
DNS824607	DNS824538/354	5	43763
DNS824608	DNS824538/355	5	53400
DNS824609	DNS824538/356	5	57038
DNS824610	DNS824538/357	5	60675
DNS824611	DNS824538/358	5	64313
DNS824612	DNS824538/359	5	67950
DNS824613	DNS824538/360	4	71588
DNS824614	DNS824538/361	4	75225
DNS824615	DNS824538/362	4	78863
DNS824616	DNS824538/363	4	82500
DNS824617	DNS824538/364	4	86138
DNS824618	DNS824538/365	4	89776
DNS824619	DNS824538/366	4	93413
DNS824620	DNS824538/367	4	97051
DNS824621	DNS824538/368	4	100688
DNS824622	DNS824538/369	4	104326
DNS824623	DNS824538/370	4	107963
DNS824624	DNS824538/371	4	111601
DNS824625	DNS824538/372	4	115238
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DNS824627	DNS824538/374	4	122513
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DNS824629	DNS824538/376	3	129788
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DNS824655	DNS824538/402	2	224364
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DNS824658	DNS824538/405	1	235277

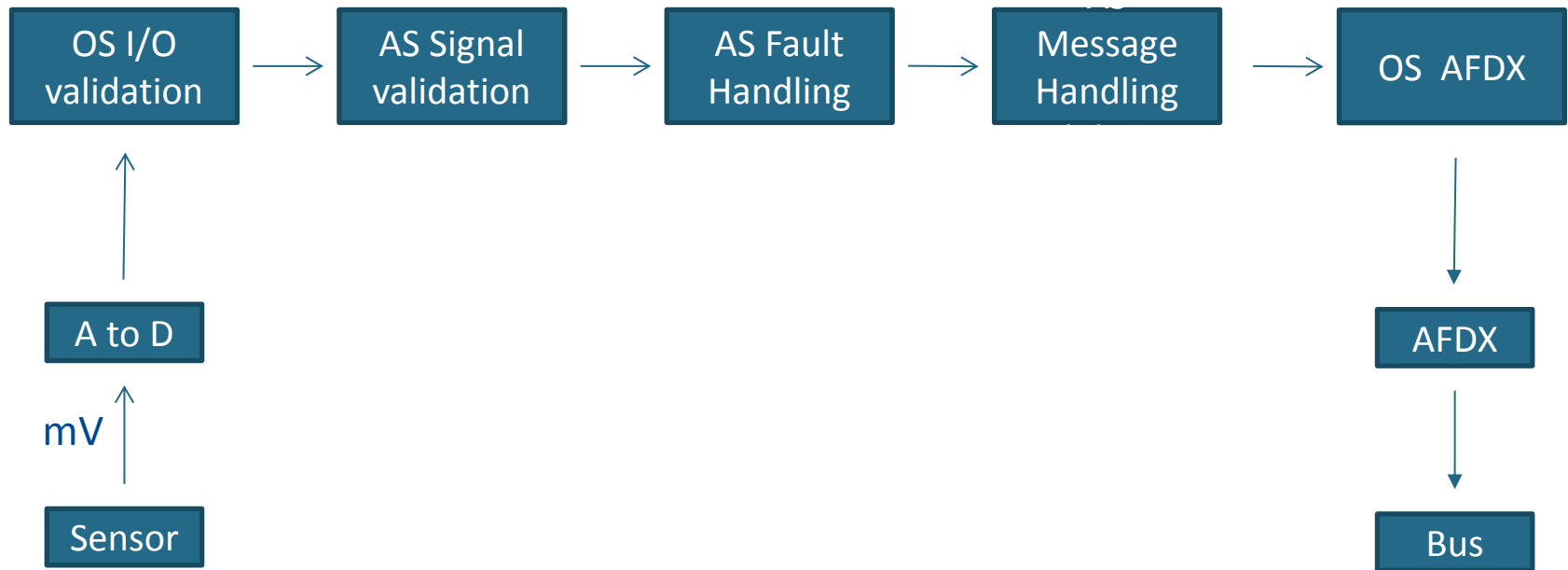


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Example:

When temperature exceeds a limit - generate a message in the cockpit.



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Hardware, firmware, OS level testing

- Tests box I/O and fault detection
- Tests under arduous conditions, such as:
 - Bake and Shake (high temp and vibration)
 - Hot, Cold
 - EMC
 - Internal faults, e.g. unstable reference voltages etc
- Provides the underpinning for the software layers above.



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Software code level testing

- Functional block testing
 - Software Requirements tracing
 - Coverage of higher functional requirements where possible
- Formal methods
 - Code coverage / MCDC etc
 - Requirements traceability



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AS/OS integration

- Representative hardware
- Often single lane
- Limited realism, e.g. pressures, temperatures etc run to crude model.
- Ability to perform deep inspection of software / force values etc.



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Software / Hardware integration

- Real hardware
- OS/AS
- Real-time rigs
 - Run real-time engine model
 - Aircraft interfaces
- Run as white box testing



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System Testing

- Tests end-to-end signals, e.g. temperature in to message out. Therefore tests hardware, firmware, OS and AS.
- Same real-time rigs
- Run as black box testing
- Realistic scenarios
- Can test areas of the envelope that engine test cannot e.g. extreme speeds or temperatures
- Tests system responses, e.g. signal short-circuits through validation, fault detection, limiters, governors, signal selection, control loop selection, message generation.



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Engine test

- Real hardware on real engine
- Limited scenarios (engines are expensive!)
- 95% realistic (no variation in airspeed, temperature, pressures etc)
- Expensive (£5,000-10,000 /hr)
- Test engines heavily used for engine development
- Test stands heavily used for production passoff



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Flight test

- Ultimate reality
- Limited time - airframers don't want to spend their time testing our engines – they expect us to do that
- Even more limited range of tests (aircraft are even more expensive, and we're sitting in them!)



Collate results

Vehicles



Tests



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DNS824603	DNS824538/350	4	47822
DNS824604	DNS824538/351	7	45678
DNS824605	DNS824538/352	2	45789
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DNS824611	DNS824538/358	5	64319
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IP

SAM
45678
3432
14
47789
2235
47822
45678
45789
45678
43763
53400

Results



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Collate results

- Multiple vehicles and tests
- Multiple levels of requirement
- Some requirements tested at many levels, e.g. cockpit message generation, tested ‘everywhere’
- Easy to get 99 “passes” and assume success. Was there a 100th test which failed?



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Certification

- Engine is certified independently of airframe
- Need to prove:
 - Requirement traceability up and down
 - Code traceability – code ↔ requirements
 - Test coverage
 - Results



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Summary

For a highly complex system:

- Intelligence is not so much in the nature of the tests
 - Each individual function is generally simple
- Intelligence is in the management of the process
 - Thorough (all software tested)
 - Effective (all functionality tested)
 - Affordable (cannot have team of millions)
 - Achievable (needs to finish before first flight)
 - Ensure everything covered adequately, nothing missed
- Commitment to complete the process



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Arriving on holiday...



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