











Combining sensor data with Intelligence






Steve Pennock










Outline






- I. Work Package Aims
- II. The Vehicle and position referencing
- III. Data Fusion
- IV. Data Modelling and Hypotheses (depth, size, location) Extraction
- V. Inclusion of Ground Knowledge
 - Focussing error susceptibility
- VI. Common Data Format








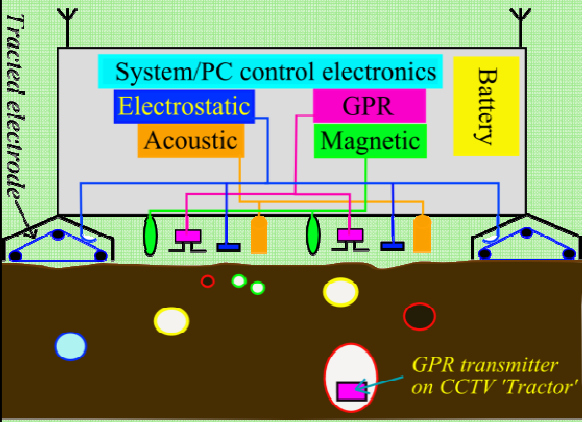
Work package Aims

- Project involves four sensors, each of which have their particular advantages and disadvantages:
 - Ground Penetrating Radar
 - Low Frequency Electromagnetic
 - Acoustic
 - Magnetic
- Integration of individual sensor data with ground knowledge
- Investigate the sharing of survey information between the individual sensors to improve local ground knowledge and so improve target location for sensors and their fusion.



















Multi-sensor Vehicle

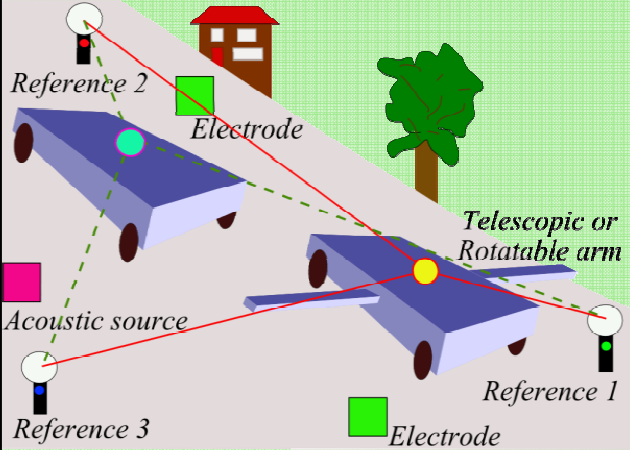


- Mobile surface vehicle may contain four sensor systems and the main system control.
- Mutual interference between the four sensor packages needs to be considered











Sub-location within survey area




- Sub-location from reference points determines positions
- Can use single wide swath vehicle or multiple vehicles










Sub-location schemes - 1






- **RTK-GPS:** Differential measure relative to a reliable location, 1 - 2 cm resolution claimed. Is this reliable enough in an urban (canyon) area?
- **Ultrasonic:** Problems with acoustic interference? Range of 10-15m with resolution of 1 - 2 cm. Range can be increased using cooperative transponder.
- **RF/Microwave radio location:** Overcoming multipath needs some sophistication. Radio Tracking specifications identifies the 6GHz-8.5GHz band with a basic resolution of only 12 cm. UWB bandwidth up to 10GHz would be sufficient.








Sub-location schemes - 2

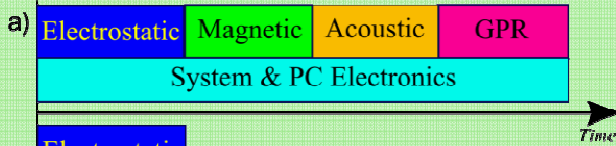
- **Optical:** Laser rangefinders are able to deliver accuracy of 2mm in distance if it can be aligned sufficiently well. Rotatable 'web-cams' could find reference points with image processing.
- **All systems:** More than three reference positions gives redundancy to overcome blocked paths.

