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SOFTWARE SYSTEMS

Changing the way the world does software

The Cost of Autonomy

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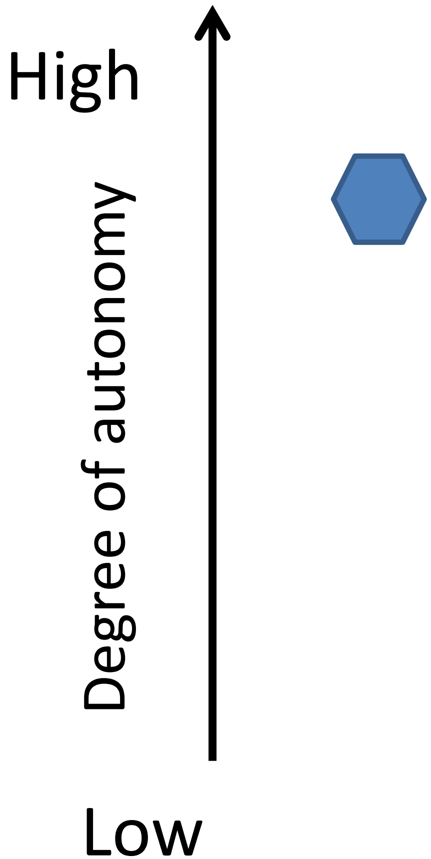
Insurance

- Vehicles will need to have an acceptable safety case to get insurance
  - Cost prohibitive otherwise
- Over the horizon operations
  - Communication delays/interruptions
  - Operator cognition in doubt
  - If 100% operator cognition required there is a cost in training & monitoring & user acceptance.
- Assurance of behaviour required


High
Degree of autonomy
Low

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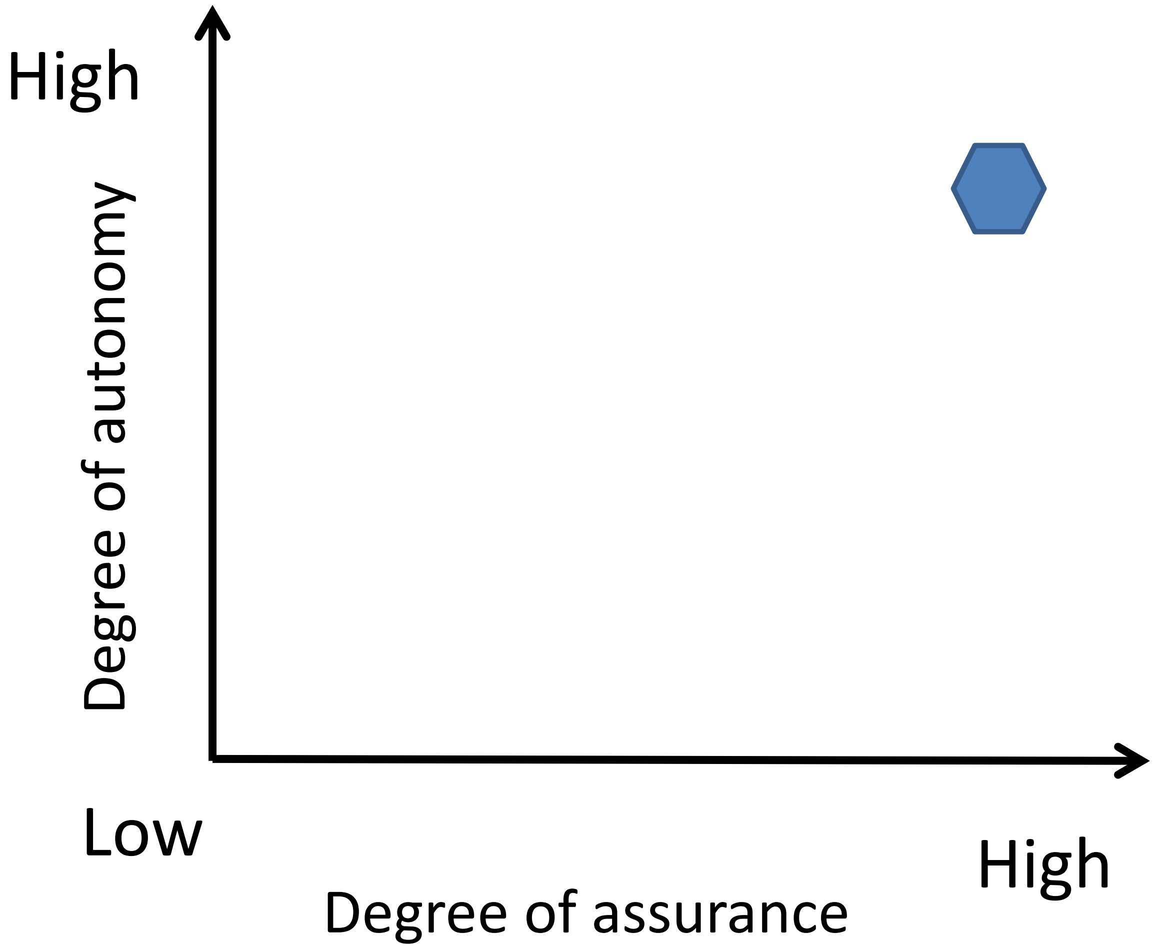
Autonomy vs Pilots

