# Close Integration of Weapon and Targeting Sensors: a Key Enabler for future Deep Strike Missions

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Abstract

The timely and accurate engagement of a broad spectrum of mobile and relocatable targets are key requirements within the future Deep Strike capability. There are a number of approaches to meeting this requirement ranging from direct operator control of the weapon to the exploitation of fully autonomous seekers. The latter has the attraction of minimising the operator workload and reducing the need for key tactical assets to enable the mission. However, there are significant technical challenges that need to be addressed to ensure high confidence that such a weapon can be used within potentially tight Rules of Engagement (ROE). This paper addresses the particular problem of ensuring that the weapon seeker acquires the designated target. A methodology is proposed for directly exploiting signature and contextual information within the seeker target acquisition process. This is seen as a key enabler as it allows the seeker target selection logic to be tuned to the specific target and mission. The information could either be down-loaded at weapon launch or broadcast following weapon launch. A key output is a confidence measure in the target selected, which can be used within the ROE to support the final decision to engage. Having developed the generic framework, it is then illustrated using the example of a RF targeting system and weapon exploiting an imaging RF seeker. Implications for the design of the seeker and associated sub-systems are then discussed.

## 1. Introduction

The asymmetric nature of modern conflicts has resulted in a major shift in the required capability of future weapon systems. Key objectives now include the need to engage a broad, and evolving range, of relocatable targets, not just classic Main Battle Tanks, and the need to engage them in a timely fashion. A key consequence of these is a reduced mission planning time, with the desire being to be able to adapt the mission either in flight or even post weapon commit. This clearly requires a very close interaction of the weapon and the information environment in which it operates. The simplest method of achieving this is with a human operator in the loop. We currently have such weapons as Laser Guided Bombs and Maverick which are directly guided onto the target or locked by the operator before launch.

Such approaches are entirely suitable if the launching aircraft can operate safely sufficiently close to the required target. However, if this is denied, due to the presence of Air Defence assets for example, a problem is encountered.

A potential solution centres on extending the current technical push on Network Centric warfare to include a seeker within a stand-off weapon. In this case, the seeker is the final element of the information chain that starts with long range

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strategic surveillance assets, includes shorter range tactical assets and ends with a seeker that uses this information to acquire and engage the nominated target.

In this paper, we describe a generic approach developed under MoD DTA Output 3 funding that provides a framework for the integration of information from a broad range of targeting assets with a broad range of seeker technologies. This approach is designed to support the acquisition of a specific target nominated in the mission planning and to make optimum use of the information available. In section 2, the framework is reviewed and illustrated using an example of a Synthetic Aperture Radar targeting asset and an imaging RF seeker guided weapon. Section 3 then addresses the implications of such a system on the design of the weapon and the performance demanded of the seeker within it.

## 2. Target Acquisition

The principle objectives of a seeker within the weapon are to acquire the designated target and then guide the weapon to a point where the warhead can fulfil its function. For ground attack weapons, the target acquisition problem is not trivial due to the complex and varied nature of both the target, and more importantly the background terrain. The problem becomes even more complicated if the desired target is surrounded by buildings and civilian collateral objects that must be avoided. This has driven the design of high performance seekers that can measure a great deal of information about the target and its environment. In parallel, much effort has been expended on the development of algorithms to exploit this information for successful target acquisition. Until recently, the algorithm development activities have centred on the acquisition of pre-defined specific types of targets such as MBTs.

All target acquisition algorithms essentially centre on the comparison of attributes of the target signature measured by the seeker with values defined prior to the weapon deployment. Conventionally, the pre-defined values are established during the weapon development programme. However, this requires a re-visit to the algorithm if the target specification changes. A better, and more flexible, approach is to exploit the large amount of valuable information about the target, and its environment, as measured and processed by the targeting infra-structure. This allows us to configure the algorithm dynamically for the specific engagement.

Under DEC(DTA) Advanced Air-Surface Seekers Output-3 programme, QinetiQ has been developing and assessing a framework to optimally integrate the targeting information with the information measured by the seeker. The framework essentially comprises the following steps:

- a map, referred to as the Target Object Map (TOM) containing information on the target and potential collateral objects is collated from the targeting network;
- this map is broadcast to the weapon either pre-launch or during the weapon flight;
- on arrival in the target vicinity, a corresponding TOM is generated from the seeker measurements;
- the two are fused to determine the object in the seeker TOM that is most likely to correspond to the designated target.

The key difference between this approach and more conventional approaches, in which each detection is considered independently, is that the each object detected by the seeker is considered in the context of all the other objects. The most likely detection is then declared as the target given all the available information. An additional benefit is that the target selection is accompanied by a confidence measure in the decision which allows an adaptation of the engagement decision to varying Rules of Engagement.

An example of the approach is given for the case of a SAR targeting asset and an Imaging RF seeker. For more detail the reader is referred to [1],[2] and [3]. Figure 1(a) shows a potential SAR targeting image of an array of deployed vehicles, with the required target outlined in red and the remaining vehicles in yellow. Each of these vehicles is characterised by an estimate of position and a number of physical attributes such as size. In addition, this information is augmented by estimates of the uncertainty in the measurement of these parameters. For SAR targeting, this error encompasses geo-location errors and the noise on the derived values of object size if these are derived from the imagery. In its simplest form, this information comprises the targeting TOM. Figure 1(b) shows the corresponding image of the target array measured by the seeker; the red objects showing the targets declared by the seeker. The seeker used here is a 35GHz Imaging RF radar developed jointly by QinetiQ, on behalf of MoD, and MBDA [4]. A target detection algorithm is applied to the seeker imagery to automatically separate the targets from the background. As with the targeting image, the position and attributes of the detected objects are then estimated, and combined with estimates of the accuracy on these measurements based on the design of the seeker. The two TOMs are then fused with the result shown in figure 2. This shows the probabilities of association between objects identified by the targeting sensor and those declared by the seeker. The single high values in the rows and columns indicate a high confidence in the tested association.

