The Benefits of Model Based Design to the Cost Effective Validation/Qualification of Advanced Active Optical Target Detection Devices

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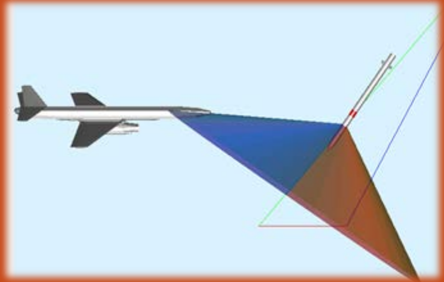
Missile Electronics UK



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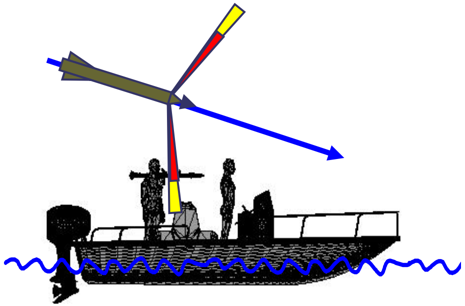
Overview

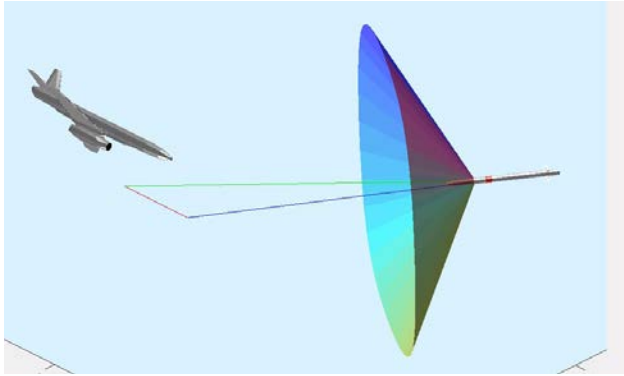
- **Next generation advanced active optical Target Detection Device (TDD) Fuzing sensors are in final stages of qualification for two new UK missiles**
  - Signal processing significantly more complex than for previous Fuzing sensors and endgame warhead triggering function is a more complex interaction of target shape, engagement geometry and relative velocity
- **In practise, real time conditions can only be realised in expensive missile qualification firings against airborne targets, the cost of which is very high**
  - Places a high dependence on the fidelity and validity of modelling
- **A Model Based Engineering (MBE) approach has been taken throughout the development of the new modular product family**
- **This briefing provides an overview of how MBE has been applied and the benefits that it has brought to cost effective qualification**

Development of Advanced Active Optical Target Detection Devices

Family of next generation Lidar TDD Fuzing sensors currently in qualification

- Sensors comprise multiple miniature fan beam lidars configured in a segmented hollow cone beam pattern, matched to warhead dynamic fragment pattern
- Low cost technology using semiconductor pulsed laser diodes, silicon detectors and moulded optical components
- Precise target detection and improved azimuth and miss distance resolution
- Combined with missile guidance data to command warhead detonation at point of optimum lethal effectiveness





Modular Product Strategy

Common Signal Processor module

- Low cost FPGA and DSP components
- Generic architecture compatible with all lidar and radar fuzing sensors
- Lidar variants shares common code
- Controls timing and modulation of sensor pulses and receiver gating
- Provides flexible weapons interface options
- Powerful platform for fuzing algorithms
- Enhanced trigger point effectiveness and clutter discrimination
- Fully reprogrammable

Body mounted lidar fuzing sensor

Common Processor

Nose mounted lidar fuzing sensor

The Model Based Engineering Approach

WIKIPEDIA
The Free Encyclopedia

[Wikipedia]... Model Based Engineering focuses on creating and exploiting domain models as the primary means of information exchange between engineers, rather than on document-based information exchange

Wikipedia contributors. "Model-based systems engineering." Wikipedia, The Free Encyclopedia. Wikipedia, The Free Encyclopedia, 29 Aug. 2015. Web. 20 Apr. 2016.

