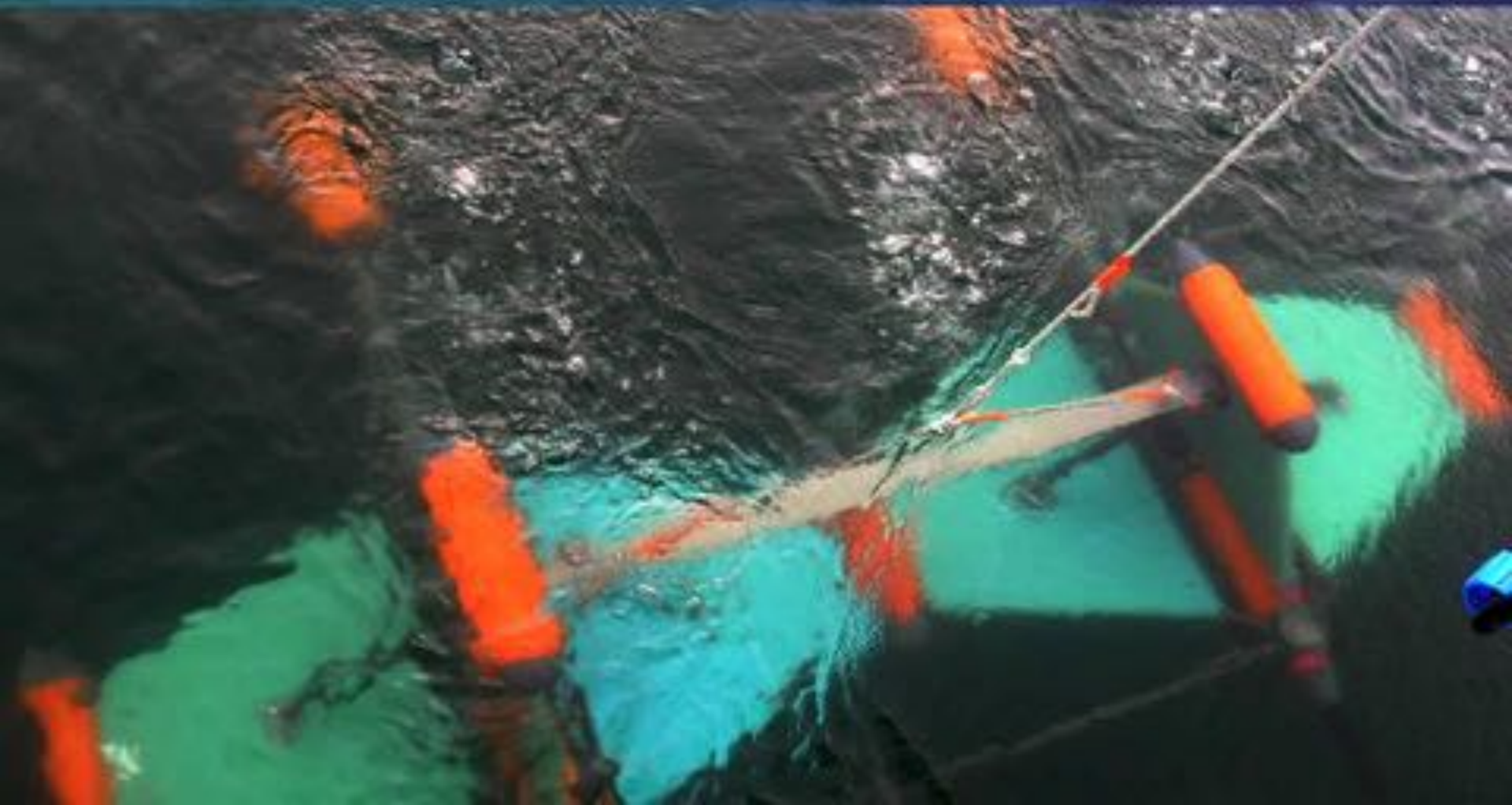
An Integrated Marine Gradiometer Array System (MGA)