As the fusion framework is posed in terms of attributes measured of the target signature, it is generic and highly flexible in nature. The important criterion is that the corresponding attributes can be measured in both the targeting and seeker imagery. Thus, if differing types of sensor are available it is incumbent on the algorithm designer to derive techniques for estimating corresponding attributes. However, if the targeting data TOM can be assumed to provide perfect information on the classes of objects in its map, the fusion framework can also exploit discrete classifications (as opposed to feature measurements) provided by the seeker. So, for example, suppose the scenario consists of two classes of object, say, tanks and cars, and that the members of the targeting TOM can be correctly assigned to these classes. Then the framework can exploit tank /car/ clutter classifications from a seeker ATR system rather than working directly with attribute values.

## 3. Weapon/seeker Design implications

In section 2 we gave an overview of the approach to the exploitation of targeting information within a seeker. This allows the dynamic configuration of the seeker processing to support significantly enhanced flexibility in the missions that can be undertaken. In this section we draw out some of the implications on the specific design of the seeker and other elements of the weapon system.

Search Pattern: As noted above, the power of the approach arises from its ability to consider the target in the context of surrounding objects. This therefore requires that the area of terrain imaged by the seeker encompasses these objects prior to the application of the target selection logic. This is in contrast to previous approaches in which each object is assessed only as it is viewed by the seeker. Essentially, a large area image is collated and then processed by the algorithm. The key drivers on the required size of this area are that it must be large enough to:

- accommodate likely target motion;
- include sufficient number of objects such that ambiguities arising from the attribute uncertainties can be resolved.

The required search area, and the desire to image it completely prior to target selection, and the terminal guidance requirements couple with the weapon aerodynamic performance to define many characteristics of the seeker. These include scan ambit and search range and thus seeker sensitivity. These issues are illustrated in figure 3. This shows three possible approach tracks to an example search area for an imaging RF seeker, a black circle which could represent the uncertainty in the position of a moving target. The seeker should search the furthest extent of this complete area whilst still being able to engage a target potentially at the leading edge.

Target detection: The approach is largely predicated on the desire to engage a specific nominated target, rather than one of many. This provides a different driver for the target detection performance of the seeker to that addressed in the design of many-on-many weapons. Underpinning the comparison of the targeting and seeker TOMs is the assumption that the required target is declared in both. Although there are options for accommodating a missing target through the algorithm's ability to infer a position of non-detected objects from the position of the detected ones, this is not desirable due to added complexity. Thus, the basic seeker target detection algorithm should be designed with a very high probability of including the desired target within its TOM. The corollary of this is a real challenge: to keep the number of false detections arising from clutter to a minimum which is consistent with the targeting information, as too many additional detections reduce the reliability of the TOM fusion process. This demand for high Pd and low false alarm densities is being addressed through the development of a high performance imaging seeker.

Data-links: The performance of the TOM matching process arises from its ability to compare and match attributes of common objects as measured by the targeting sensor and the seeker. One of the most powerful, and generally available attributes is target position. Thus to support the engagement of moving targets, it is desirable for the targeting TOM to be updated as late as possible in the engagement. Further, the seeker will not be able to accommodate the entire target motion that might arise in a flight time of several minutes; again demanding an update. The need for an in-flight update implies a data-link. In its simplest form, the targeting TOM is very simple; comprising a list of objects and associated attributes and should be transferable in-flight. However, [1] indicates that to mitigate the false object detection problem highlighted above, an RF seeker could significantly benefit from direct access to the SAR targeting imagery itself. This potentially is a much more significant demand on the bandwidth requirements of the data-link.

Targeting asset requirements: Following from the data-link discussion, it is clear that not only is an in-flight update a key enabler, but its timing is critical. If too early, the target motion will be greater than the search basket and if too late, the weapon will have over-flown the target. The size of this window is clearly mission dependent. However, underpinning the data-link update is the acquisition by the targeting environment of the information contained in the targeting TOM. This is likely to require imagery to be acquired and processed, with an associated latency, which will be accommodated within the attribute uncertainties.

The key message from this element of the discussion is that the seeker must be considered as part of the overall information acquisition chain and the successful prosecution of the engagement requires careful orchestration of the strike and tactical targeting assets.

## 4. Conclusions

In this paper we have presented an approach which achieves high performance target acquisition for medium range stand-off weapons and which is suitable for a wide variety of seekers. The approach considers the weapon/seeker as an integral part of the Network Enabled Capability and, through the transfer of targeting information, supports the robust autonomous selection of a nominated target by the seeker and a safe stand-off for the launch aircraft. The dynamic re-configuration of the seeker ATR allows for the engagement of time critical targets and straightforward weapon tasking. As an intrinsic part of the process, the ATR also calculates a confidence measure in the associated target designation that can be incorporated within mission specific rules of engagement. The framework also naturally allows for the specific designation of collateral objects that must be avoided.

The application of this approach has some significant implications for the design of the seeker, weapon and other key sub-systems; and the orchestration of the complete engagement. However, it is believed that this capability will allow the flexible prosecution of engagements from stand-off that currently require close-in, operator in the loop support.

## References

[1] Engaging TCT from Medium Range by exploiting a-priori information, M Farrow, RAES Conference on Time Critical Targeting : Filling the Capability gap, November 2003

[2] A Bayesian technique for target selection and acquisition, D J Salmond, N O Everett and N J Gordon, Journal of Defence Sciences, Vol 3, No 4, October 1998.

[3] Bayesian pattern matching technique for target acquisition, N J Gordon and D J Salmond, AIAA Journal of Guidance, Control and Dynamics,
Vol 22, No 1, Pages 68-77, Jan-Feb 1999.