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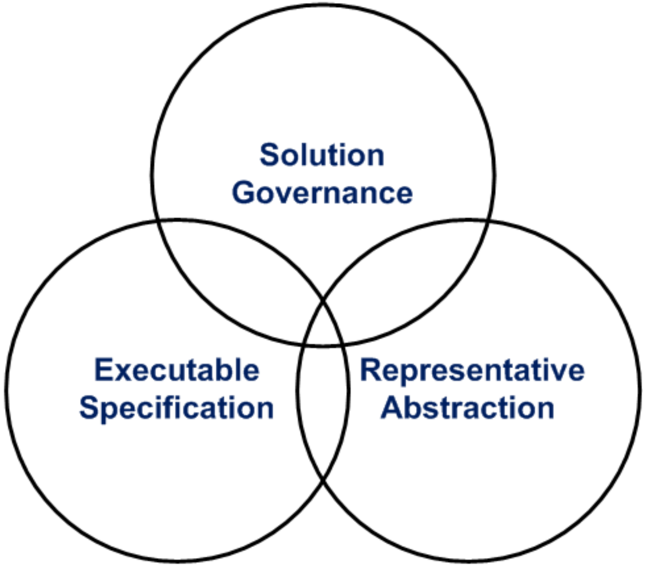
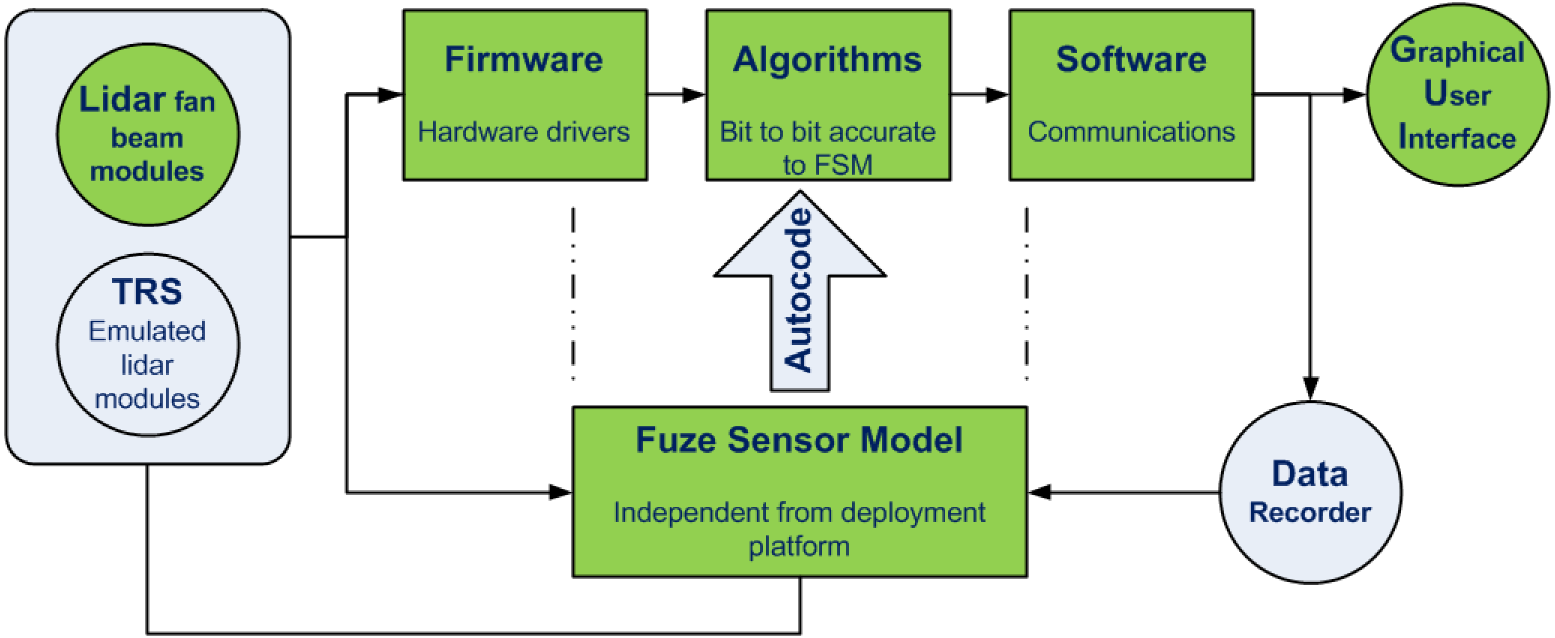


The Model Based Engineering Approach : Governance

Provides overall governance & management of solution implementation

- Including firmware, algorithm and software
- From early design concept to product deployment



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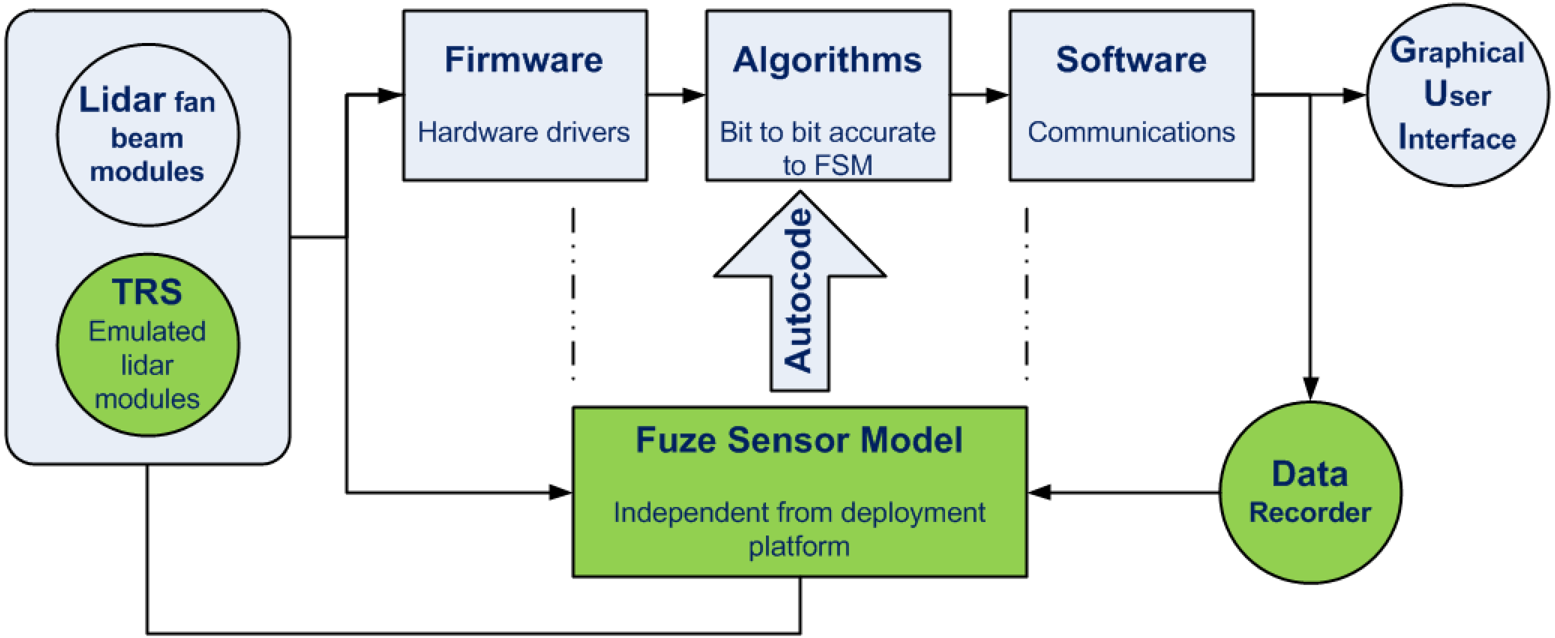
The Model Based Engineering Approach : Executable Specification