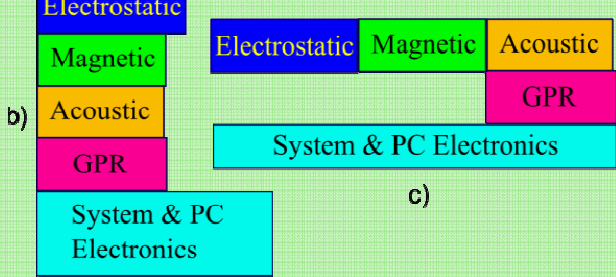






Time sequencing to control interference


a)








b)








c)








- Interference between the sensor systems can be eliminated by consecutive time schedule (a).
- All (b) or some (c) of the four sensor systems may be able to operate concurrently - with care.












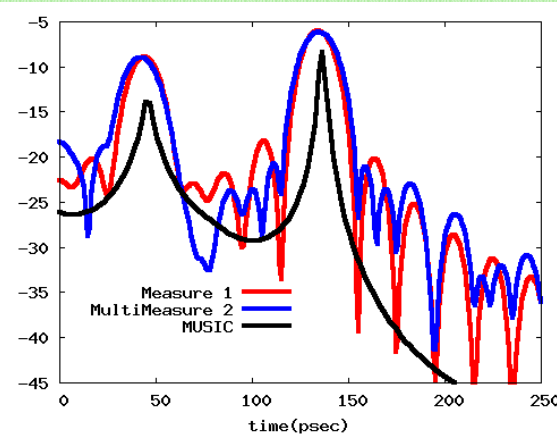
Data Fusion

- Fuse data to produce more reliable identification of targets
 - Location, type
 - Minimise probability of missing targets
- Pixel level data fusion
 - With co-located measurement from the four sensors can fuse their individual 2D or 3D pixel/voxel representation of the sub-surface
- Systems tend to naturally have different resolutions
 - Multi-resolution data fusion























Data Fusion








- Multimeasures at different resolutions can reduce unwanted sidelobes
- Super-resolution (MUSIC) may be too narrow and susceptible to co-location problems/errors












Data fusion: Feature extraction

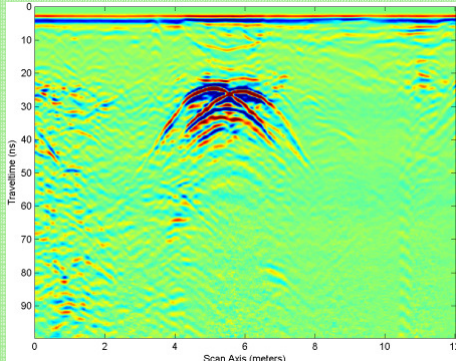
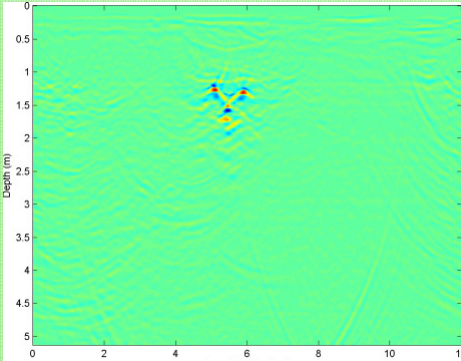
- The four sensors will extract independent information such as a focussed image of the sub-surface.
- Independent identification of basic features such as depth, size, type and location of target are determined – then fuse together
- Compensates for weaknesses in the individual sensor systems, and at best produces confirmation and a more accurate description of the target.
- Minimise probability of missing targets