[4] A new MMW Radar for Surface Attack Weapons, A Britton & D Joynson, Proc 4th Military Sensors symposium, Dec 2000

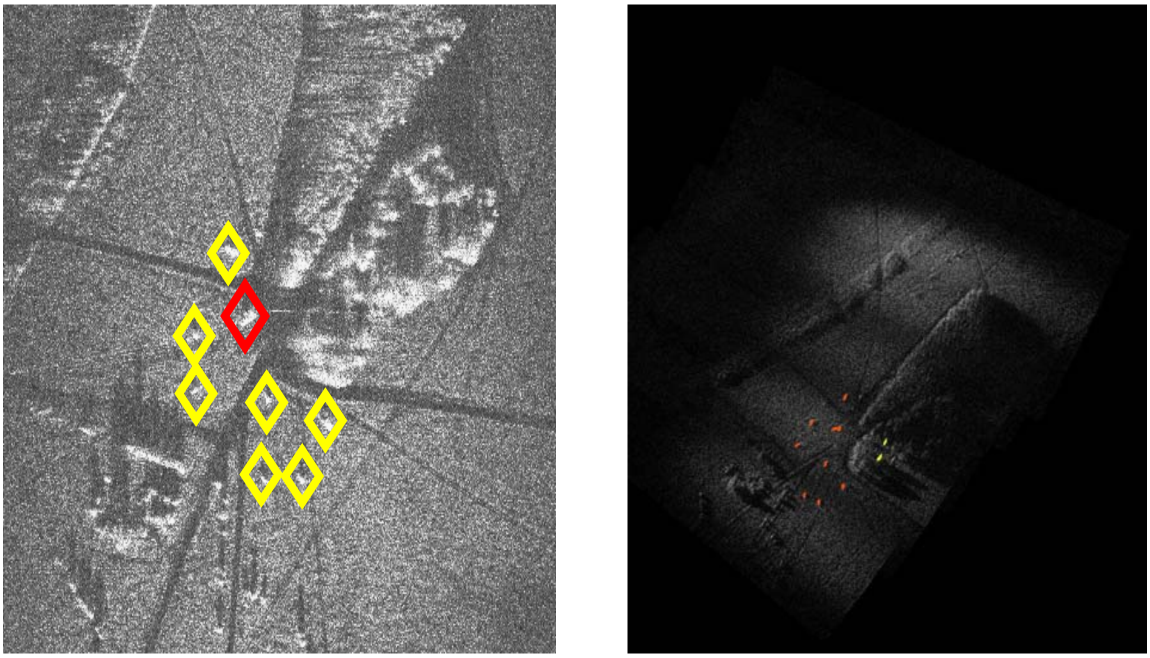

Figure 1 (a) Example SAR targeting map and corresponding 35GHz RF Seeker Imagery

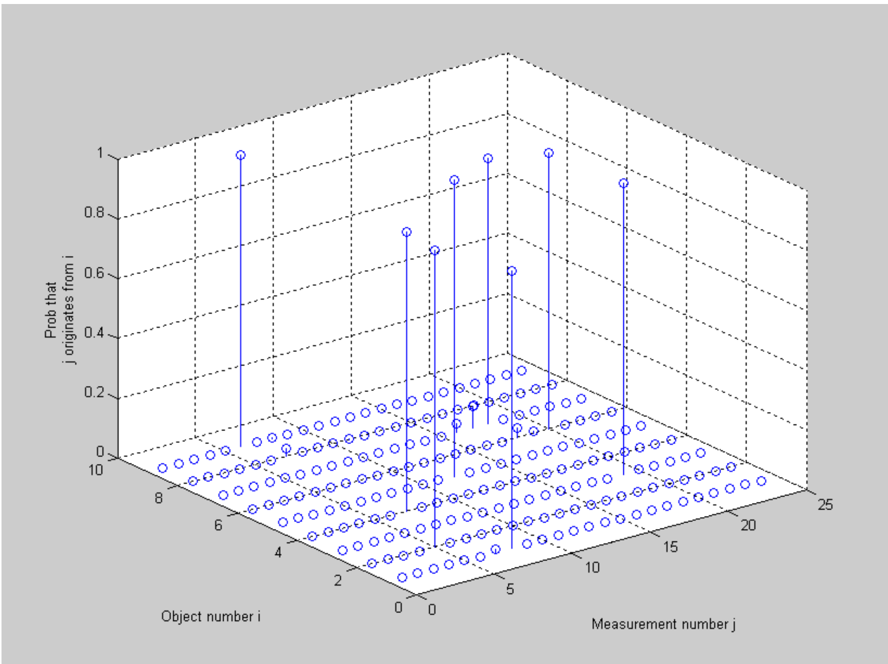


Figure 2: Bayesian Framework Output from fusion of imagery in Figure 1

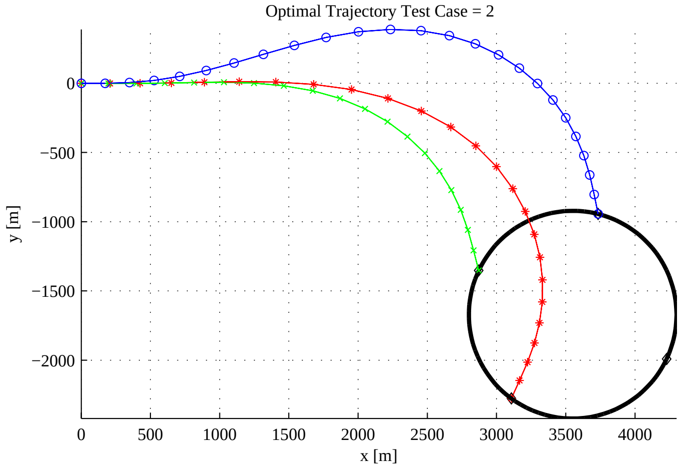


Figure 3 – Exemplar trajectories for Imaging RF seeker to engage any point within the required Target Search Basket (black circle)