- Avionics support pilot through automation
  - Pilot typically alerted to failures
  - Training to cope with failures
  - Pilot expected to have 100% environmental cognition
  - Even then Eurofighter's automated carefree handling required high assurance.
- Qantas QF32
  - Catastrophic engine failure
  - Multiple systems failures – plenty of warnings!
- Autonomous systems will have to be able to cope
  - Cannot just dump information onto the [remote] pilot


High
Degree of autonomy
Low
High
Degree of assurance

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The Problem – RAND Study (Cars)

- Current fatality rate (USA) is 1.09 fatalities per 100 million miles
- Say we have a fleet of 100 autonomous vehicles driving 24 hours a day, 365 days a year, at an average speed of 25 miles per hour
- Need to demonstrate with 95% confidence their failure rate to within 20% of the death rate (1.09/100million miles)
- How many miles (years) would the autonomous vehicles have to be driven ?
- Answer: 8.8 billion miles, which would take 400 years with such a fleet
- Conclusion: "…developers of this technology and third-party testers cannot drive [read 'test' or 'simulate'] their way to safety."
- Alternative methods to supplement real-world testing [are needed] in order to assess autonomous vehicle safety and shape appropriate policies and regulations

Assuring the 'System'

- Have a set of requirements/behaviours
  - Must do — Routine to achieve using 'conventional' techniques
  - Must NEVER do — Not achievable using 'conventional' techniques
  - Failure behaviour — Very expensive using 'conventional' techniques
- This sets boundaries for the vehicle behaviour

Conventional Approach

- Some modelling may be done
  - Perhaps using tools such as Simulink/Stateflow
- Often code is developed first
  - Applying retrospective assurance is difficult [at best]
- Documentation can be sparse
- Programming language selection often fashion based
- Tested, and then some more, and then…
  - The cost of change is proportional to the size of the system
  - Not the size of the change
  - Leads to extended project time & budget overrun
- Support to safety case…tenuous?

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Safety Critical Systems

- Require verification at all stages of development
- Evidence set by domain standard
  - ISO26262 automotive
  - DO-178C/ED-12C aerospace
  - …etc, but none for maritime systems
- Typically require evidence generated based upon requirements and verification of implementation

