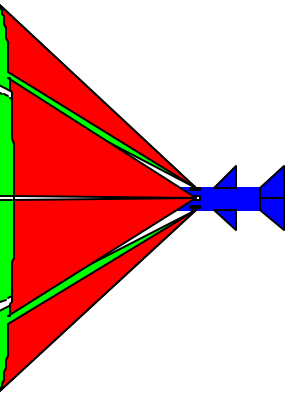
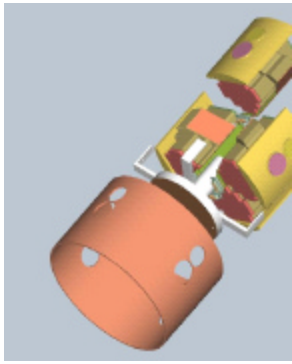




Developments in Laser Target Detection Device Technology

Presented by

Gary Buzzard

Manager, Proximity Fuzing Product Group

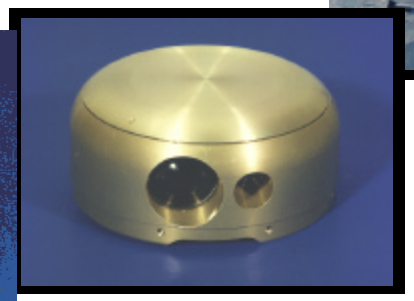
THALES

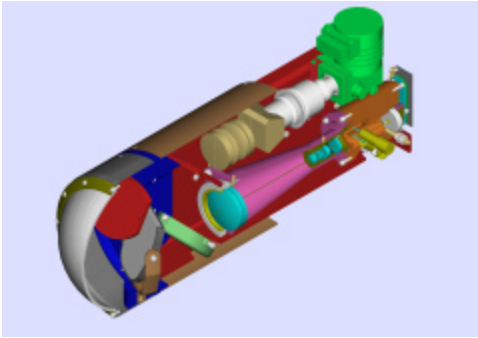
THALES MISSILE ELECTRONICS LIMITED

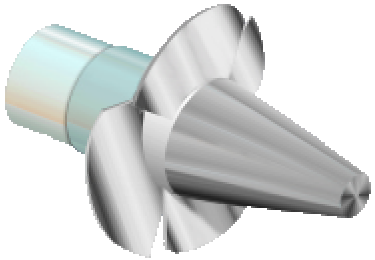
TME Background

Europe's leading Fuzing and Missile Electronics Supplier

- Hard Target Fuzing
  - MFBF, MAFIS, HTSF, MEHTF
- Anti-Armour Fuzing / TDDs
  - FITOW, MR TRIGAT, TOW-2B
- Air Target Fuzing / TDDs
  - Rapier, ASRAAM, Seawolf
- Smart Artillery Munitions
  - STAR, LCGM
- Airborne Seekers
  - DMS, DMIIRL







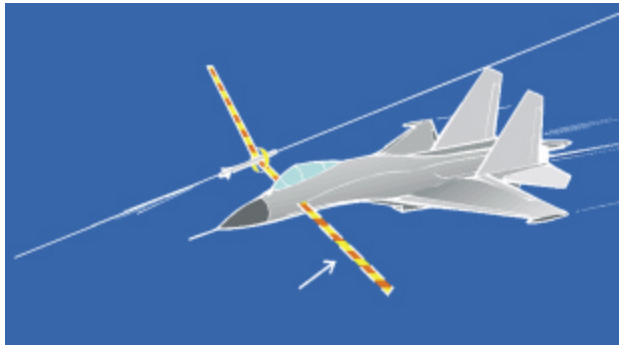
US Activities

- Core Team Member of US/UK PIOS Programme
- Sole Source Supplier of TOW-2B TDD
- USAF HTSF and MEHTF Hard Target Fuzes (with ATK)

The Role of the TDD

Target Detection Device [US] = Proximity Fuze [UK]

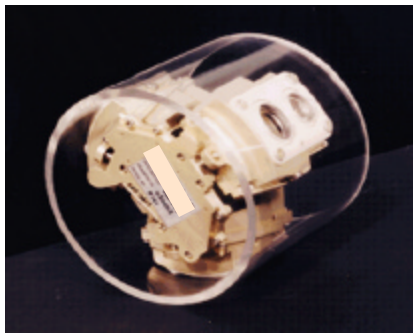
- To issue a trigger signal commanding initiation of the lethal mechanism at a point during an engagement designed to provide optimum lethality
- To be resistant to false triggering in the presence of naturally occurring clutter, man made clutter and countermeasures



Existing TME Laser Fuze Products

- Semiconductor laser sources
  - Near IR Pulsed
  - Compact and mature
- Silicon detectors - uncooled, low cost
- Well defined beams
  - Conical, sectored or spoked
- Time of flight down-beam range
- Closest point of approach triggering

ASRAAM Proximity Fuze



Rapier Proximity Fuze

Meeting Future Requirements

Future laser TDD requirements likely to demand

- Increased sensitivity and coverage (stealthy & manoeuvrable targets)
- Enhanced resolution (control of directional warheads)
- Enhanced clutter discrimination (full performance in cloud, etc.)

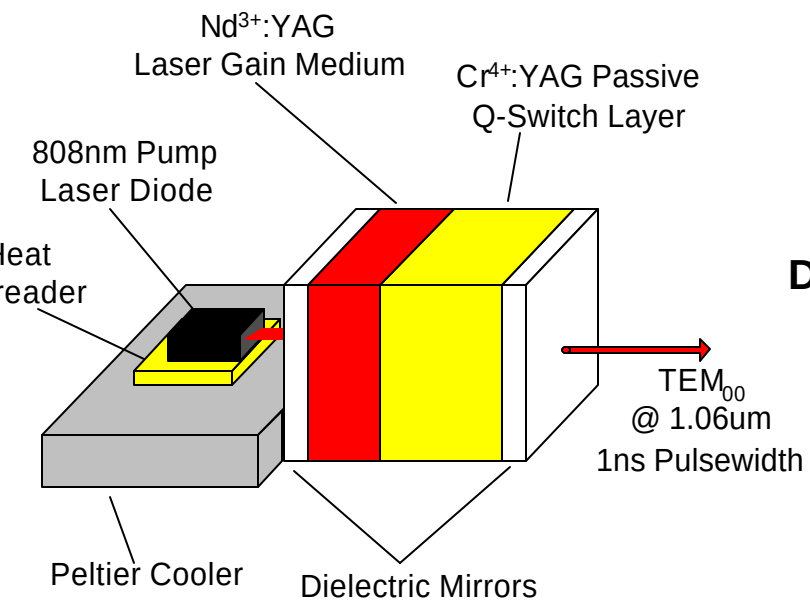
Existing laser TDDs constrained by pulsed semiconductor laser diode limitations

- Mature technology
- Device technology unlikely to evolve further

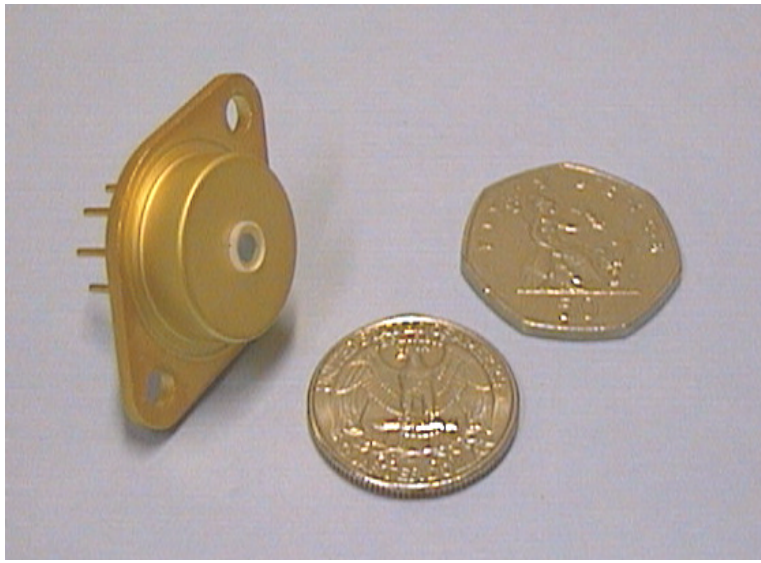
Laser diode pumped Nd:YAG ‘Microlaser’ devices offer an attractive alternative

- Significant potential performance improvement
- Compact and robust devices now available
- Several commercial sources