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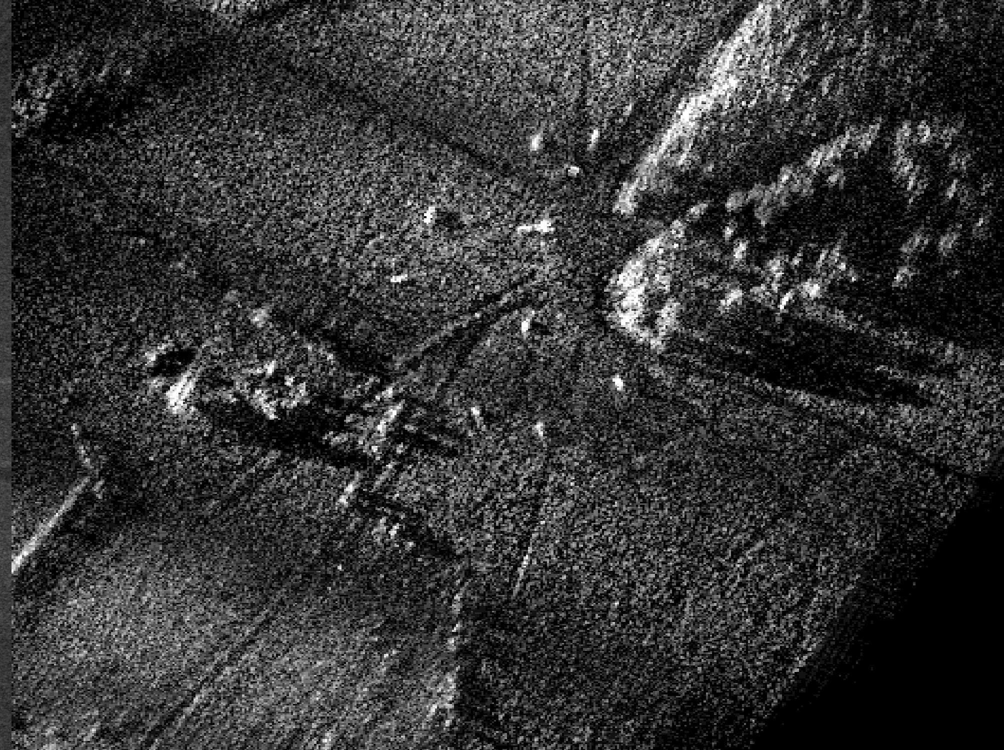

# Close Integration of Weapon and Targeting Sensors- a key enabler for future Deep Strike Missions

A.Britton, S. Manchanda, D Salmond, M Farrow

A Presentation to MATRIX 2005

11th May 2005

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1. Requirements
2. Exploitation of targeting information
3. Application to Imaging RF seekers
4. Implications for Weapon
5. Summary

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# Requirements

- Mission
  - mobile & re-locatable targets
  - engage from medium stand-off range
- Key drivers
  - broad target set/rapid mission planning
  - low collateral damage/high precision
  - high weapon availability
  - tight ROE

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# Rules of Engagement

- Suggest the ROE will shift the required operation of the weapon seeker from
  - engage ***a*** valid target
- to
  - engage ***the*** nominated target
- Weapon will only be used if there is high confidence that it will do what it is told to do

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# Implications for seeker ATR

- Broad and mobile target set
  - difficult to extensively characterise *a priori*
  - potentially large target location error due to weapon flight time
  - complex clutter

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# Approach

- Compile information from targeting infra-structure into Target Object Map (TOM)
- Consider seeker as final stage of NEC
  - broadcast TOM to seeker
  - seeker re-measures its own Target Object Map
  - targeting/Seeker TOMs fused within seeker
  - nominated target selected and engaged
- Seeker is closely integrated within Targeting infra-structure rather than hardwired at production

# Exploitation of Targeting information

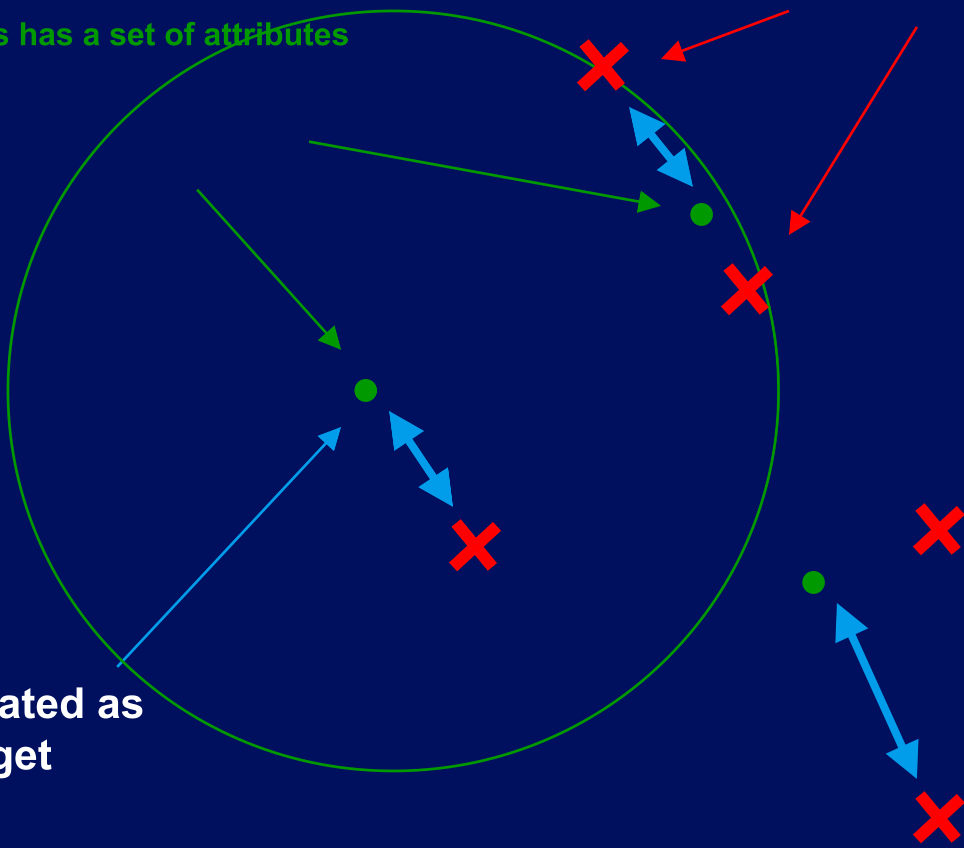
- Target Object Map (TOM)
  - represents the targeting information as a list of objects declared by targeting system
- Generic approach to exploitation of targeting information
  - fuses TOM with objects declared by seeker
  - targets defined in terms of attributes plus uncertainties
  - fusion implemented in a rigorous probabilistic fashion