Data Modelling and Hypotheses Extraction

- Back-propagation based on Spatial Fourier Transform

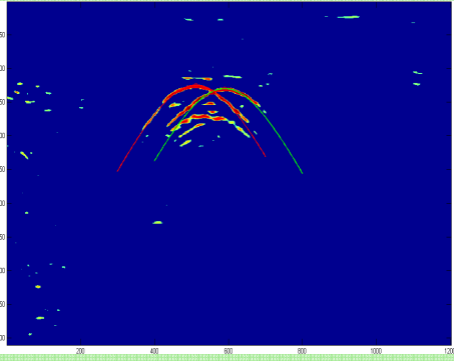
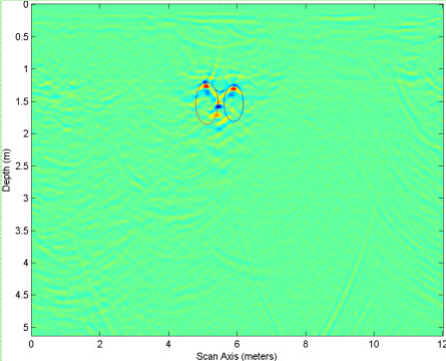

























Hough Transformation

- Hough Transformation (searching optimal a and b) applied to Real Data, an example.