Nd:YAG Microlaser

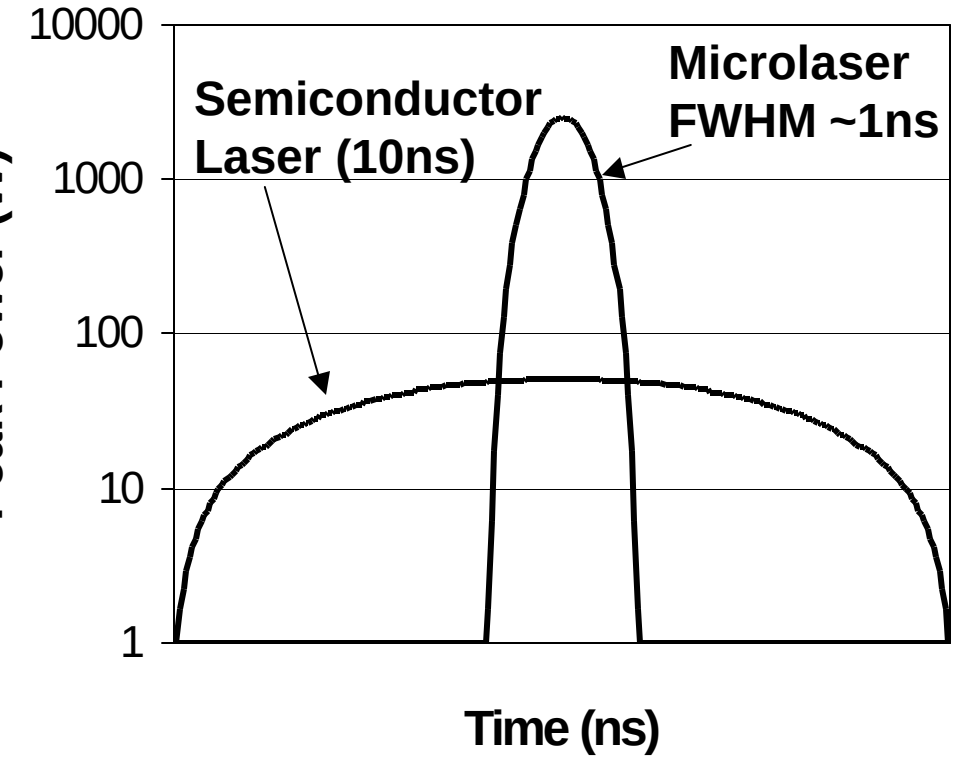


Reproduced courtesy of the PolyScientific Division of Litton systems Inc.



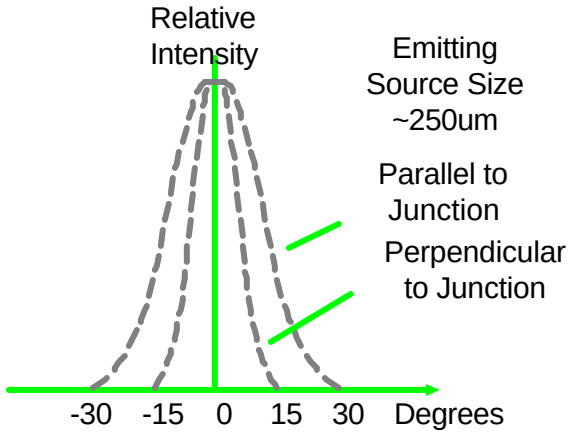
- Semiconductor laser pump source
  - ~1Watt mean power CW
  - Peltier cooled
- Nd:YAG gain medium
- Cr4+:YAG Saturable absorber
  - Pulsed output
- Integrated in compact TO3 package
  - Commercially available
  - Compact
  - Missile compatible
  - Blocking filter

icrolaser Versus Semiconductor - Pulse Characteristic

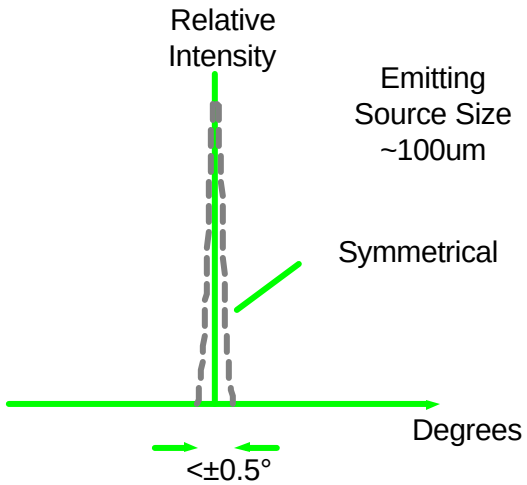


- Microlaser pulse much narrower than semiconductor laser
  - Enhanced range resolution
  - Lower aerosol backscatter
- Microlaser peak power much higher
  - ~ 5kW (~ 50 X higher)
  - Pulse energy ~ 5 µJ
- Pulse repetition rates similar
  - Microlaser ~ 15kHz

Microlaser Versus Semiconductor - Beam Divergence



SEMICONDUCTOR LASER

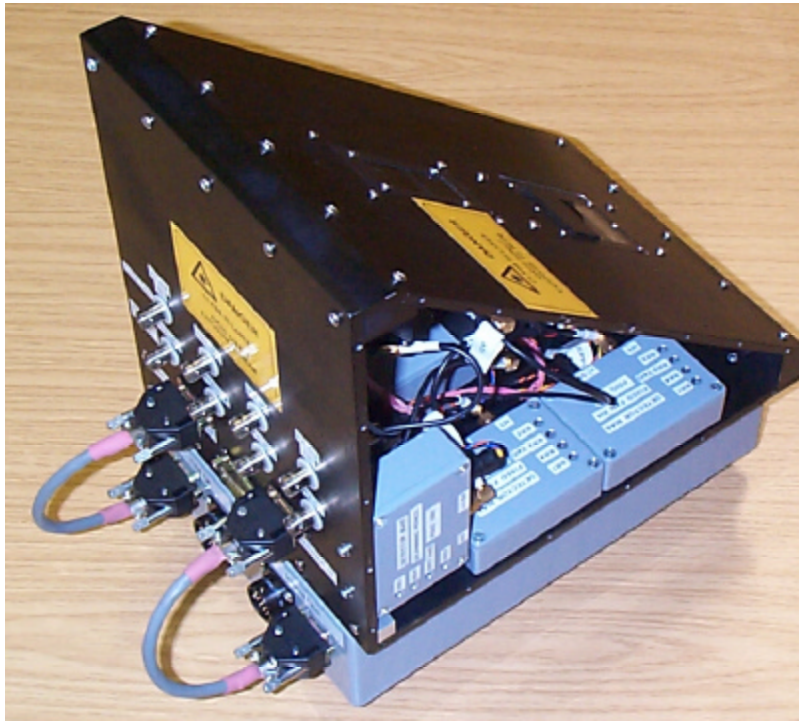


MICROLASER

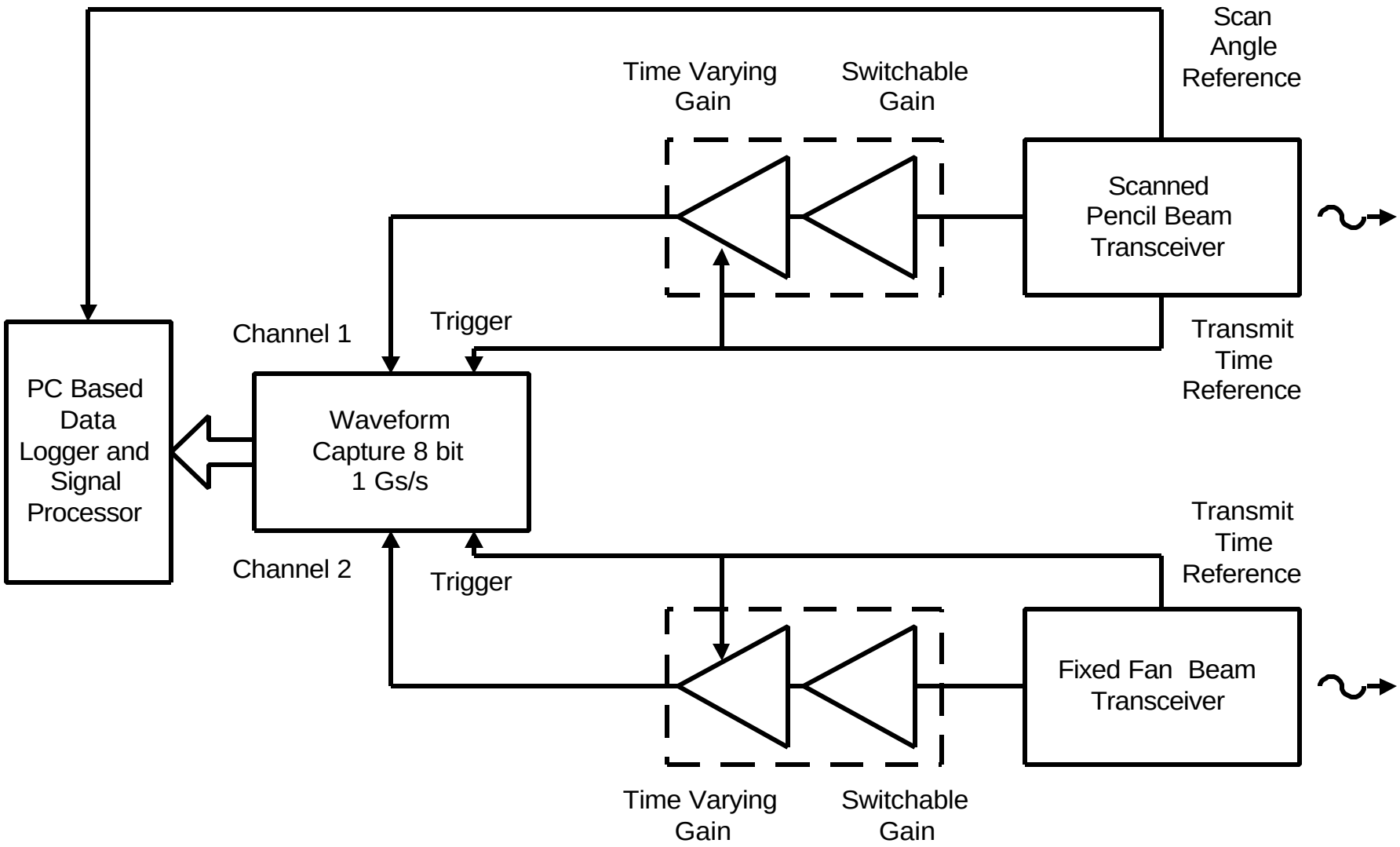
- Semiconductor laser output
  - Large emitting area (facet ~300 μm)
  - Highly divergent (up to ±30°) & asymmetric
  - Requires (~F1) collimation
  - Resulting beam width large ~10mm
- Microlaser output
  - Small emitting area (<100 μm)
  - Low divergence (<1°)
  - Further collimation unnecessary
  - Very narrow beam
  - Allows compact beam forming optics
  - Allows high forward look angles