# Target Object Map

**Seeker detect and measures object attributes**

**Targeting Information**

**Each objects has a set of attributes**



**One designated as the target**

**Uncertainties associated with each object**

# Benefits

- Performance arises from the formation of a global view of the target and its environment
  - establish which objects is most likely the target
- Advantage
  - exploits direct information about the target
  - allows for preferential selection of nominated target
  - provides a confidence measure in target selection
- Disadvantage
  - requires an image of the target and its environment
  - impact on seeker design

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# Imaging RF seekers

- High spatial resolution
  - waveform encoding
  - Synthetic Aperture techniques
- Coverage
  - antenna scanning
  - image shows run  over target array
- Advantage/disadvantages
  - all weather, day night
  - non-intuitive imagery

Radar developed jointly between QinetiQ, for MoD,  and MBDA

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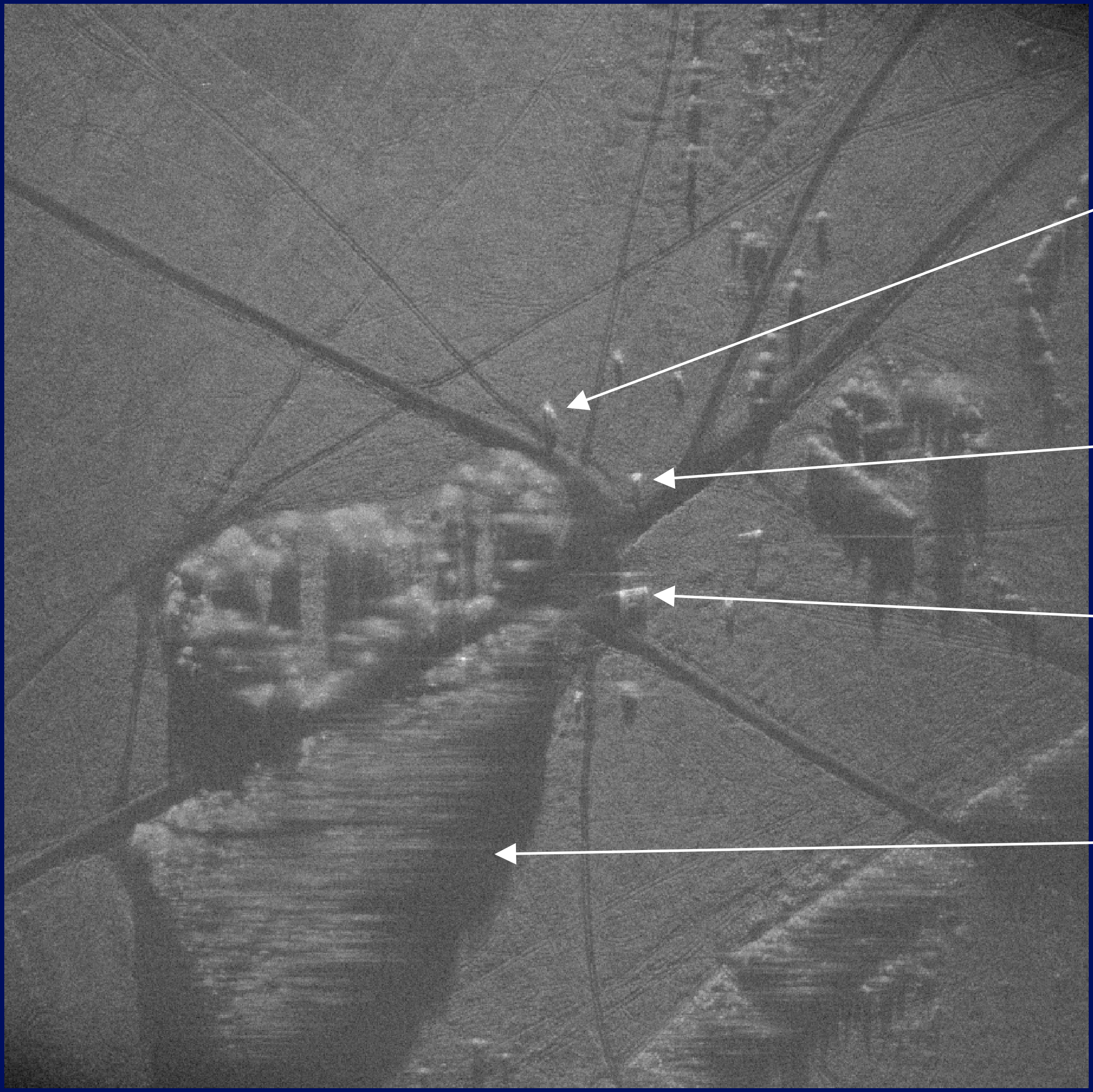
# Exemplar SAR targeting imagery