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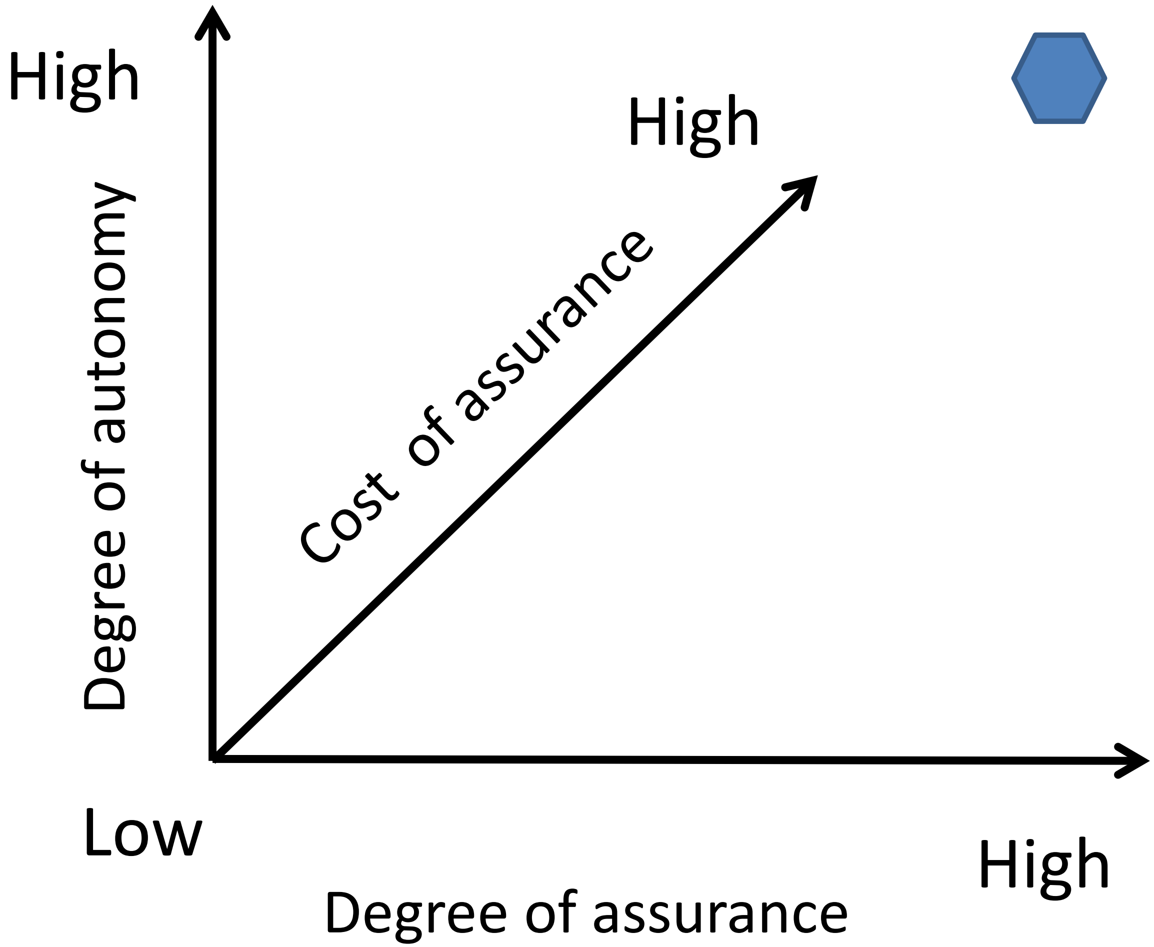
Standard Selection

- No software standard specific to safety of autonomous systems
- Aerospace DO-178B:
  - Over 20,000 certified jet aeroplanes in service worldwide since 1992
  - No hull-loss accidents in passenger service have been ascribed to software
  - DO-178C released in 2011 and authorised for use 2012
  - Verification cost: 50-80% of software production.
  - Prerequisite for Autonomous Air Vehicles – sets a baseline for autonomy?

Standard Selection

- Automotive ISO26262:
  - Only lower Levels (ASILS) typically or/and very simple systems
  - Tiny experience for autonomous driving relative to fleet of all cars
  - Of the reported crashes where an autonomous car has hit something it ‘shouldn’t have’:
    - Autopilot isn’t an autonomous system and the driver should always be ready to take control Give up – over to you! ☺
    - Autopilot should only be used on highways where pedestrians and cyclists are not present as it can’t always detect them Significant environment constraint


High
High
Cost of assurance
Degree of autonomy
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High
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Need new approach to assurance

- We build systems beyond our ability to understand them
  - Space Shuttle
  - Ariane 5
- We do not understand the consequences of our high level designs (models) and low level designs (software).
- Assurance is a limiting factor for adoption of autonomous systems.
- If the assurance doesn't matter then the market is significantly smaller.
- Conventional simulation and testing is expensive and insufficient to provide evidence of absence of unsafe/undesirable behaviour.