An executable specification independent from the deployment platform

- To help understand, communicate & clarify the real needs of all stakeholders
- To ensure assumptions are clear, transparent and readily shared



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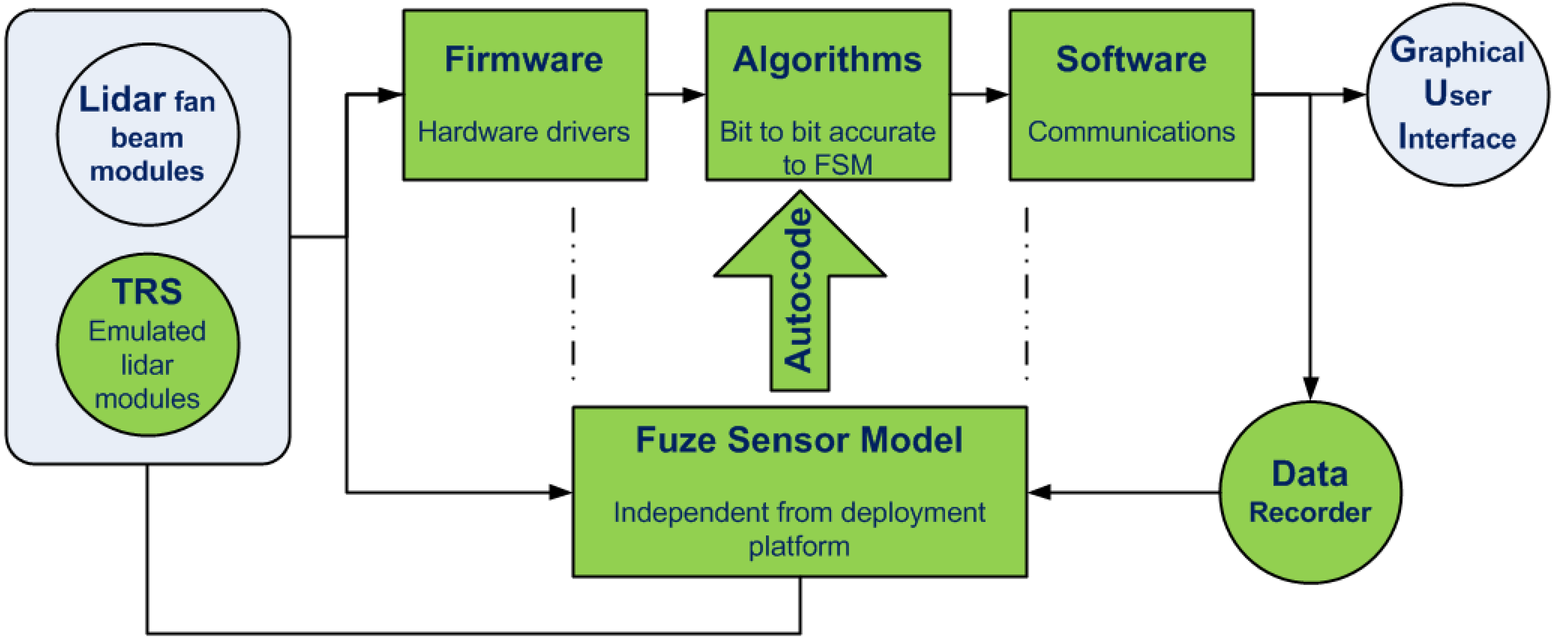
The Model Based Engineering Approach : Representative Abstraction