Microlaser Fuze Demonstrator

- UK Pathfinder programme jointly funded with UK MoD (Dstl)
- Demonstration of the potential application of new technologies
  - Microlaser devices
    - Improved coverage and resolution
  - Received signal digitisation and signal processing
    - Enhanced clutter discrimination
- Experimental fuze Demonstrator
  - Integration completed early 2001
  - Scanned pencil beam transceiver
  - Fixed fan beam transceiver
  - 1Gsample/second 8 bit received pulse waveform capture
  - Signal processing (PC based)

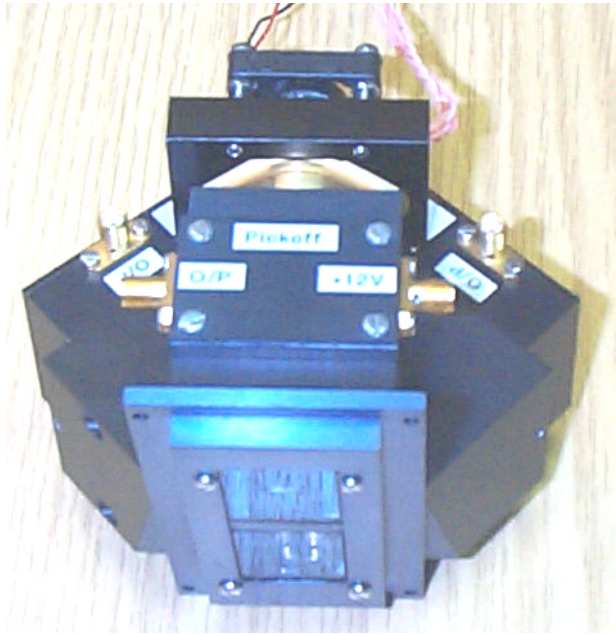


Demonstrator Functional Block Diagram



Fixed Fan Beam Transceiver

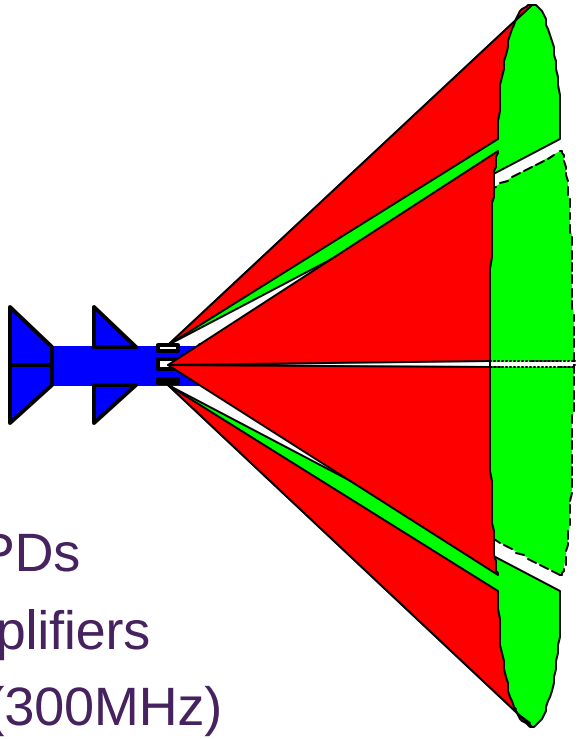
Fixed Conical Fan Beam Transceiver Configuration



Transmitter

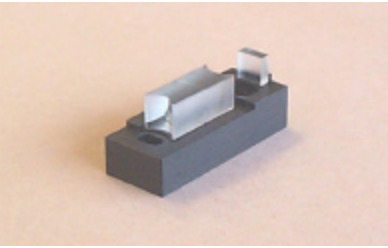
- Microlaser
- Beam spreading optics
- Prism window
- 50° forward looking cone
- 90° roll coverage

- Receiver
  - Prism window
  - Cylindrical lenses
  - Bandpass filters
  - Focusing lenses
  - Avalanche Silicon APDs
  - Transimpedance amplifiers
    - High bandwidth (300MHz)
    - Switchable & Time varying gain



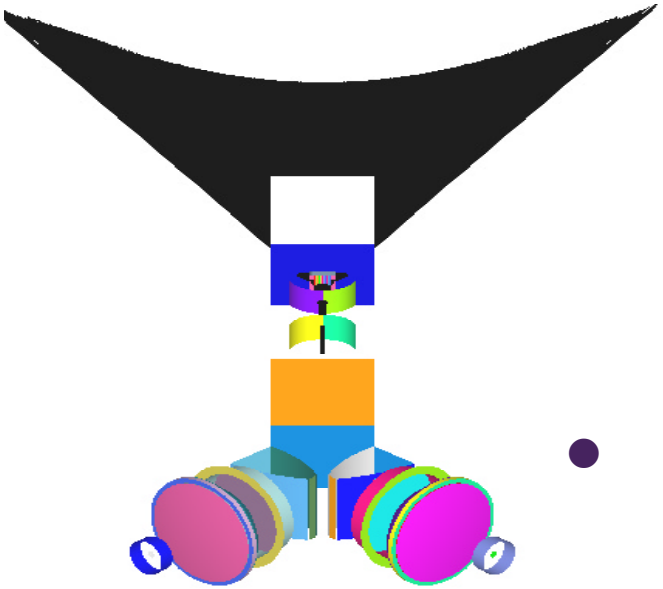
- Full 360° Roll Coverage would be achieved using 4 transceivers

Fixed Fan Beam Transceiver Design



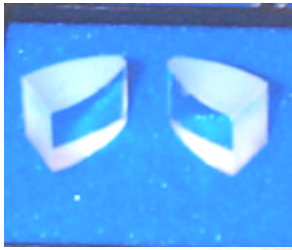
Bi-concave cylindrical lens & Microlens array used to generate planar fan beam

- Optical design generated using the ASAP tool



- Focussing lens/detector assemblies generate collimated filed of view

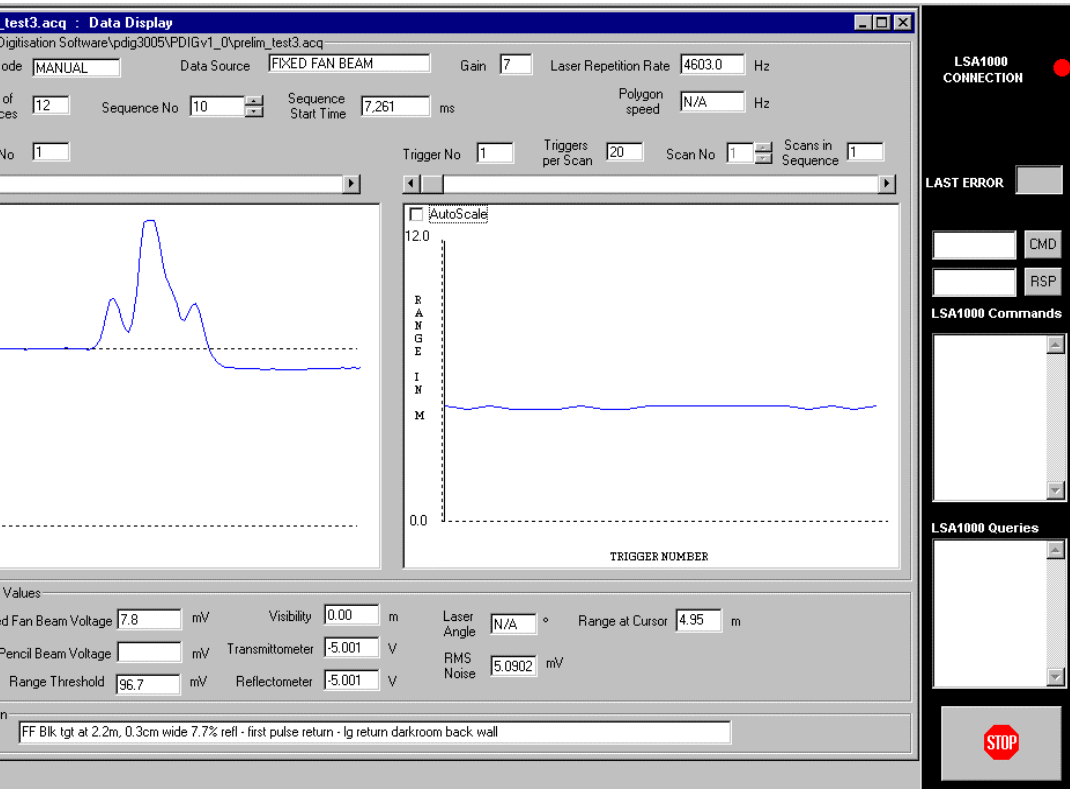
- Convex cylindrical lenses provide fan response