SA-8 "Gecko"
SAM
DESIGNATED
TARGET

T72 MBT

Scud TEL

Tree-line

Other vehicles
present in scene

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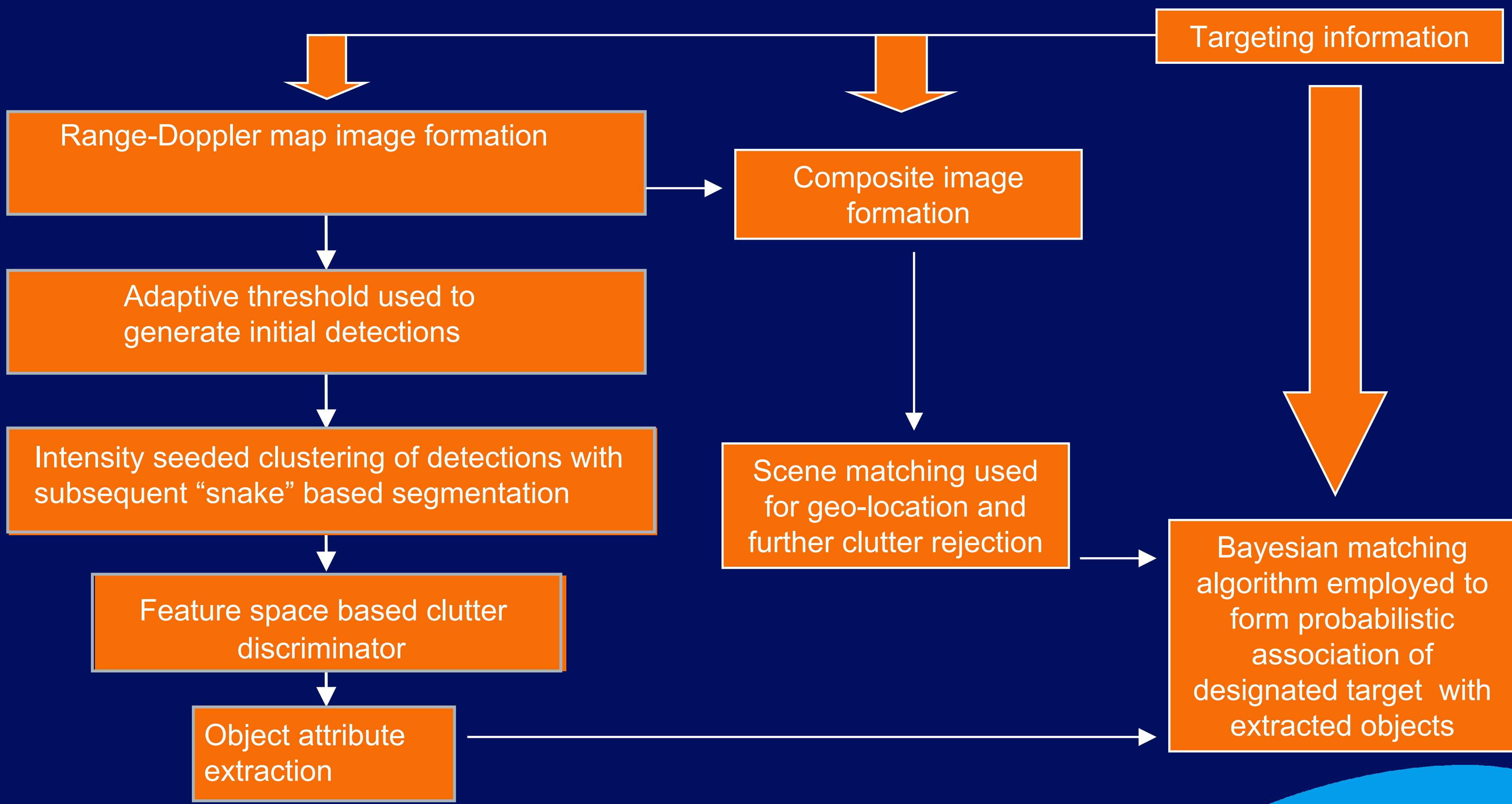
# ATR Implementation