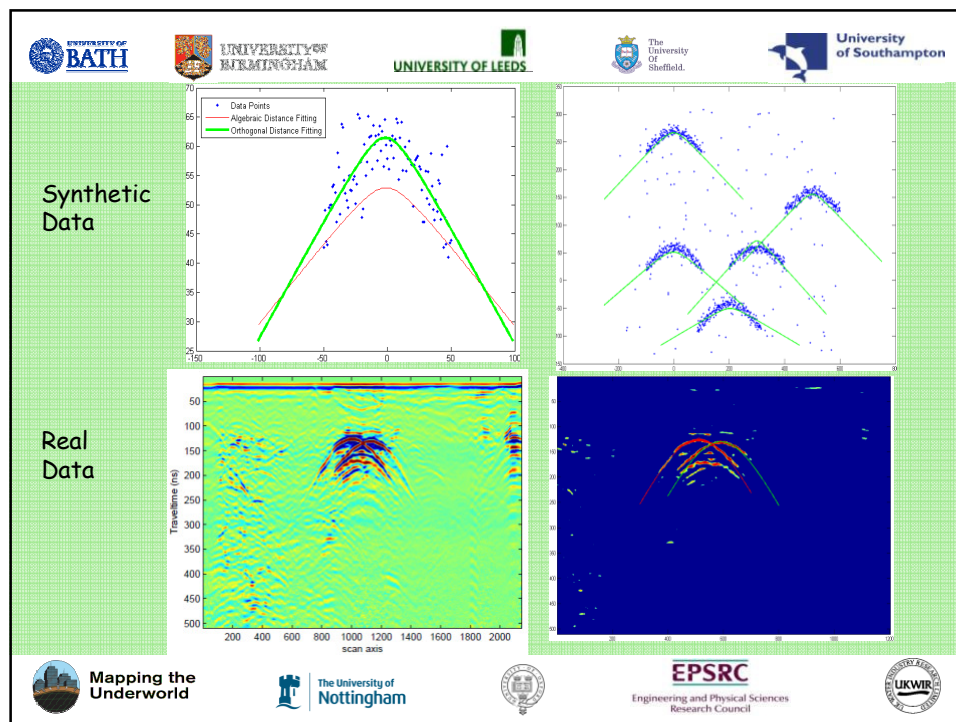






Robust and Fast Hyperbole identification

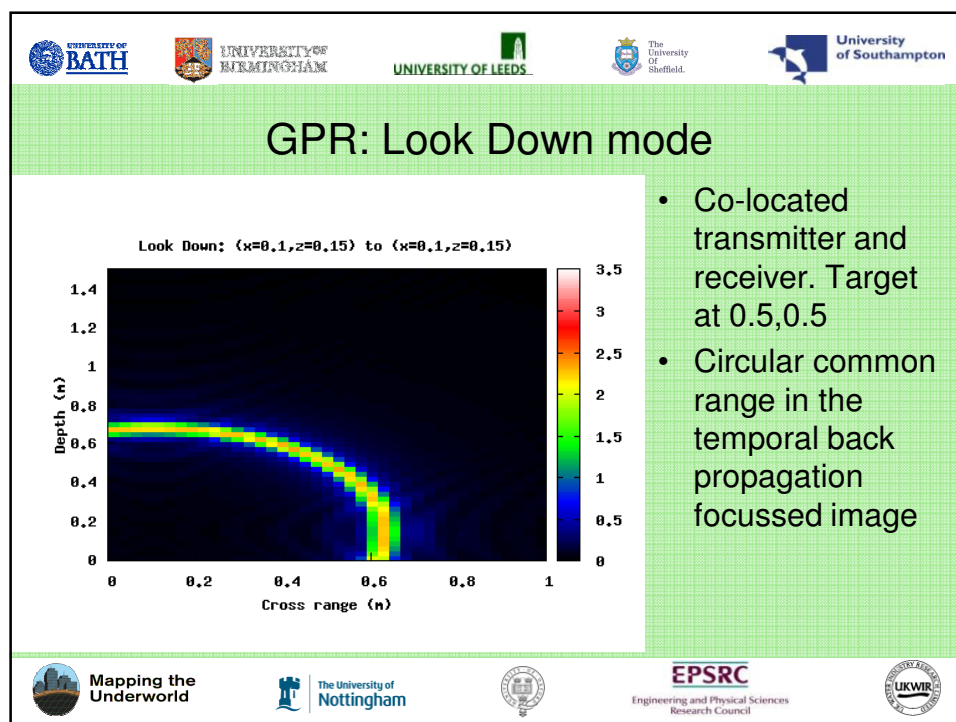
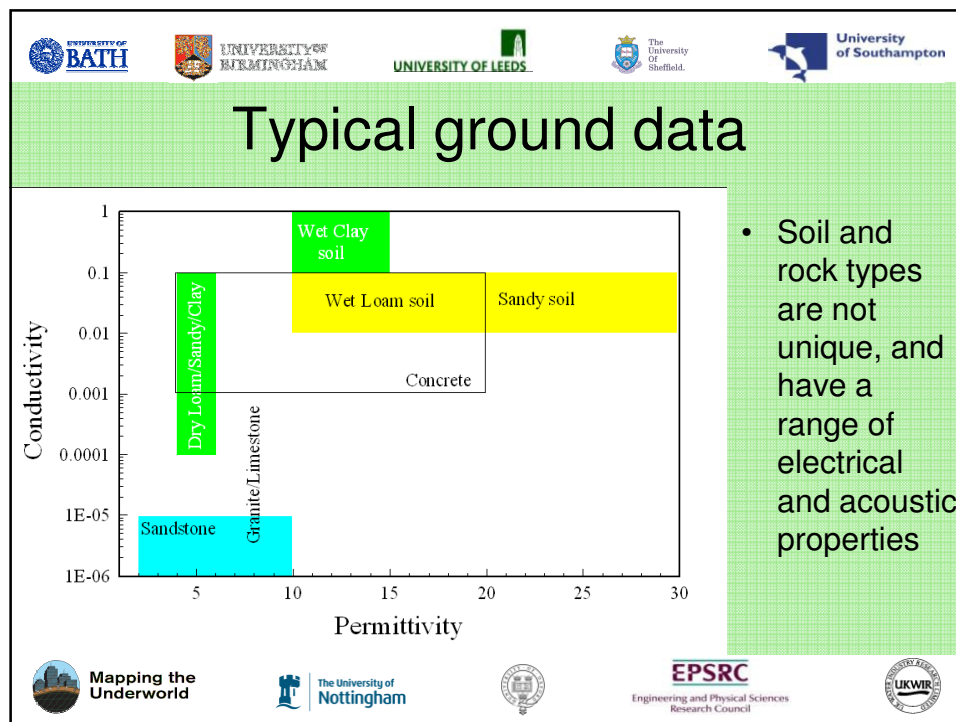
- Hyperbole fitting Algorithm
 - Algebraic distance: fast, sensitive to noise
 - Orthogonal distance: robust
 - Probabilistic conic mixture model: fast and robust