Prism window forms conical fan transmitted laser beam

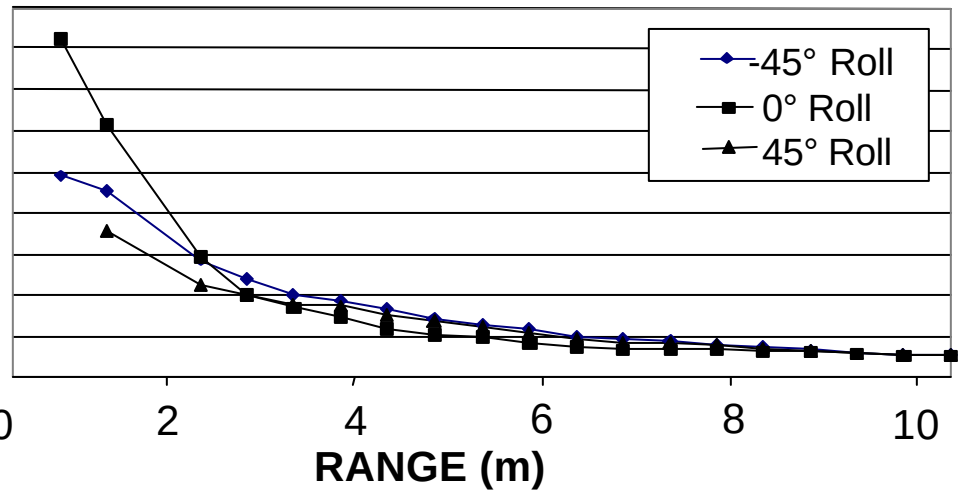
- 2nd Receiver prism window forms conical receiver field of view

Fixed Fan Beam Transceiver - Typical Logged Output



- Data capture controlled by PC
  - Bespoke software
  - Configurable sequences
- Each received pulse waveform captured at 1Gs/s and logged
- Left window shows typical captured pulse waveform
- Right window shows calculated range
  - Determined from pulse time of flight
  - Typically accurate to 10c

Fixed Fan Beam Measured Sensitivity Characteristics

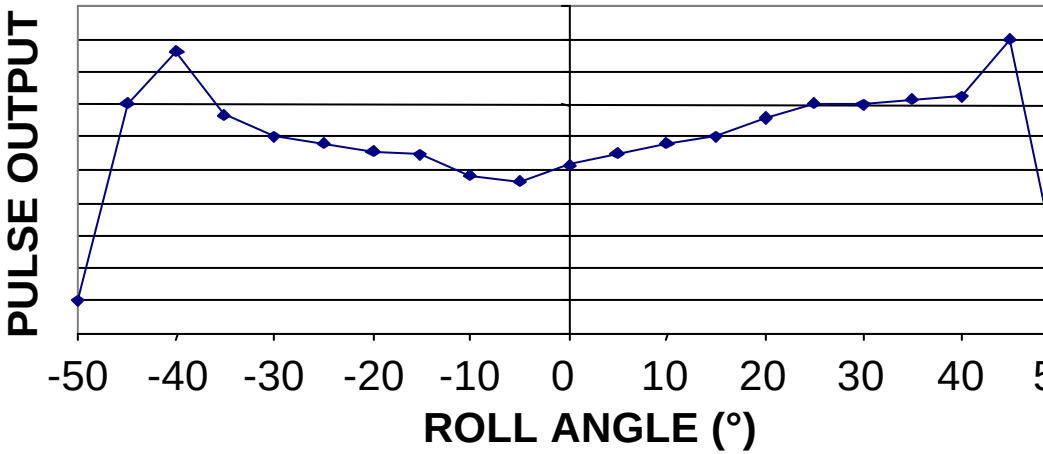


- Characterised using small target
- Impressive detection sensitivity compatible with expectations
- Dynamic range greatly compressed by swept gain amplification

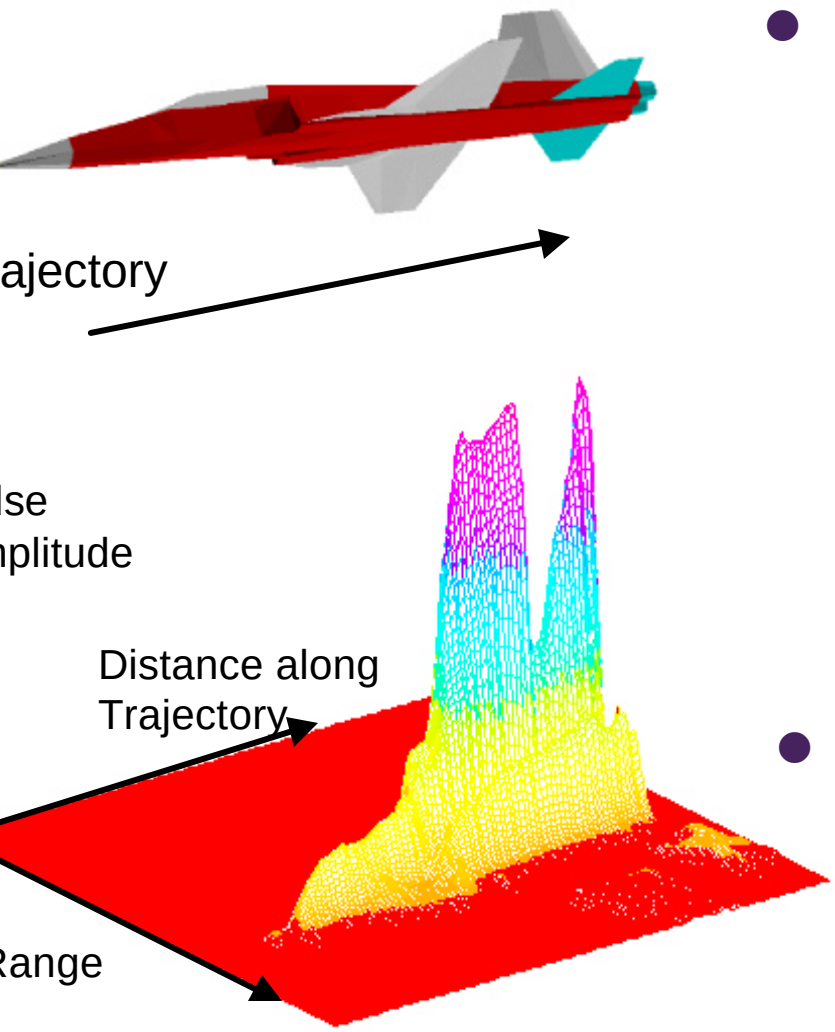
90° roll coverage achieved

A ‘flat’ Roll Response had been a specific design objective

Largely achieved

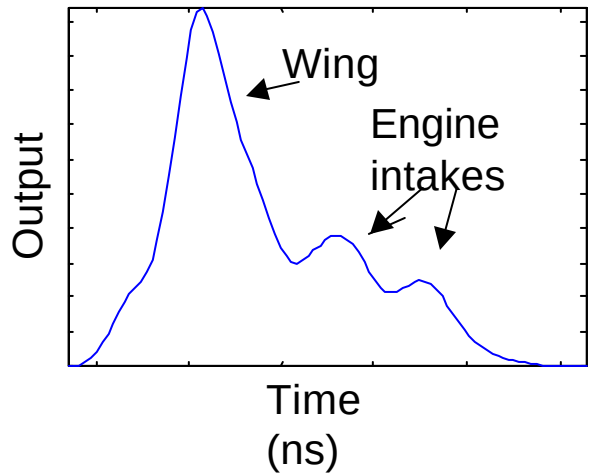


ixed Fan Beam Sensor – Target Engagement Modellin



Received waveform sequence

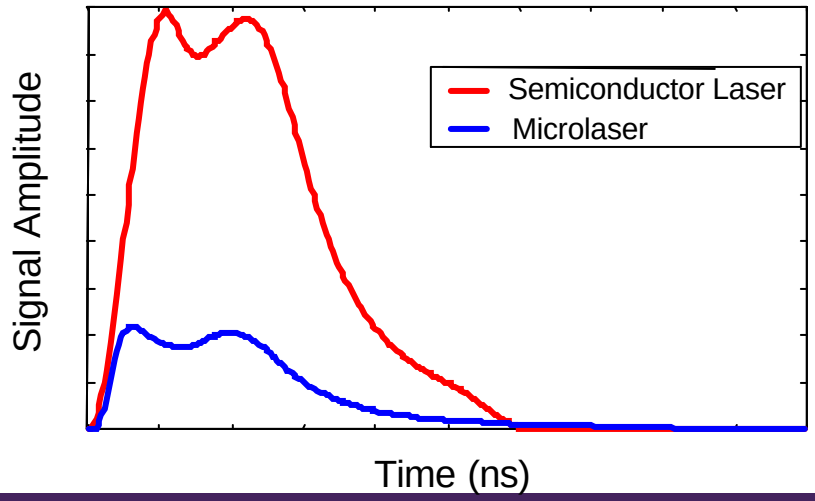
- Target engagement simulation model generat
  - Received waveforms predicted
  - Plots of sequential waveforms



- Potential exploitation of digitised pulse shape
  - Waveform is sum of pulse reflections fro illuminated target regions
  - Separated target features can result in distinctly identifiable pulse returns
  - Potential for more intelligent fuzing