Representative abstraction of product function

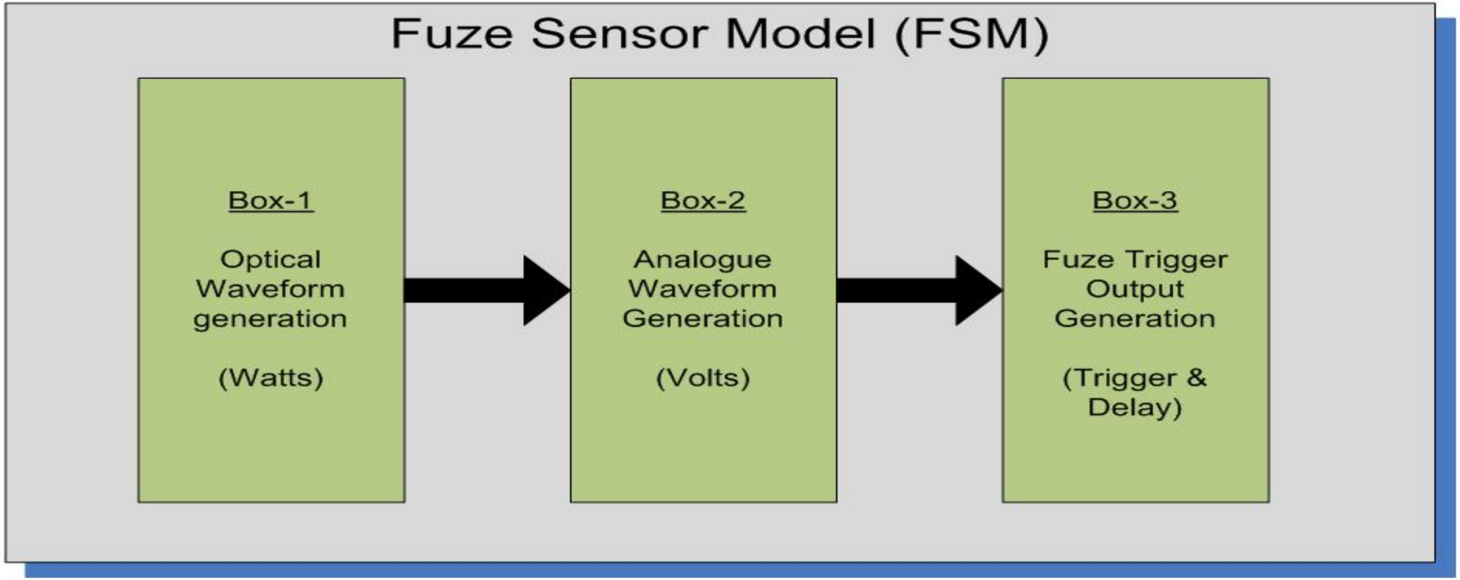
- Rapid change impact analysis & platform verification using Target Return Simulator
- Autocode algorithms to achieve bit-bit accurate correspondence with model

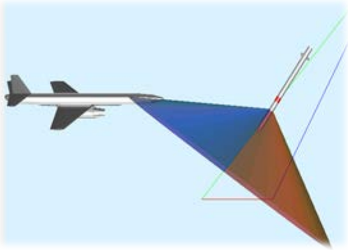


Fuze Sensor Model (FSM)

Matlab Simulink model

- Full end to end target interaction to fuze trigger output simulation
- Validated by comparison between simulation and measured sensor responses





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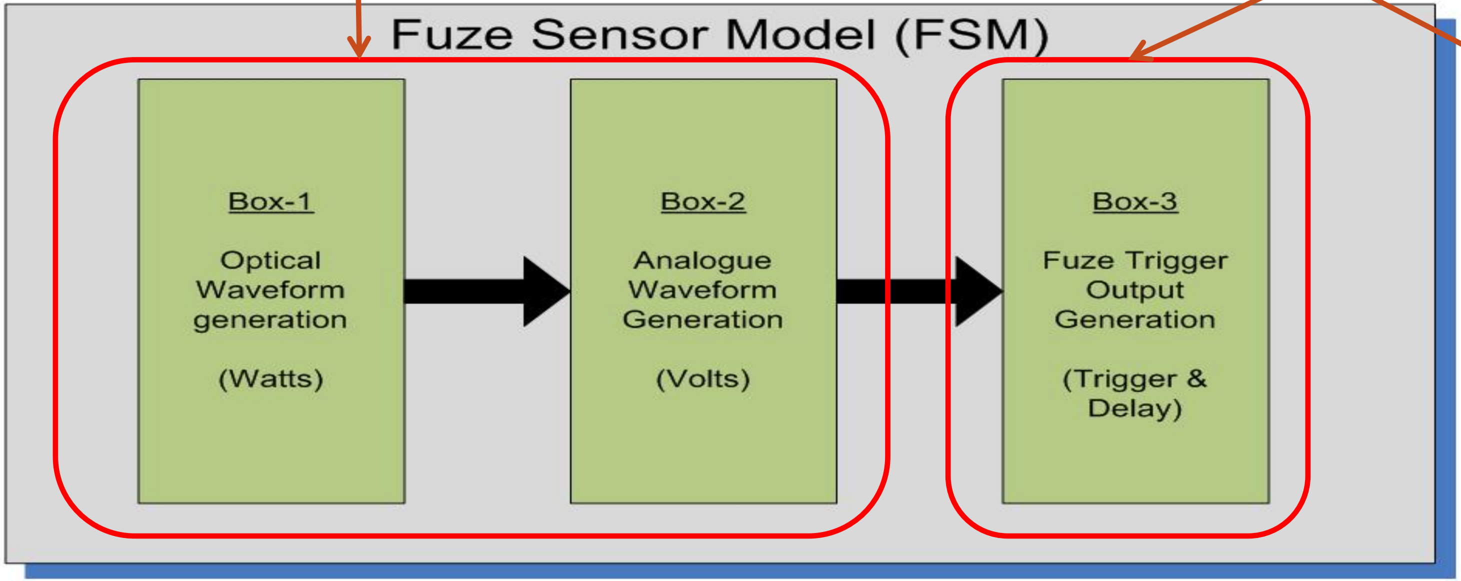
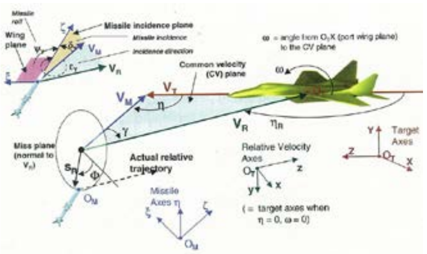
Fuze Sensor Model (FSM)