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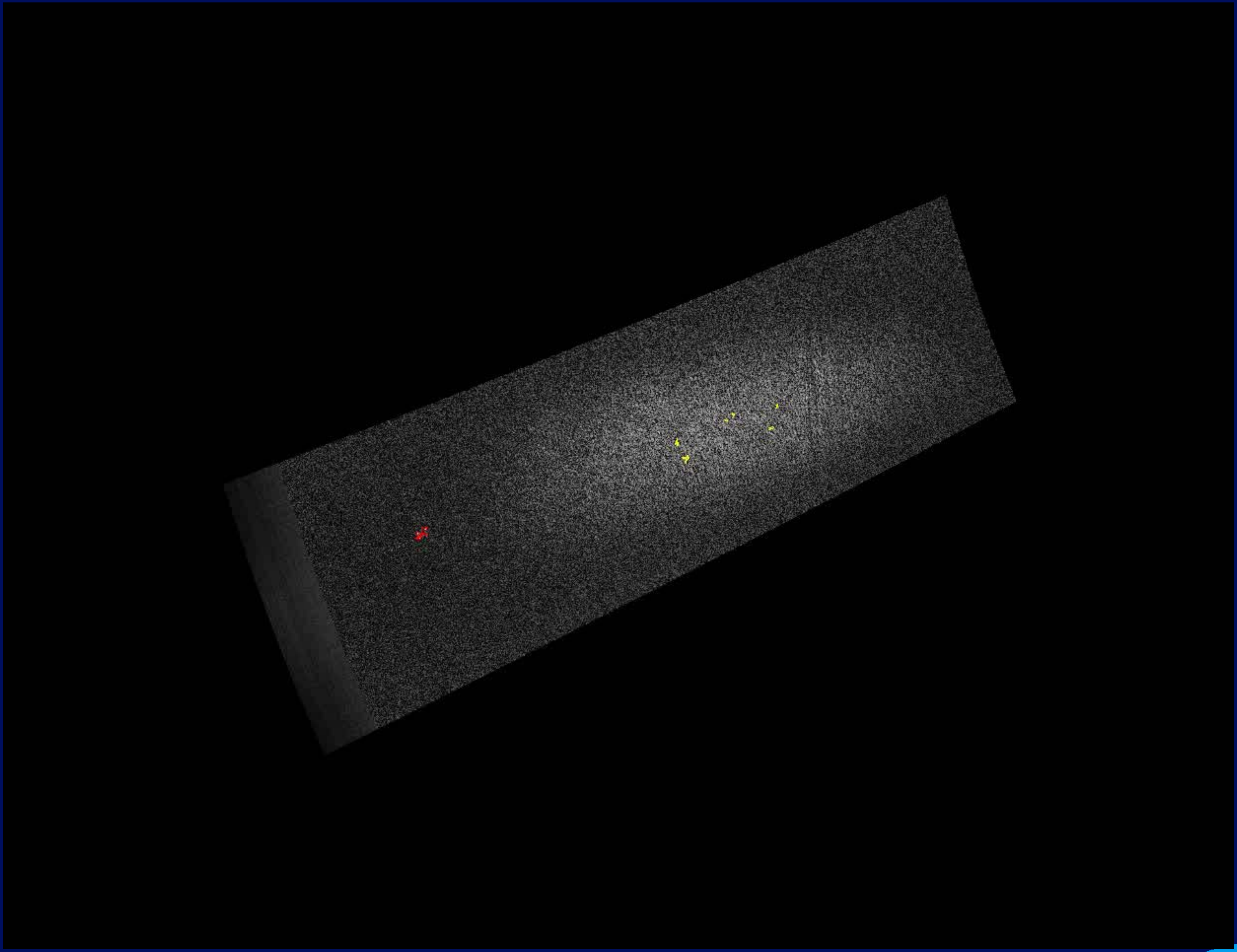
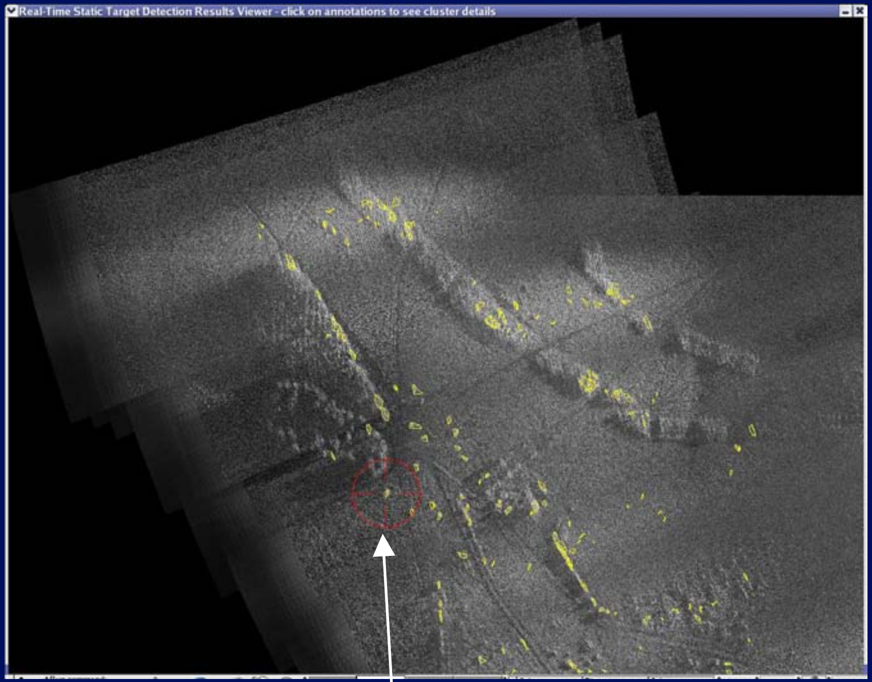
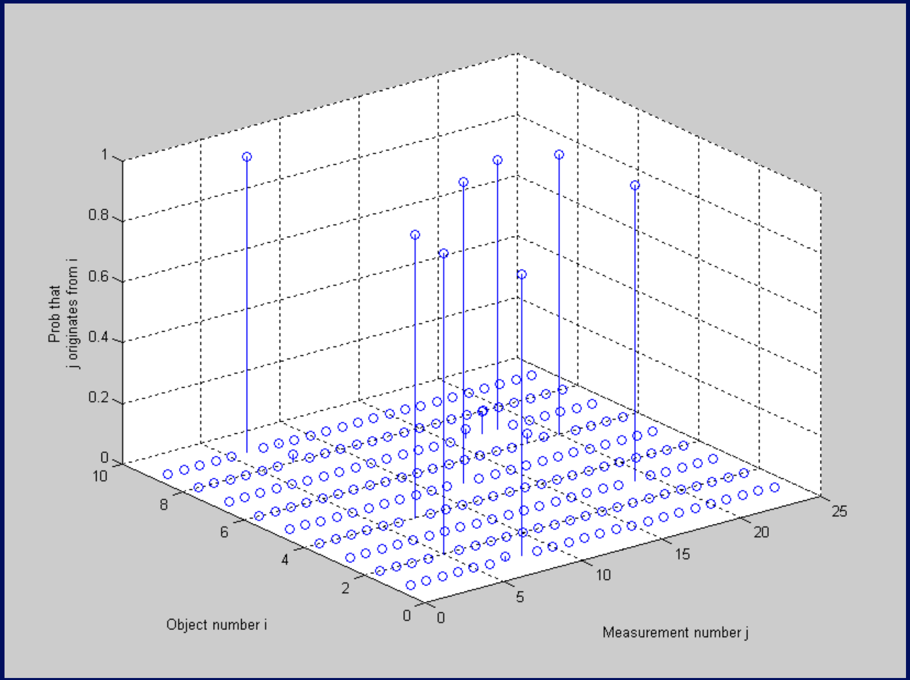


# Fusion of TOMs




SA-8 "Gecko" correctly chosen
for seeker prosecution

# Performance issues – I

- Conventional performance measures (PD/RFTD) are now only interim measures
- Performance defined by Bayesian matching
  - result is probability of mission success
  - sensitive to scenario
  - sensitive to type/fidelity of targeting information

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# Performance issues - II

- Fusion performance is defined by
  - accuracy of attribute information
  - missing targets in seeker object map
  - unexpected objects in seeker object map
- Thus demands on seeker
  - accurate attribute measurement - key i/p to sensor design
  - high probability of target declaration - key I/p to ATR
  - low number of false target declarations