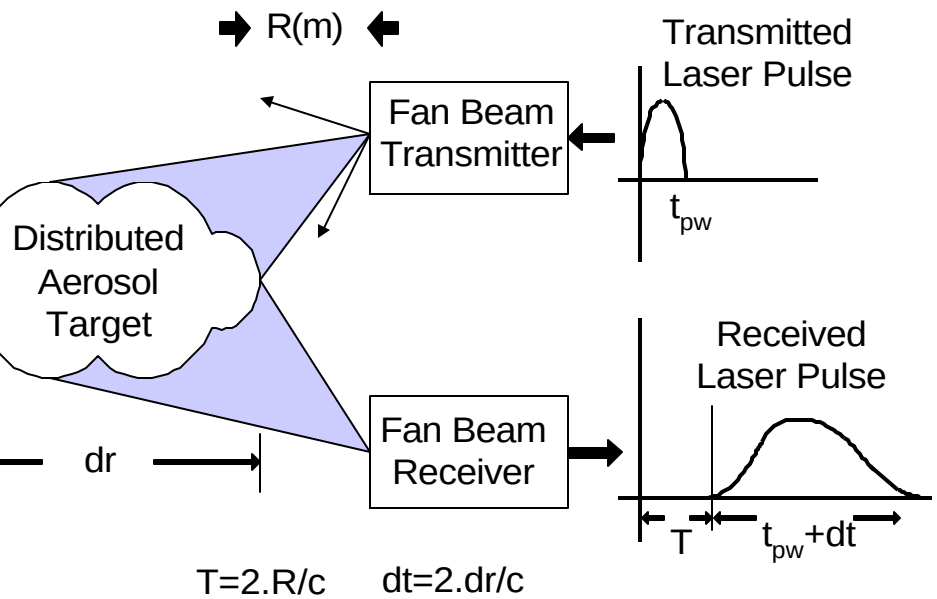
xed Fan Beam Sensor Cloud Backscatter Discriminatio - Simple Threshold

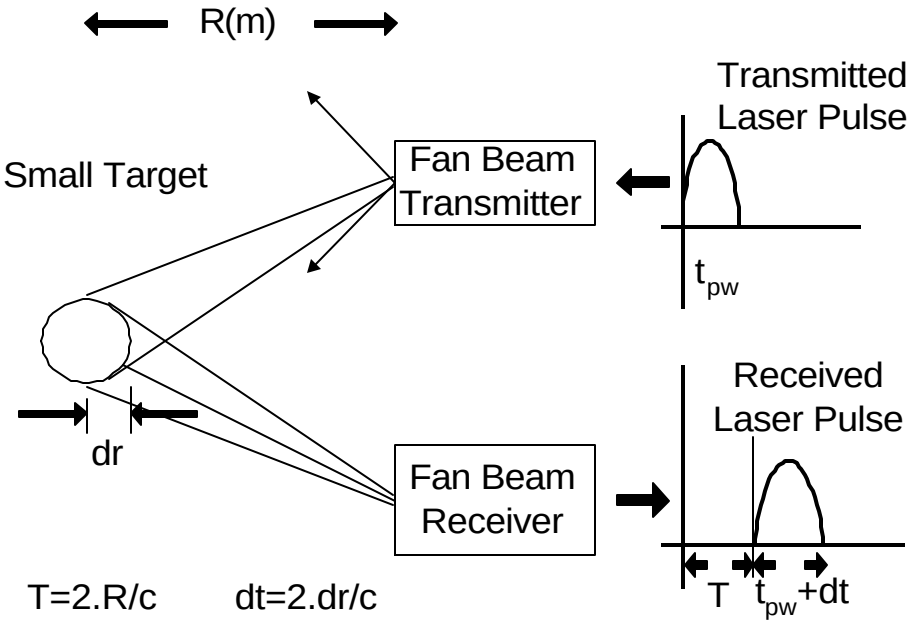
- Important to prevent false alarm when entering and immersed in cloud
- An amplitude detection threshold offers a simple means of discrimination
  - Threshold set above maximum backscatter envelope
  - Places a constraint on maximum sensitivity and detection range
- Backscatter pulse amplitude and shape is dependent upon:
  - Cloud density (extinction coefficient, β, is a useful measure)
  - Particle size distribution (Scattering Function, is useful measure)
  - Fuze sensitivity versus range
  - Transmitted pulse width
- Narrower Microlaser pulse width gives reduced backscatter amplitude
  - Improved discrimination



xed Fan Beam Sensor Cloud Backscatter Discriminatio - Pulse Shape

- Valid target is localised in range
- Reflected pulse exhibits minimal temporal extension

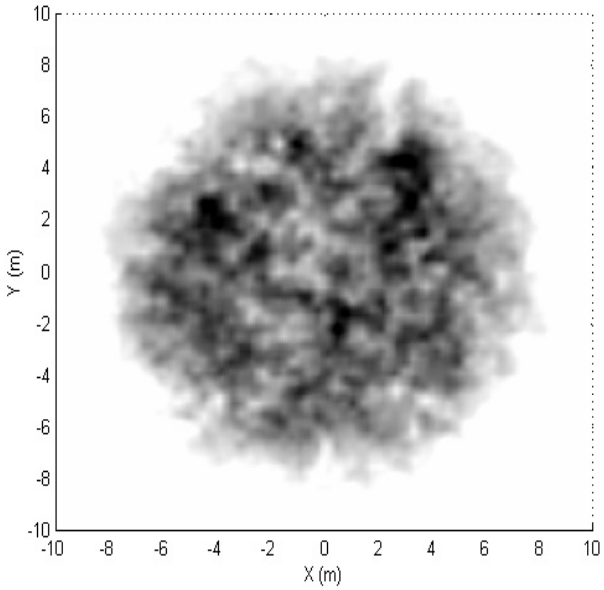




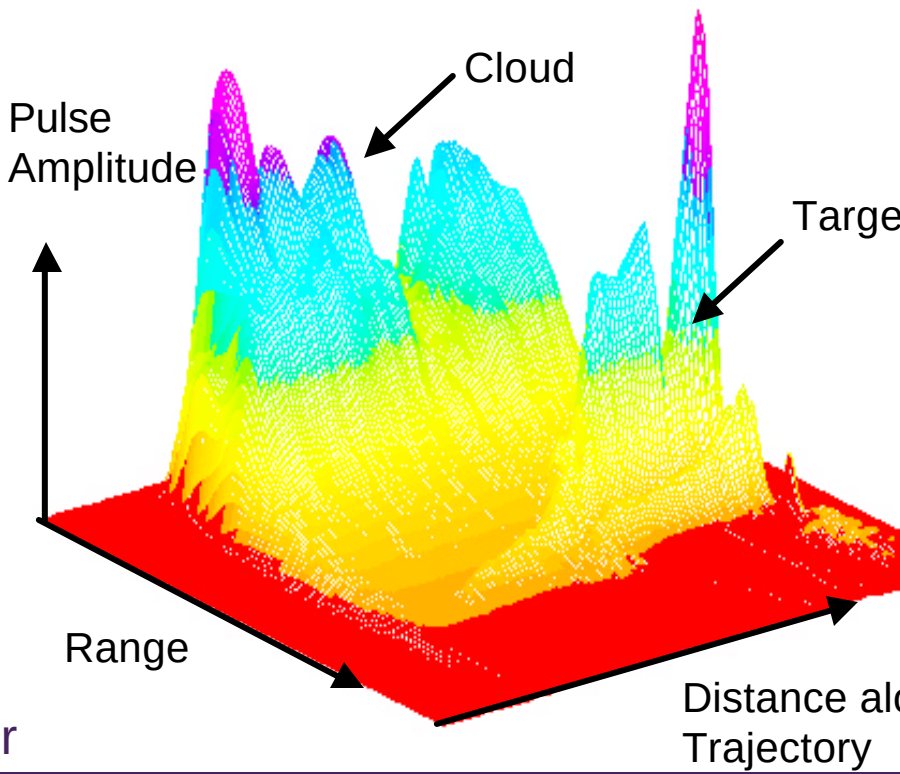
- Scattering sites distributed in range
- Backscattered pulse exhibits significant temporal extension
- Can discriminate on the basis of pulse shape

Cloud Discrimination – Algorithm Development

ey scale of xtinction oefficient 2-D slice ough centre ractal cloud



- Fractal based cloud model developed [jointly funded with UK Dstl]
  - 3-D lattice of extinction coefficient
  - High spatial resolution (0.1m)
  - Allows rapid spatial variations in density



Cloud discrimination algorithm evolved [Dstl contract] that incorporates

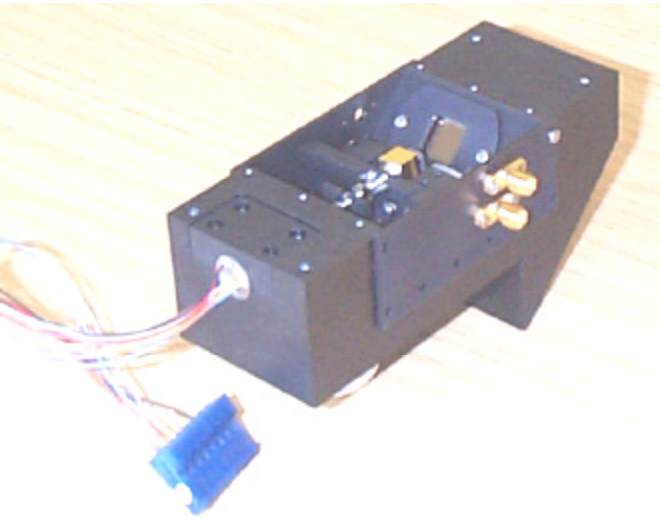
- Pulse shape analysis of consecutive waveforms
- Analysis of pulse shape history
- Logic to combine sector outputs