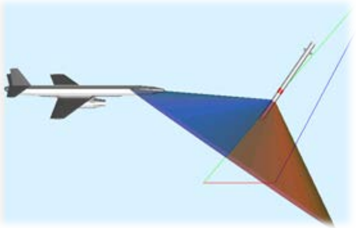
Matlab code emulating sensor response to a specified target/engagement

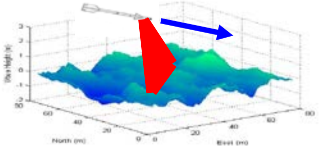
MEX code performing target detection and trigger point processing identical to C code resident in sensor processor

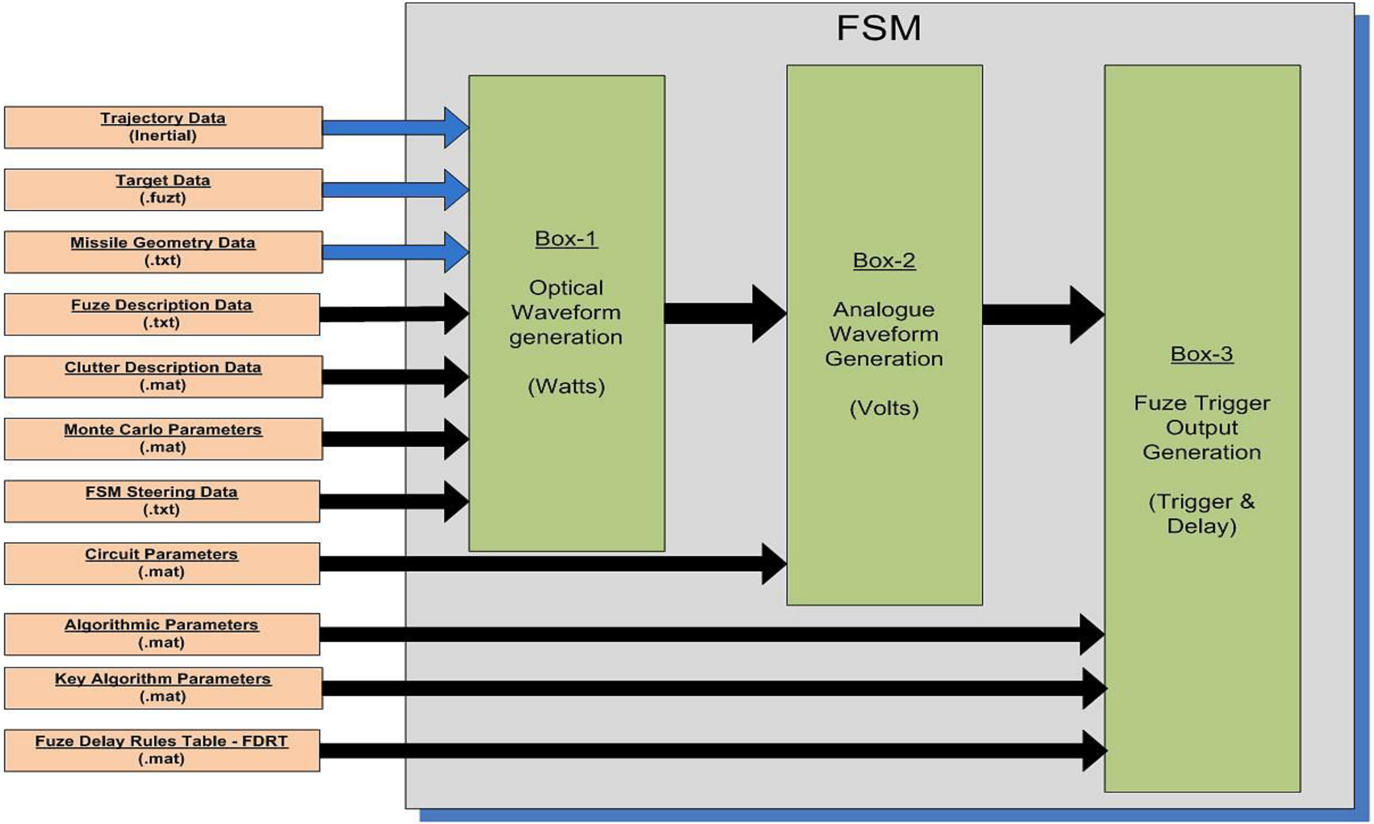


Fuze Sensor Model Interfaces









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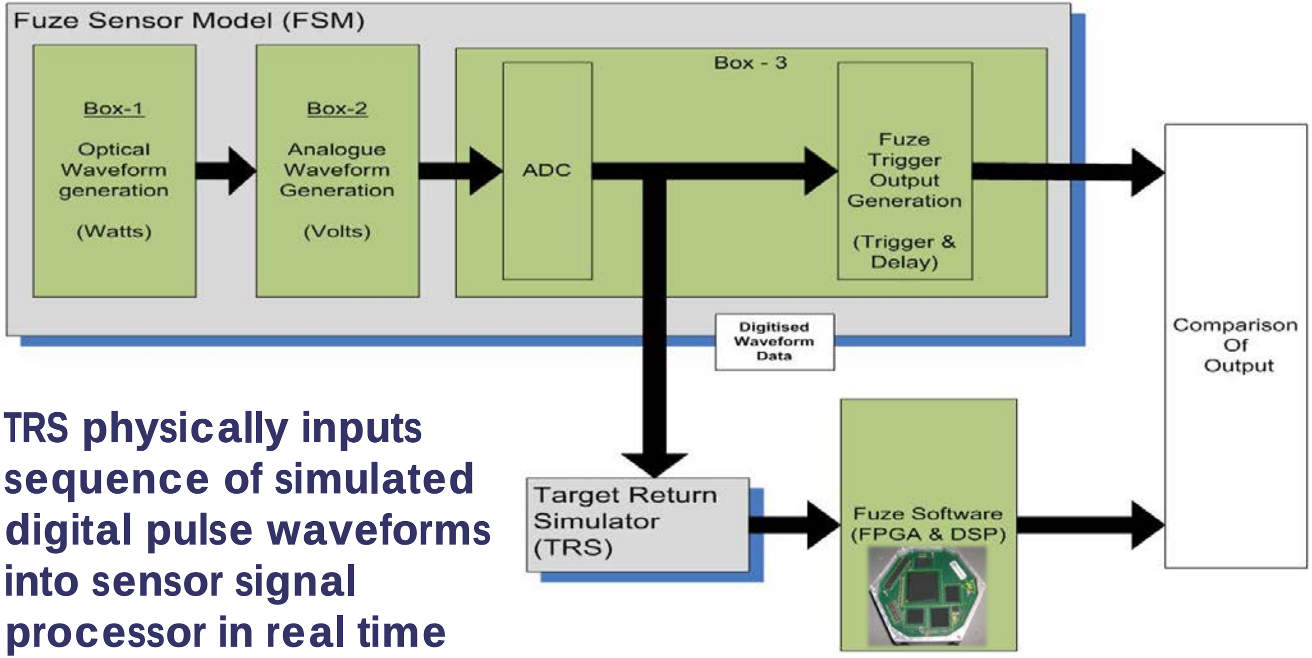
Real time validation of coded algorithm running in sensor processor

Target Return Simulator

- Digital pulse waveform sequences simulated by FSM for set of engagements
- Comprehensive coverage of endgame engagement space



- TRS physically inputs sequence of simulated digital pulse waveforms into sensor signal processor in real time

- Simulated sensor detection outputs compared to sensor processor outputs bit by bit to ensure 100% correspondence for all cases
- Effective validation of real time processor function

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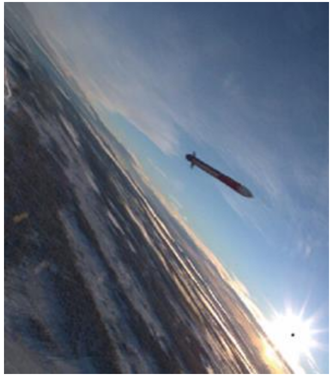
Missile Firing Trials