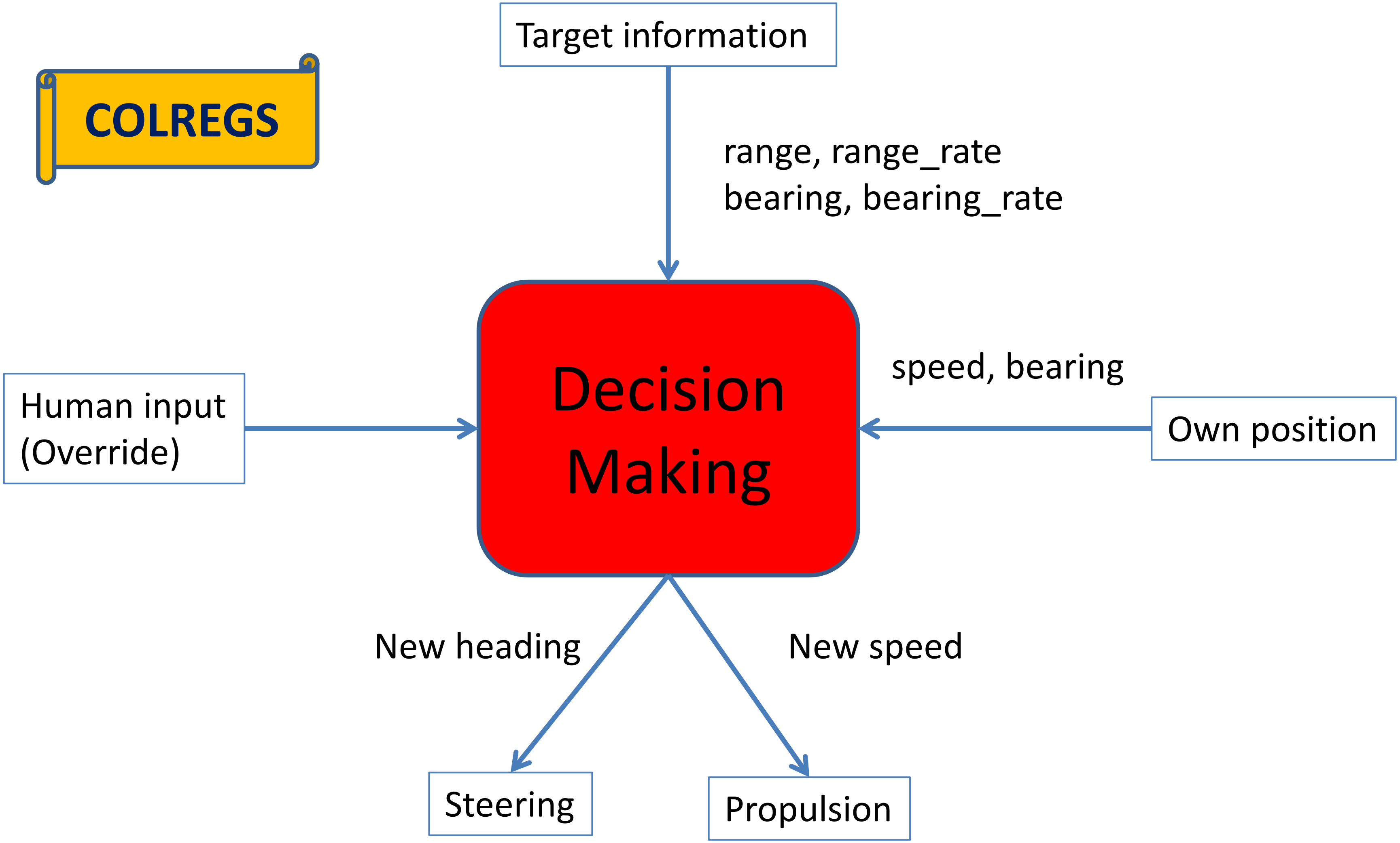
Automating & Hiding Formal Methods

- D-RisQ enabling users to extract benefit without expertise in formal methods
- Used for systems and software analysis against requirements (Modelworks®)
  - Automotive sector: Electro/hybrid vehicle system
  - Aerospace: Undercarriage system; Display
- Used for source code verification (CLawZ®)
  - Verified 350,000 Lines of Code
- Also used for binary verification (FEVER®)
  - In development
- Formal Methods Supplement to DO-178C [DO-333]