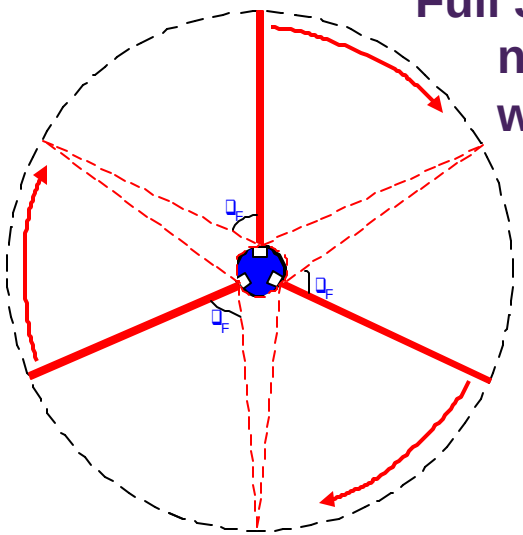
Successfully demonstrated by modelling cloud interaction

Limited confirmation in TME smoke chamber

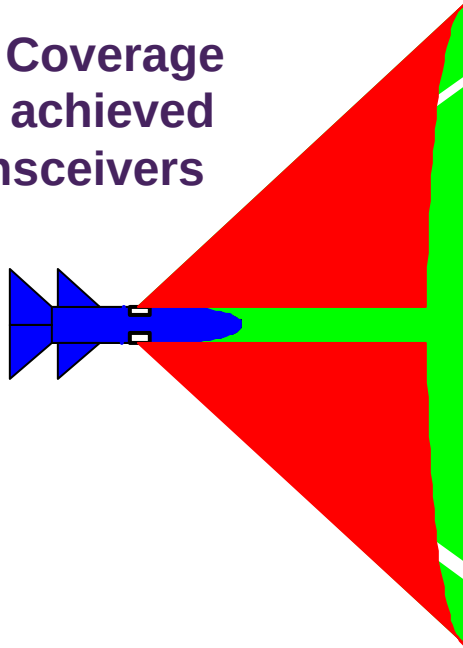
Scanned Pencil Beam Transceiver

Scanned Pencil Beam Transceiver Configuration





Full 360° Roll Coverage notionally achieved with 3 transceivers



Transmitter

- Pulsed Microlaser
- Scanning mechanism
- 45° forward looking hollow cone
- 120° roll coverage (scanned)
- 4kHz max scan repetition rate

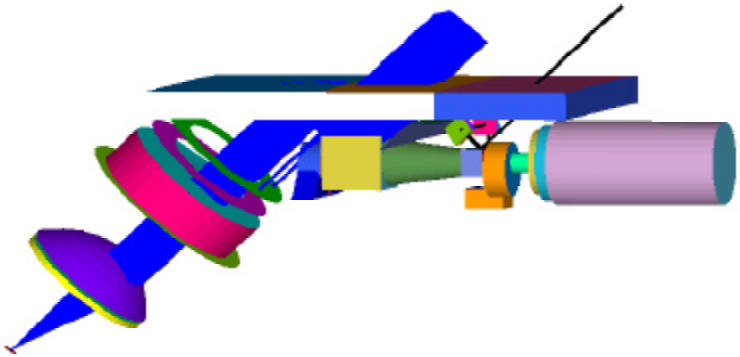
- Receiver
  - Complementary scanning mechanism
  - Narrow band filter
  - Focusing lens & Avalanche Silicon A
  - Transimpedance amplifier
    - High bandwidth (300MHz)
    - Switchable & Time varying gain

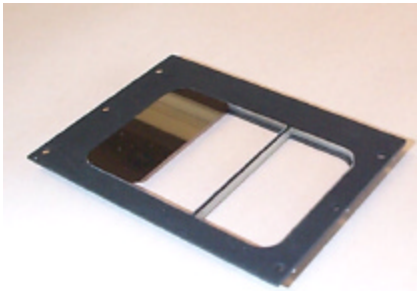
Scanned Pencil Beam Transceiver Design

Same Microlaser as Fixed Fan transceiver

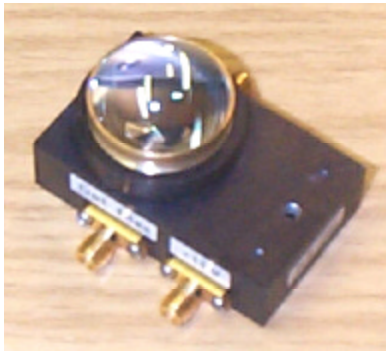
45° prisms route laser beam to scanning mechanism

- Optical design generated using the ASAP ray tracing tool





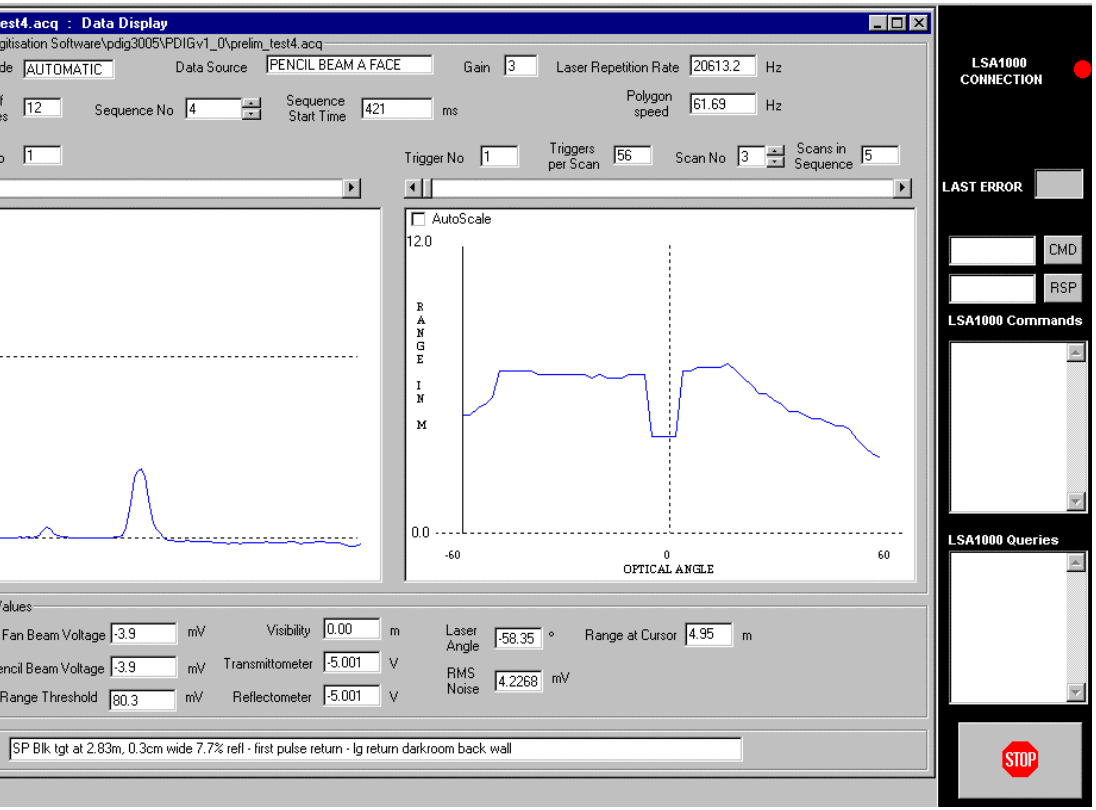
- Glass exit wind
- Receive window partly silvered



- Spinning reflective assembly scans the laser beam and receiver field of view in a conical locus
- Brush less DC motor
- 1kHz spin rate demonstrated

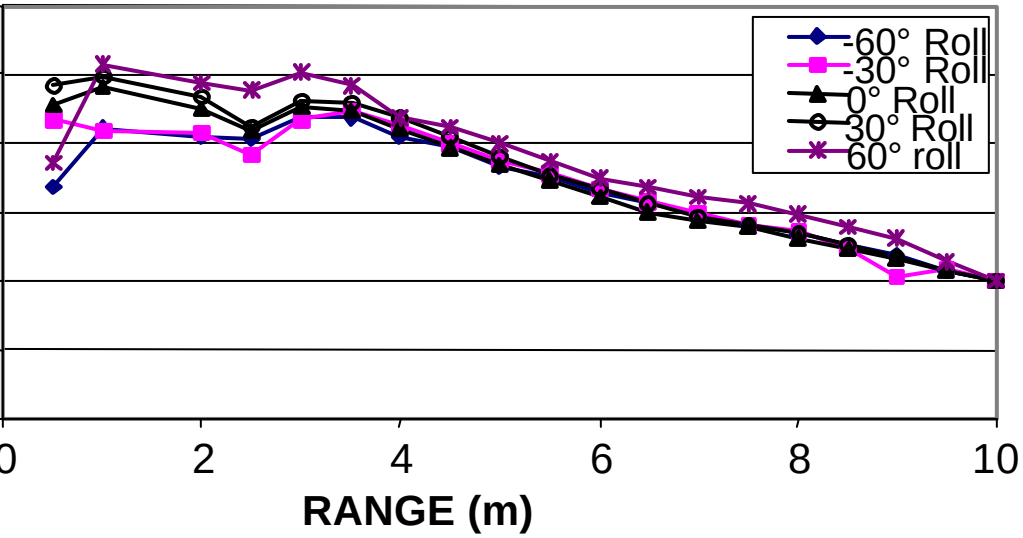
- Focussing lens/detector assembly

anned Pencil Beam Transceiver - Typical Logged Outp



- Data capture controlled by PC
- Left window shows typical captured single pulse waveform
- Right window shows measured range as a function of roll angle
  - Single 120° scan
  - Determined from time of flight of consecutive puls
  - Typically accurate to 10c
  - Narrow flat plate at ~3m centre of sector
  - Rear wall of test room at range ~7m