Simulations & Images reproduced courtesy MBDA UK

- **Final verification of correct function in real environment**
  - Number of firings constrained due to high cost
  - Provide full end to end validation of Fuze Sensor Model
  - FSM embedded into weapon level simulation suite
  - Validates comprehensive weapon level performance predictions
- **Accurate determination of target engagement parameters**
  - Drone target fitted with Miss Distance Indicator and video camera
  - Match data from video, MDI and missile to derive pass-path
    - Matlab simulation to step missile along predicted trajectory
    - Simulation of frame by frame view as seen from drone video camera
    - Comparison with real recorded camera images of approaching missile
  - Refinement of engagement parameters to achieve close match
- **FSM can then be run accurate trial engagement conditions**



Video from Drone

Matlab simulation

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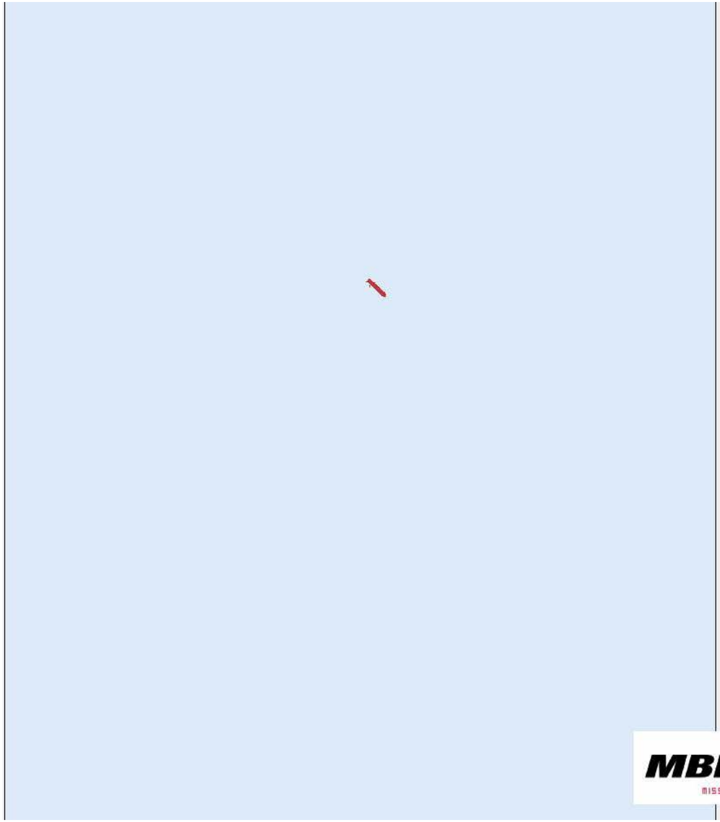
Comparison between simulation and firing trial video