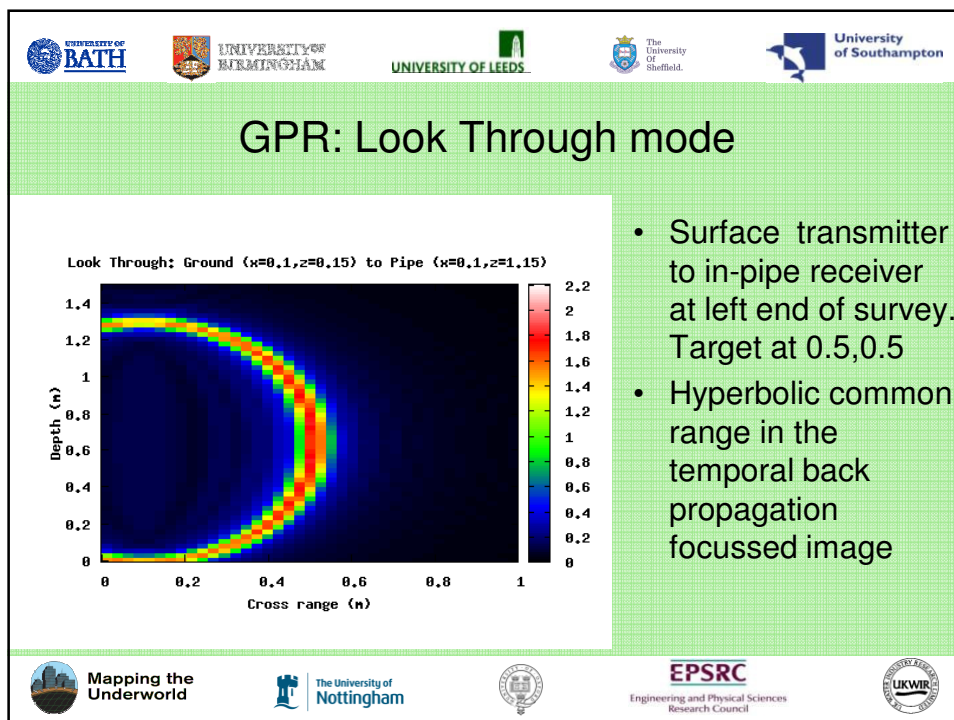
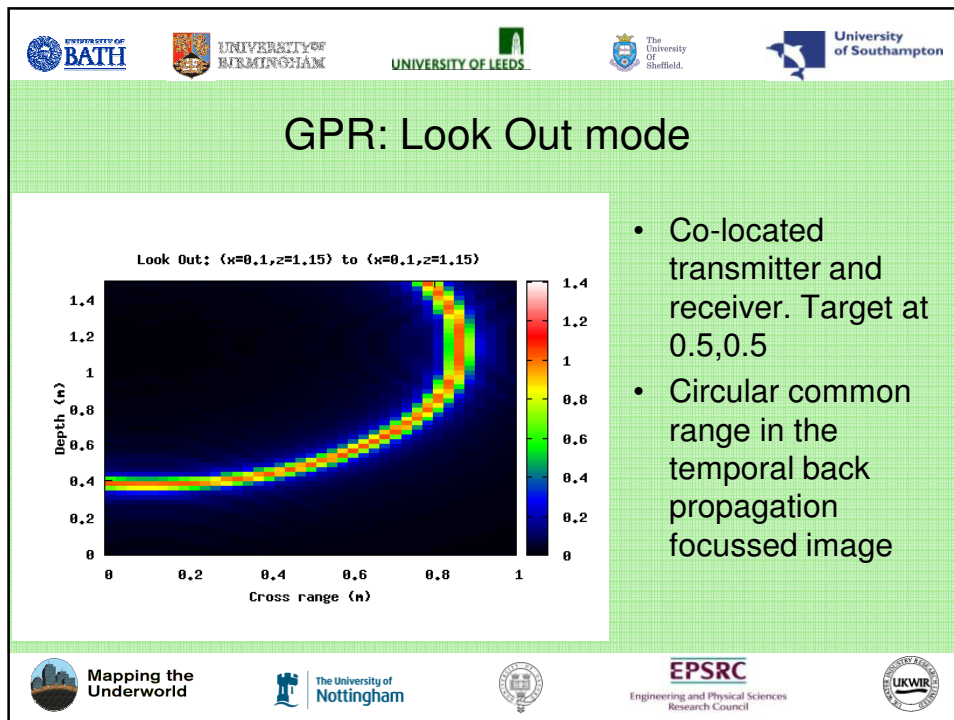