anned Pencil Beam Measured Sensitivity Characteristi

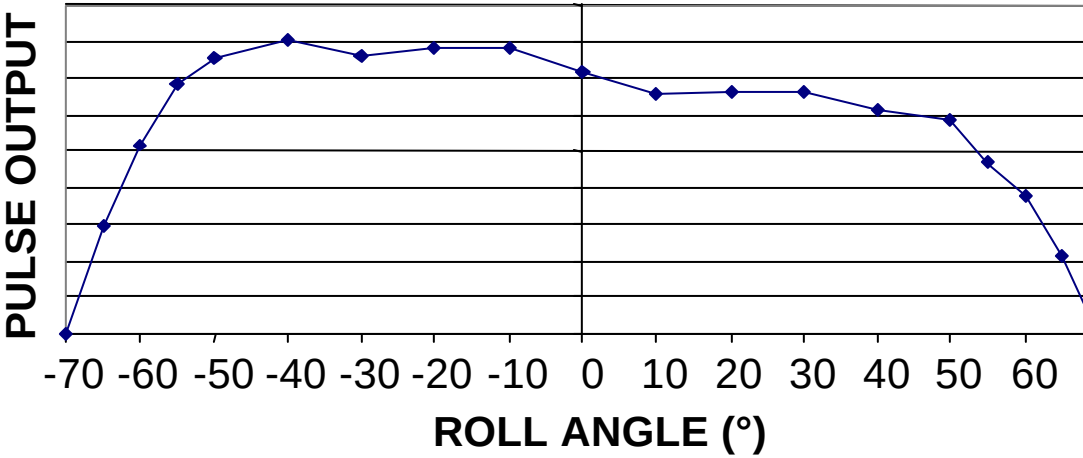


- Characterised using small targe
- Impressive detection sensitivity compatible with expectations
- Dynamic range greatly compressed by swept gain amplification

120° roll coverage achieved

A ‘flat’ Roll Response had been a specific design objective

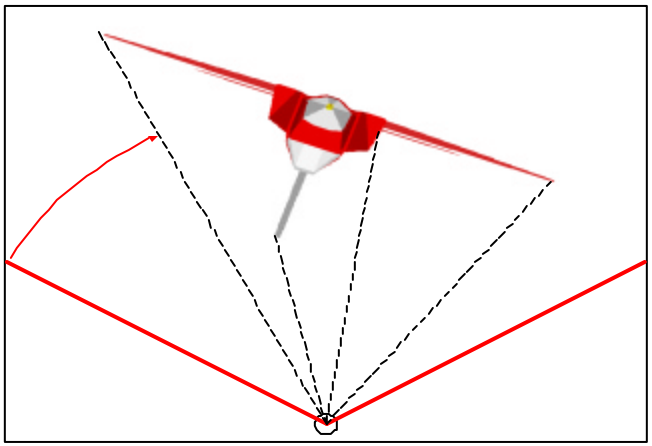
Largely achieved



nned Pencil Beam Sensor – Target Engagement Model

Target engagement simulation model generated

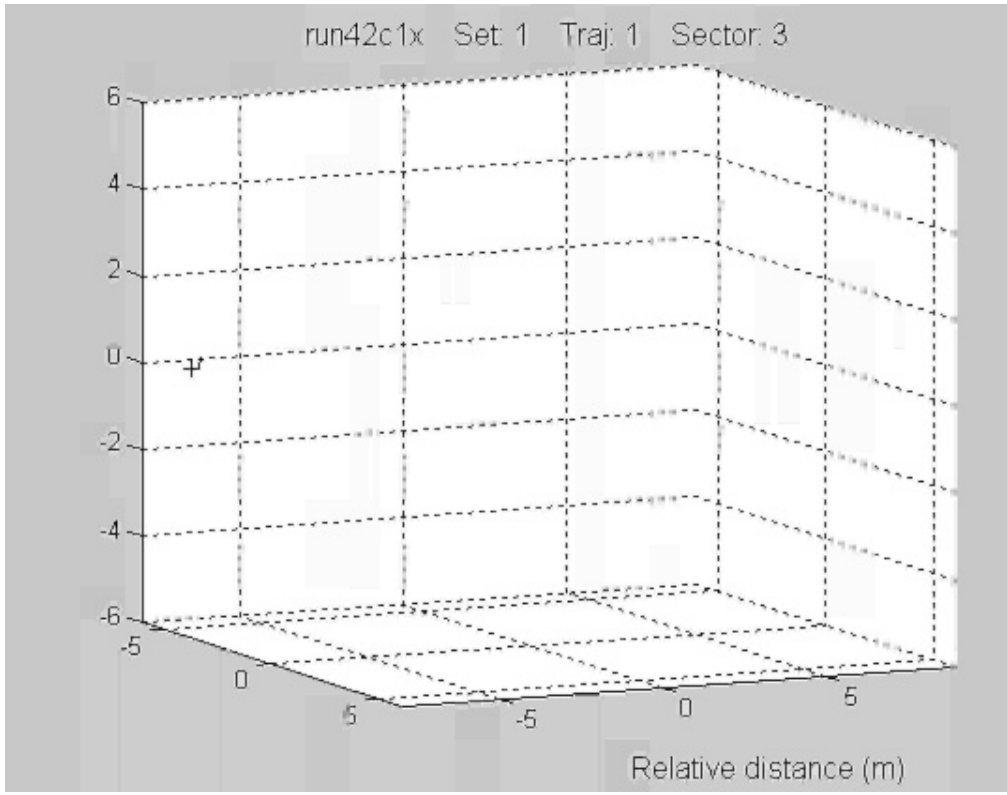
- Consecutive received waveforms
- Measured range for each pulse



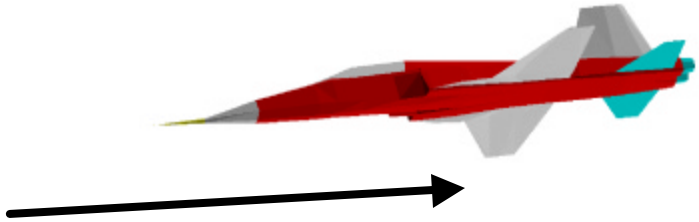
2-D range profile of target surface

- Derived from each conical scan
- Repeated at scan rate (4kHz)
- Roll angle resolution dependent on laser repetition rate

- 3-D surface profile of target
  - Built up from consecutive scans
  - Available up to trigger point