For Detection and Location of Chemical and Conventional UXO/MEC in Shallow to Deep Marine and Freshwater Environments



Introduction

- Tetra Tech EC, Inc. has over 20 years of experience in the MEC/UXO business
- Over 100 MEC/UXO projects including terrestrial MEC/UXO assessment and clearance, marine chemical munitions removal and MEC/UXO disposal and demilitarization
- Technical experts with 30+ years of individual experience
- Over $3 million dollars in MEC/UXO and geophysical equipment
- Work in challenging environments including arctic and desert regions, as well as underwater

Marine Capabilities

- 9 Geophysicists on staff with more than 50 years of combined experience in land based, airborne and marine geophysics
- 4 Oceanographers and hydrographers on staff with more than 40 years combined experience in marine survey methods and software.
- Personnel with past experience working with sonar manufacturer (RESON) conducting development and systems integration
- EOD trained divers
- Over $1 million dollars in marine geophysical and navigation equipment

Marine MEC/UXO Recovery Experience

- *An Example Project in Washington*
  - *Conducted 912 Dives in 35-50 ft water depth for conventional MEC/UXO*
  - *1603.5 Hours of Bottom Time*
  - *Recovered 3,577 Ordnance Items Without Incident*
- *Marine Chemical MEC/UXO*
  - *Recovery & packaging of almost 400 chemical munitions for disposal*
  - *20 to 50 foot water depths*
- *Developing the ability for unmanned MEC/UXO recovery in deeper water*

Technology Description

- Multifaceted approach
- High-resolution bathymetry and/or imagery sonar
- Subbottom profiling
- Mapping with Tetra Tech's advanced Marine Gradiometer Array System (MGA)
- Performance verification with ROVs and/or EOD trained divers
- Data fusion with commercial and Tetra Tech developed software

Technology Benefits

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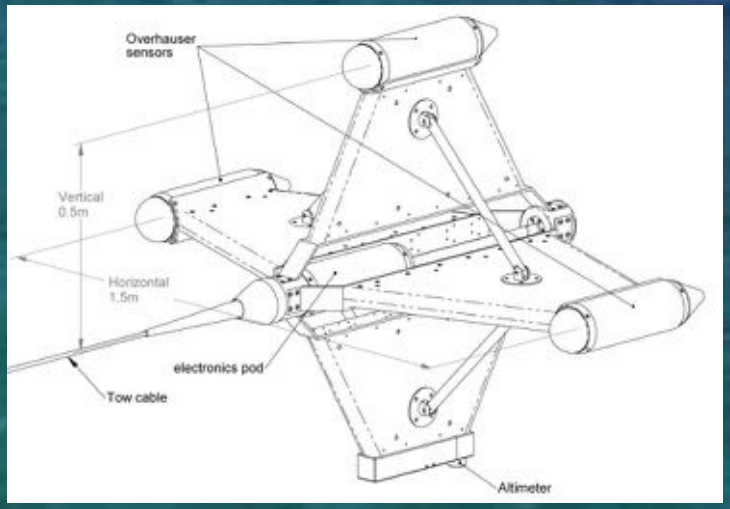
- Simultaneous collection of multiple data streams
- Modular design of MGA for scalable architecture and adaptive configuration
- Low risk proven technologies with commercial hardware and software support
- Improved accuracy for reduced remedial / monitoring cost
- Tetra Tech funded Field Testing
  - System has been tested repeatedly over 4 year period

Base Platform Design



- Commercially available gradiometers measure magnetic gradients 3-D.
- All measurements synchronized
- Rigidly mounted sensors – no relative motion
- Highly stable platform – no rotational motion
- Very sensitive sensors – detects minute gradients accurately
- Magnetically clean – no platform-effect on data results
- Thorough support sensors – heading, pressure, altitude, pitch, roll
- Single unit (SeaQuest) tested & proven on a variety of applications