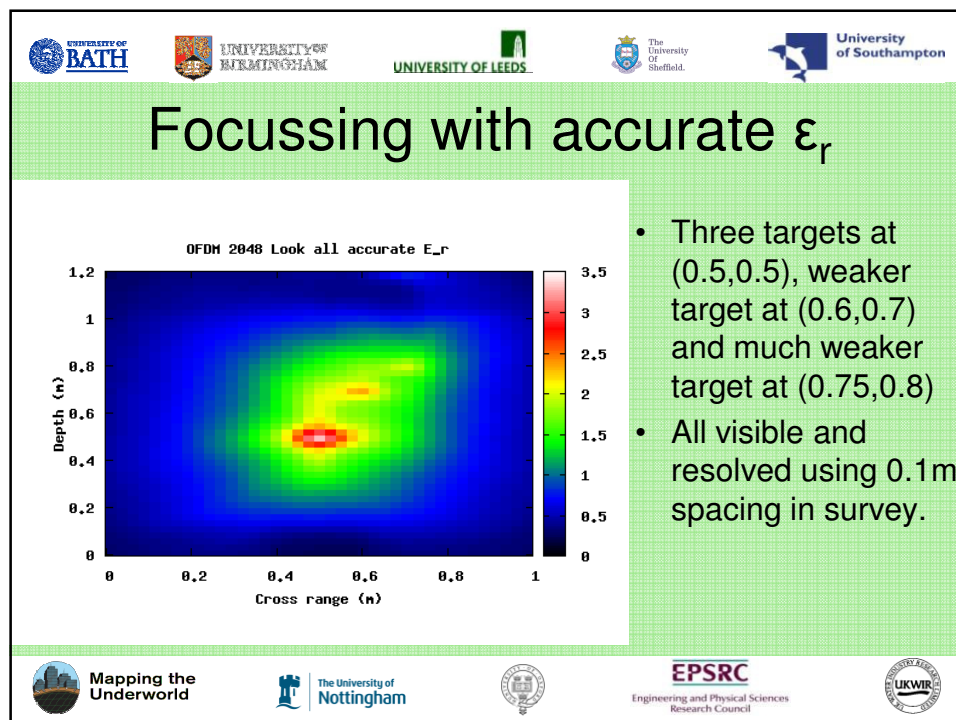
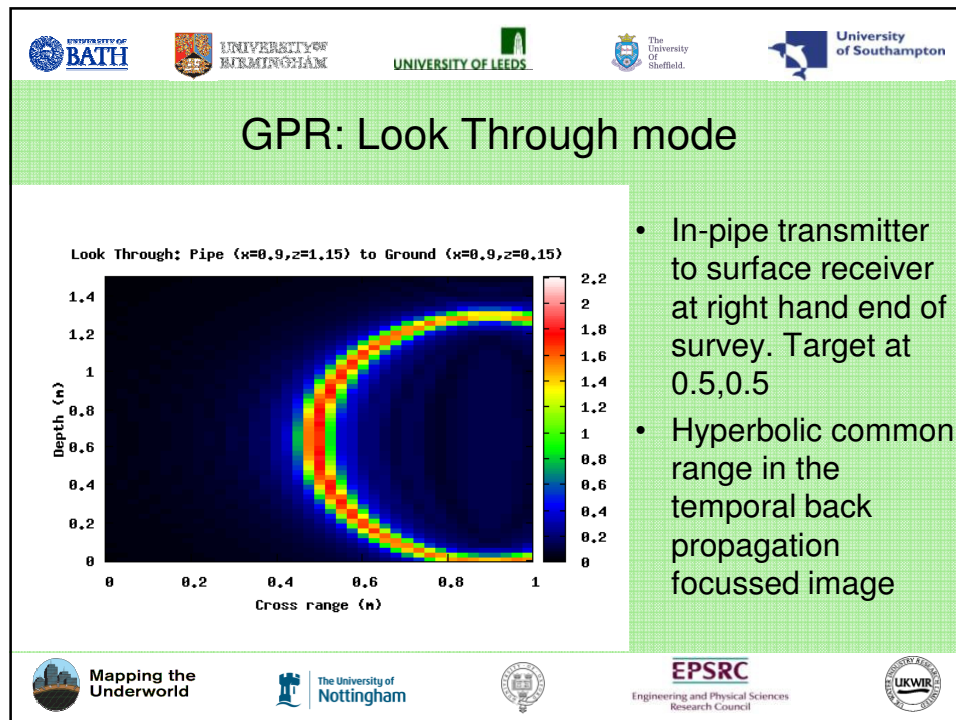