Simulations & Images
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Simulated target engagement for derived trial trajectory

MBDA MISSILE SYSTEMS

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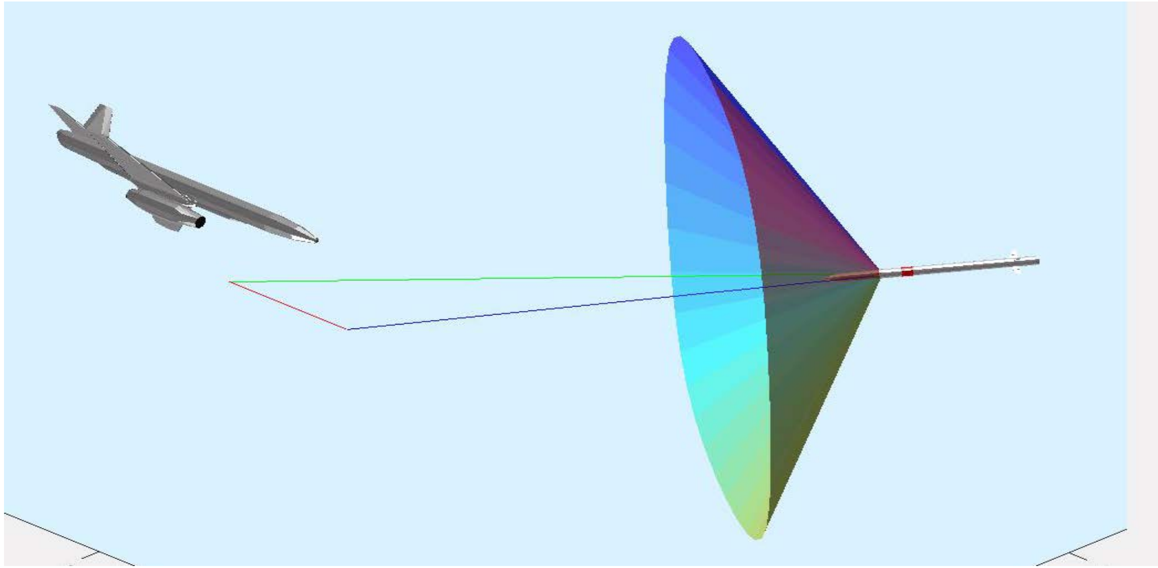

Representation of:

- Fuze Sensor beams (not drawn to scale)
- Engagement trajectory
- 3D target model

Crossing engagement

- Target mainly expected to cross single sector ‘N’
- Should also briefly enter adjacent sector ‘N-1’
- Only present in beam over short distance of travel

Simulated Trajectory – Top and Side Views

Target expected to appear abruptly in sectors 'N' and 'N-1' for short distance of travel

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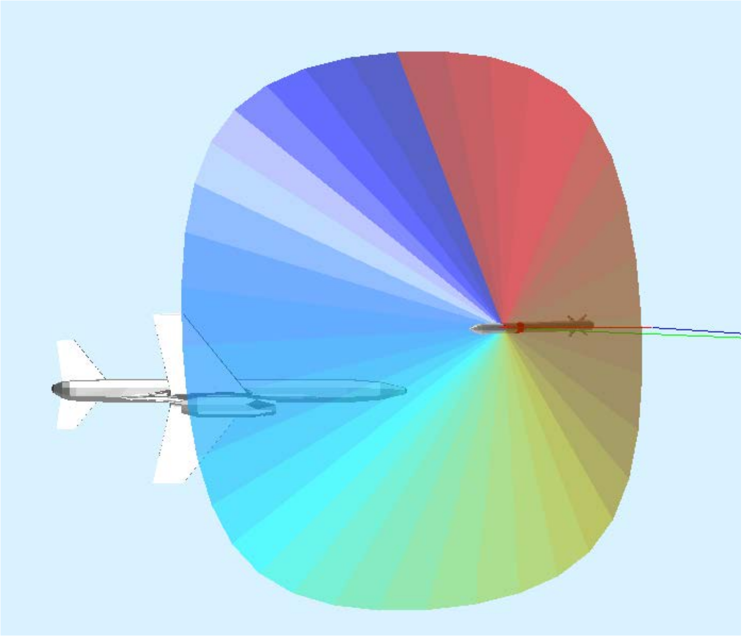
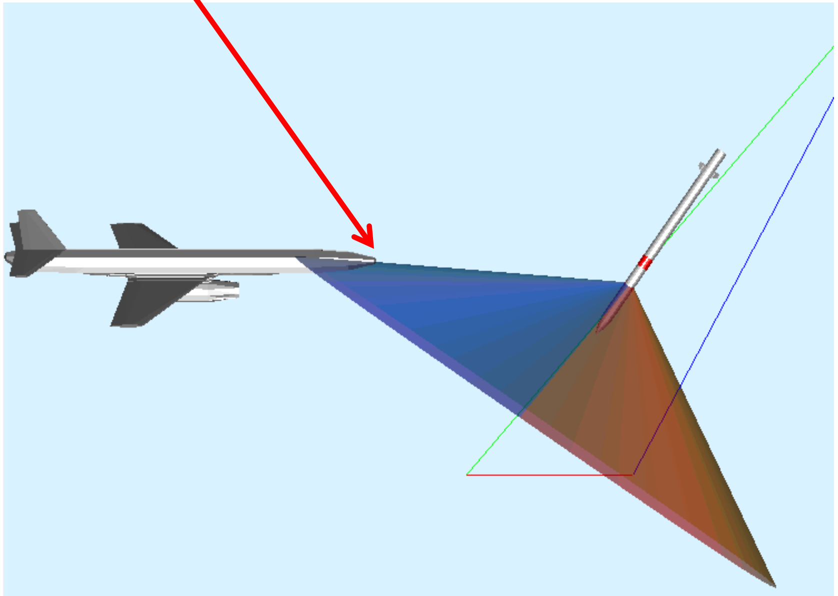
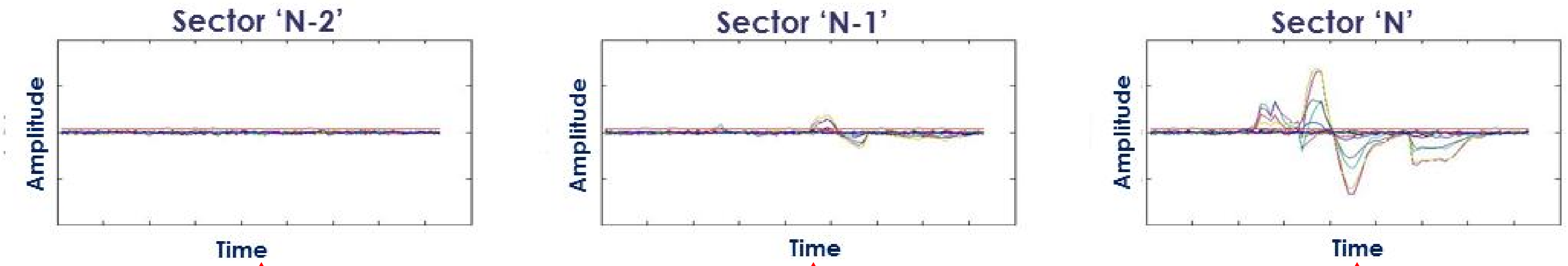