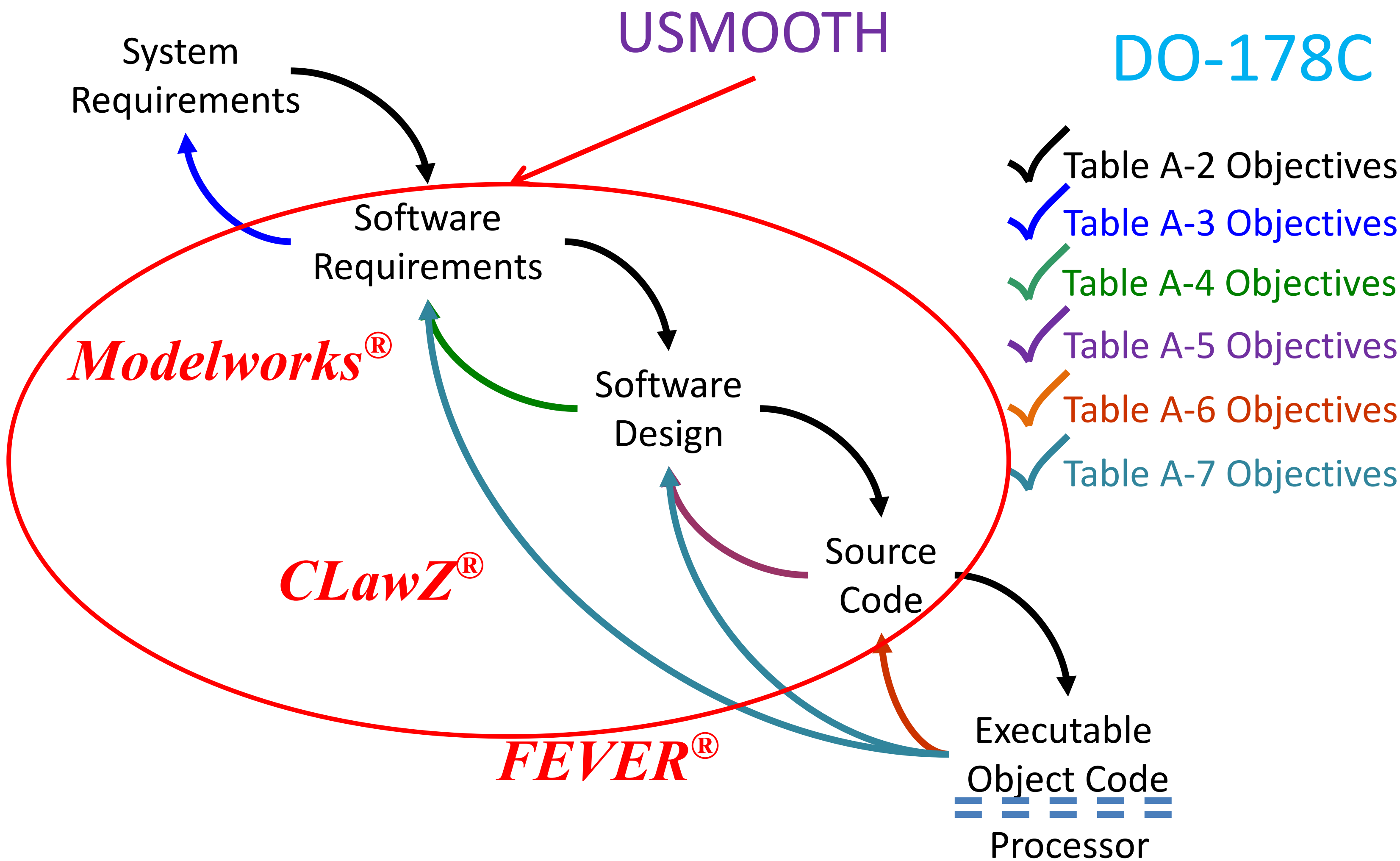
The USMOOTH Problem

- IUK Project led by ASV Ltd.
- How to design a decision making system that can be support Unmanned Systems (Maritime) Operations Over The Horizon for extended durations (weeks)?
- How to provide assurance that the software does what is required and nothing else?
  – How could we support a safety argument
- What standards could be used?
  – Not necessarily maritime standards
- At what cost and can the process be easily [cheaply] repeated?

Decision Making System



Systems, Software and Certification



Summary

- Defining behaviour in English
  - Easy for all to understand
  - Translate to maths (hidden)
- Defining specification in model
  - Simulink/Stateflow
  - Translate to maths (hidden) and check against requirements

Modelworks®

- Auto-translate model to source code
  - Independently automatically prove against model

CLawZ®

- Compile to Executable Object Code
  - Independently automatically prove against source code
  - NB stretch target

FEVER®

- Use of DO-178C/DO-333 provides evidence to support safety case
- Automation makes adaptation easy, i.e. cost effective

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