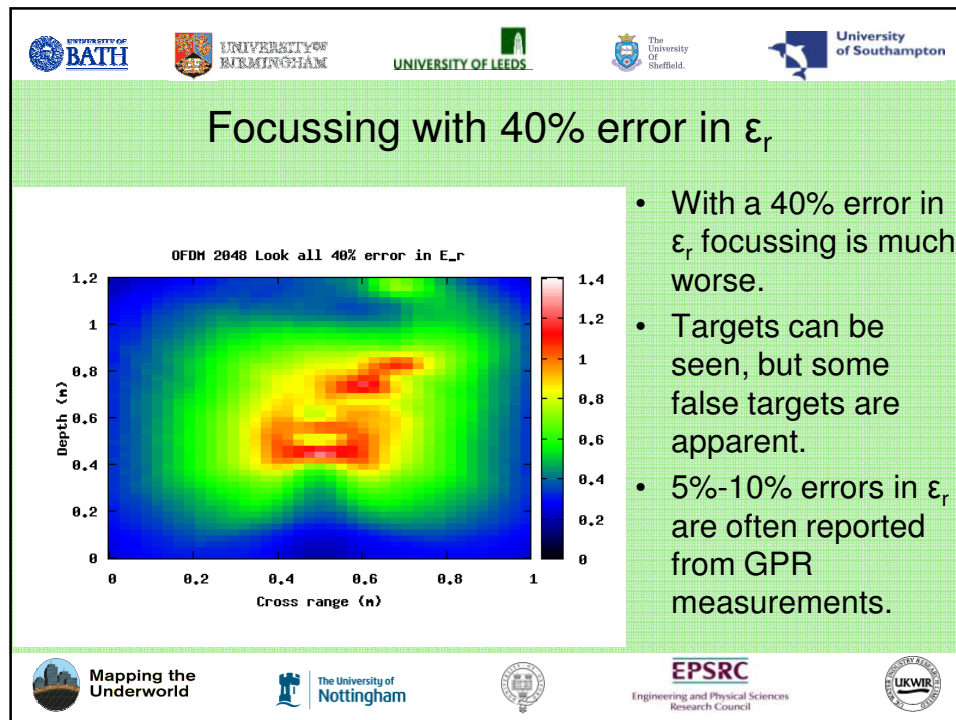
Inclusion of Ground Knowledge


- Available data on local area will suggest ground properties – broad estimates of conductivity, permittivity, density, etc.
 - Include seasonal factors.
- Independent measures from the four sensors will also be able to estimate these parameters.
- Then modifications to the signal processing or operation on site of the multi-sensor system.

















Common data format






- Estimate 160MBytes of data in Binary
 - 0.1mx0.1m grid over 10mx10m survey area
 - More than 1GByte in Ascii
- Common data format has been outlined.
 - The netCDF format can interchange binary data between C,C++,Java,Fortran,MatLab...
 - Allows simple interchange between sensor systems and facilitate multistage processing.





Multistage Measurement

- Individual independent measures from the four sensors
- Informed measures - suspect target location from one sensor informs other sensors to 'optimise' for that target.
- Information gained on ground conditions informs the focussing/fusion processes.
- Fusion/correlation combinations of data.





Thanks for your attentions! Any Questions?