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# Performance issues - III

- Current algorithm
  - designed for near-unity Pd against camouflaged target
  - achieves respectable RFTD
  - simple attributes used – target size measured to 1-2m
  - exploitation SAR targeting information is a key enabler
- TOM fusion algorithm
  - use of contextual information introduces significant robustness to RFTD
  - can tolerate higher RFTD than conventional strip-map search

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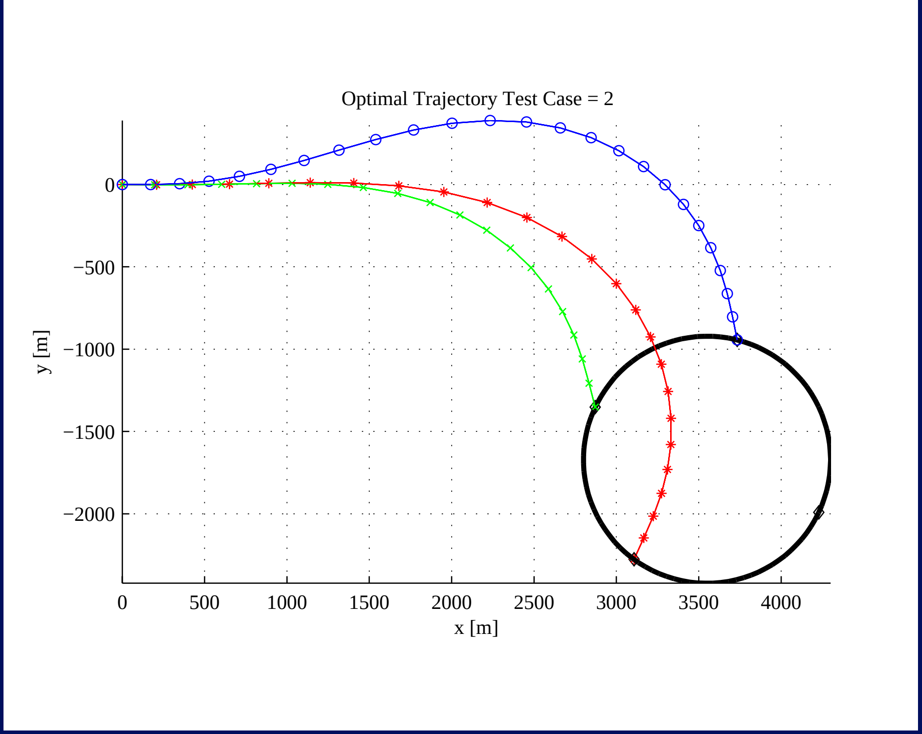
# Search Pattern

- Technique optimal if target location uncertainnty is searched prior to target selection
  - increases acquisition range
  - increases seeker sensitivity requirements
  - increases complexity of terminal guidance
- Seeker design should not be done in isolation of overall kill chain data-flow

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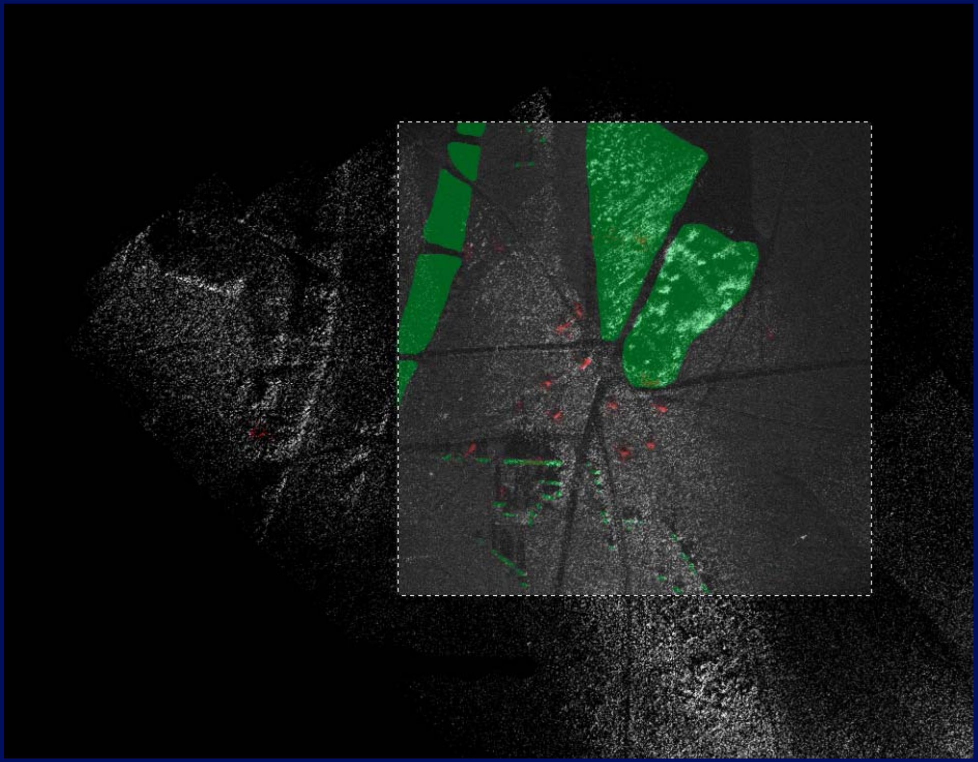
# Data-links

- Data-link timing is critical
  - defines target location uncertainty for moving targets
- Simplest Target Object Map
  - small list of numbers
  - should be easy to transmit
- RF ATR enhanced by direct exploitation of SAR targeting imagery
  - much more demanding data-link requirement



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# Summary

- Approach presented for medium range engagement of mobile/relocatable targets
  - direct exploitation of targeting information
  - potentially high performance
  - highly flexible
  - consider seeker as integral part of NEC
- Number of design implications for seeker
  - must consider seeker design in association with other elements of kill chain

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# Further information

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