Proximity Fuzing Sensor response predicted by Fuze Sensor Model



Target not expected in Sector 'N-2'

Target only expected in Sector 'N-1' for short time

Target primarily expected in Sector 'N'

Model prediction only shown for three sectors

- Target predicted only to appear in sectors 'N' and 'N-1'
- Sector 'N-2' included as example of a 'no target' case
  - Other sectors with 'no target' present are essentially the same

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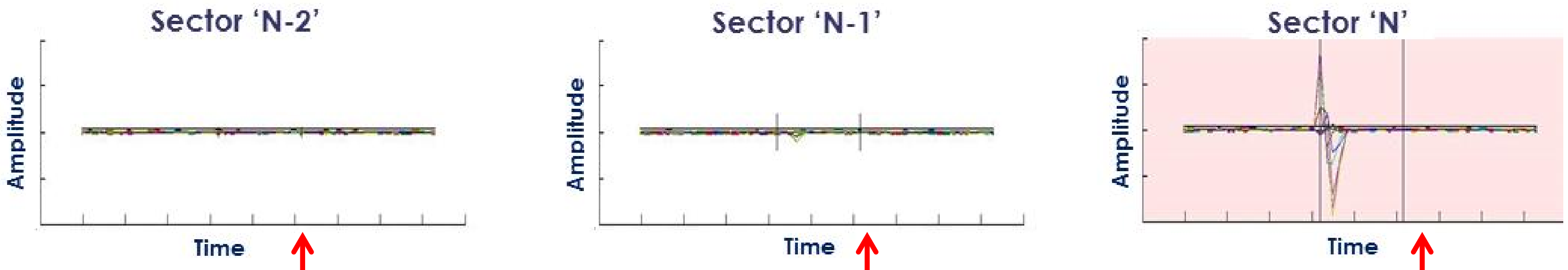
Proximity Fuzing Sensor response recorded from trial telemetry



No response in this and other 'no target' sectors

Very short response in sector 'N-1' as expected

Main response seen in sector 'N' as expected

Recorded trial response subject to telemetry bandwidth limitations

- Telemetry updates at 20% of fuzing sensor update rate
- Good correlation between recorded and simulated response given this limitation

Estimated trajectory modelled within the FSM providing an excellent match to telemetered fuze sensor data recorded at the firing trial

- Further confirmation of accuracy target engagement parameter estimates

Summary

- **Model based engineering has successfully been applied throughout the design, development and qualification of a complex new Fuzing Sensor**
- **A detailed Fuze Sensor Model has been developed that enables simulation of sensor function for specified target engagement & clutter environments**
  - **FSM and related common code validated by a combination of static lab sensor tests and real time stimulation of the signal processing with simulated inputs**
- **Excellent correlation between FSM simulations and fuze sensor responses from telemetered missile firings provides confidence in model verification**
- **Enables cost effective complex weapon level simulations (incorporating the FSM) to provide comprehensive accurate performance predictions**
  - **Supported by only a modest number of costly firing trials**
- **Model based engineering approach facilitates cost effective re-use of the FSM and related code in product derivatives for new applications**

Acknowledgements

Joe Kingham, MBDA UK — Missile engagement video analysis and determination of endgame trajectory conditions and visualisation

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Bobby Varghese, Thales UK — Fuze Sensor Modelling and prediction of endgame fuze sensor response

Questions

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