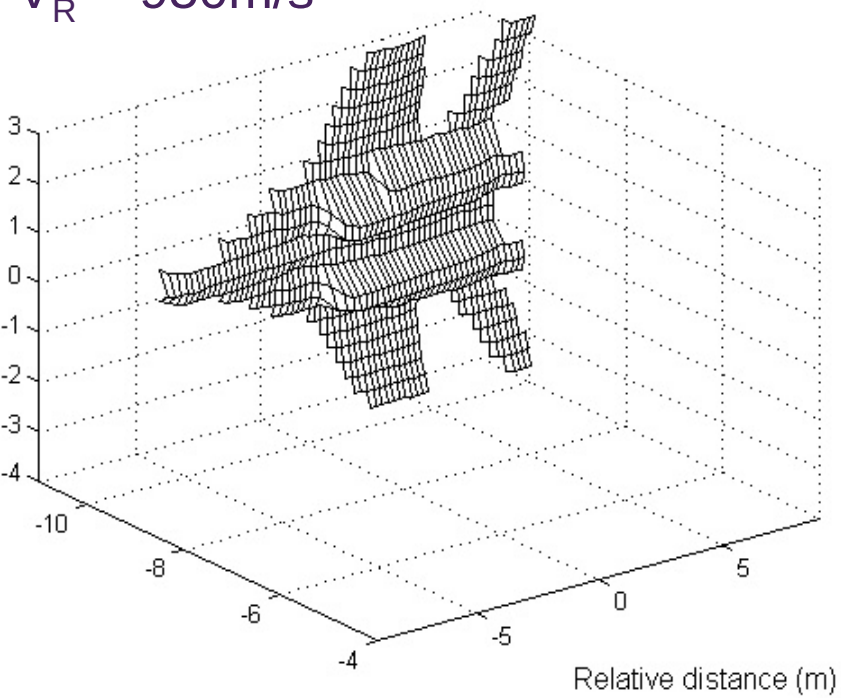


Scanned Beam Sensor - Simulated Aircraft Engagemen

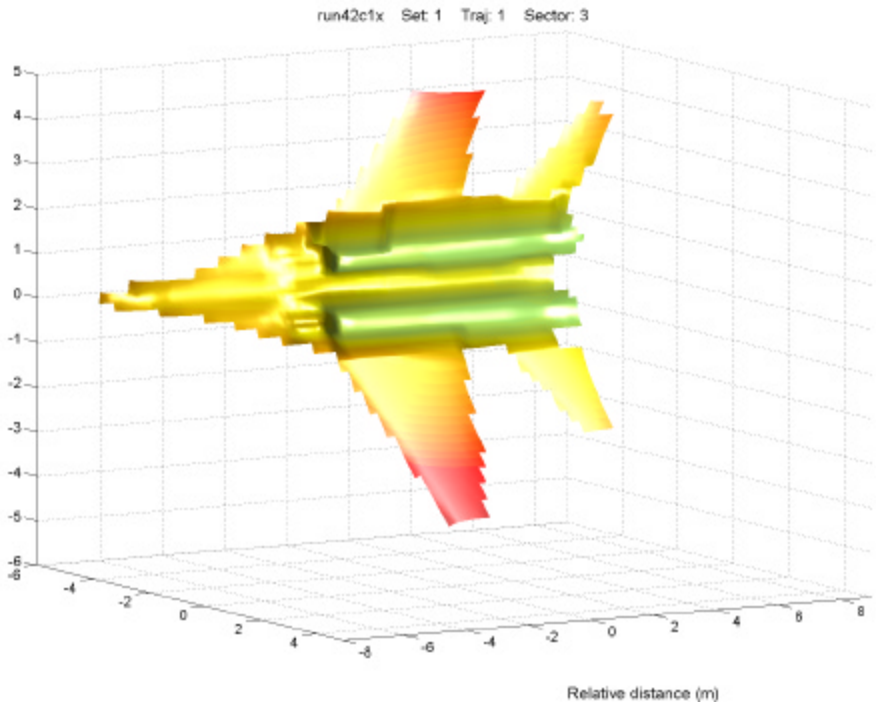


Underside head-on engagement

V_R = 950m/s

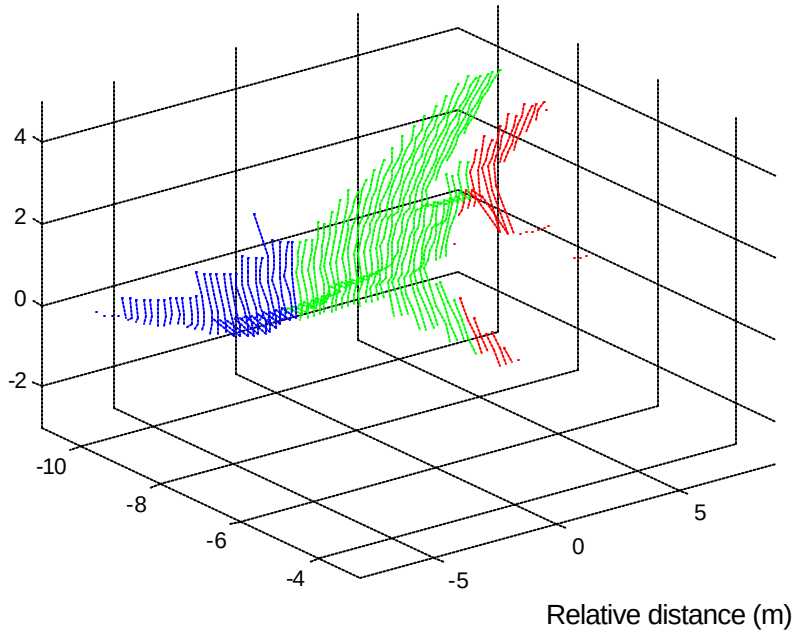


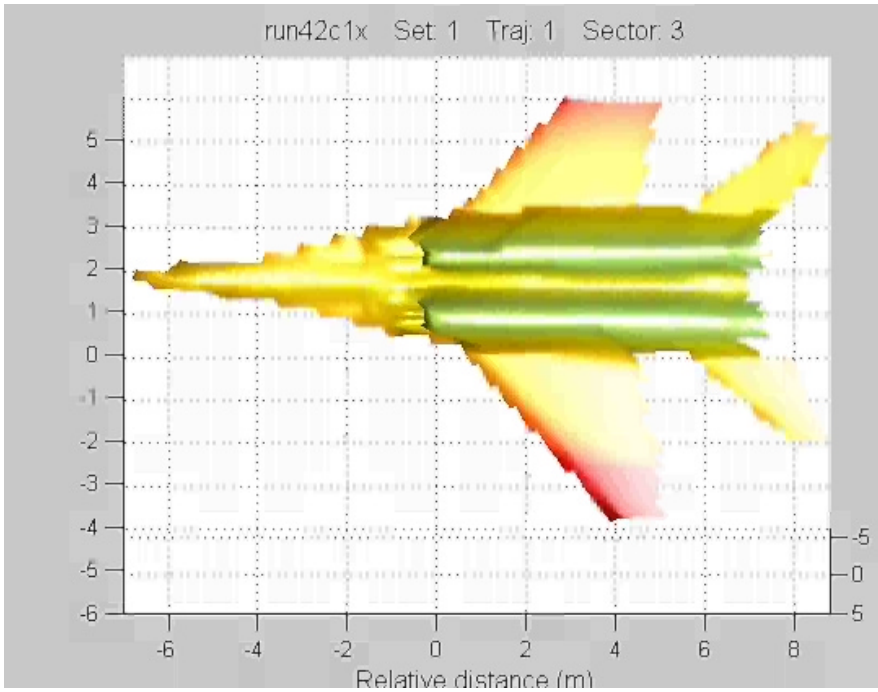
Data presented as wire grid surface plot



- Data interpolated and smoothed
- Colour coded for down beam range
- Distinct target features evident
  - Nose / fuselage
  - Wings / Engines

Scanned Beam Sensor – Fuzing Algorithm Developmen





May only have scanned part of the target by the point of optimum triggering

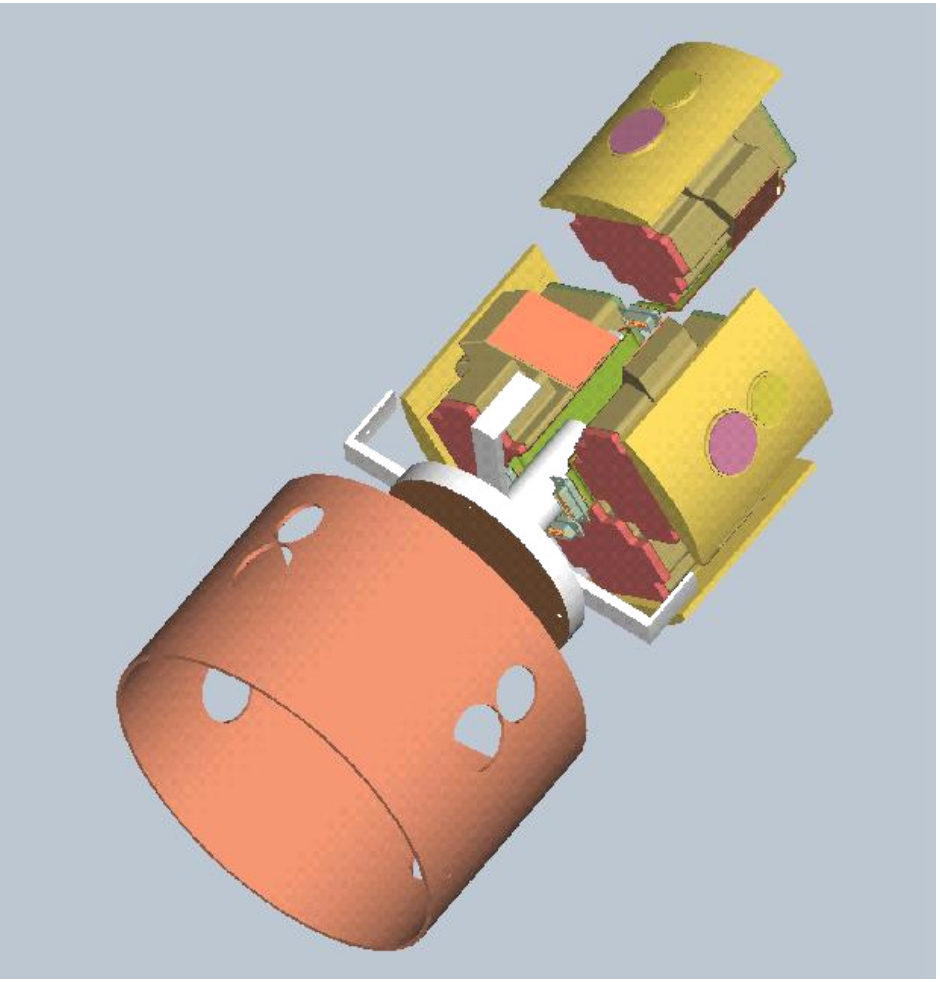
Worst for head on engagements (topside port head-on case shown above)

Scanned data colour coded for

- Blue up to first WH aim point (cockpit)
- Green up to last aim point (engines)

- 3D surface data provides great potential for algorithm developme
- Potential target feature extraction
- Autonomous algorithms
- Fuze Guidance Interaction algorithms

Packaging Studies



- Body mounted configuration
- Fixed Fan Beam optical configuration
- Same optical components as used in Demonstrator
- Four optical transceivers
- Central Electronics Unit
- Compatibility with existing ASRAAM fuze space envelope demonstrated

Summary & Future Plans

- Microlaser Fuze potential demonstrated
  - Capable of offering much enhanced detection range and coverage
  - Capable of offering enhanced resolution (range and angle)
  - Capable of enabling enhanced clutter discrimination
- Fuze algorithm development work planned
  - Utilise existing simulated waveform signature data base
  - Autonomous fuze algorithms and Fuze Guidance Interaction algorithms
- Cloud clutter trials planned
  - Demonstrator suitable for ground based trials (hilltop site)
  - Potential for future air carriage trial
- Microlaser device risk reduction planned
  - Stabilisation times & operating environment issues
- Possible full scale static target engagement trials
  - Towed past targets on ground
  - Potential use of the US MESA facility at China Lake

Questions?