Marine Magnetics
True Detection Power

3D Underwater Gradiometer Array

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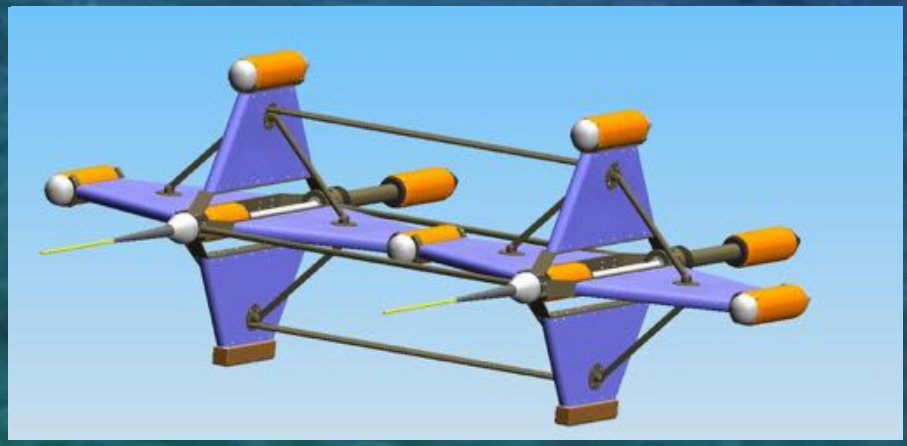
- Design
  - Coupled SeaQuests (cross bracing, & tow bridal)
  - Modifications include addition of a magneto-resistive heading sensor and a longitudinal sensors to provide true 3-D analytic signal in real-time.
- Instrumentation:
  - 7 to 10 Overhauser magnetometers.
  - Two built in altimeters
  - Two pressure sensors
  - Two pitch and roll sensors
  - One magneto-resistive heading sensor.



- The array records the total field data from each of the 7 to 10 sensors plus the 6 to 9 separate gradient components and two or three 3-D Analytic Signals
- The towed array covers a 3.0 – 4.5 m wide swath that allows for efficiently surveying the seafloor with near 100% coverage

3D Gradiometer Array with Longitudinal Sensors

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7 Magnetometer Sensors

3D Gradiometer Array – Scaleable and Versatile

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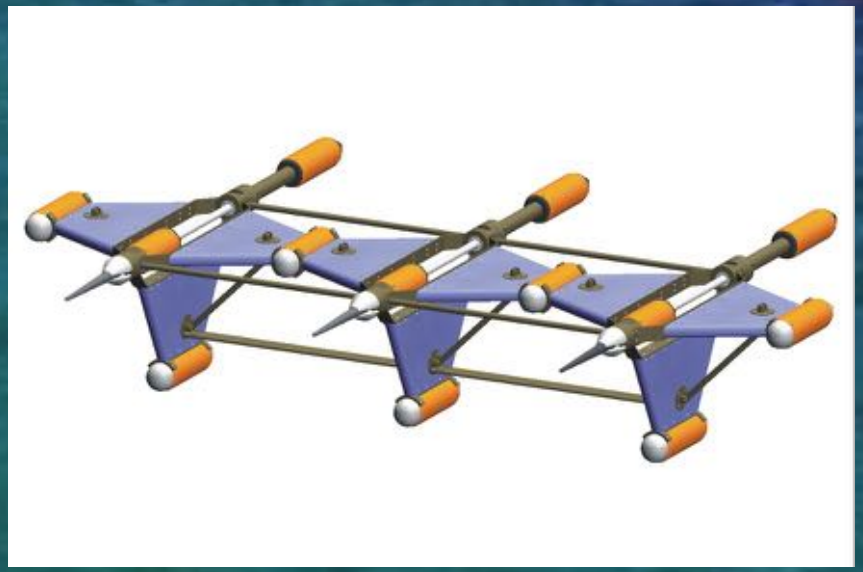
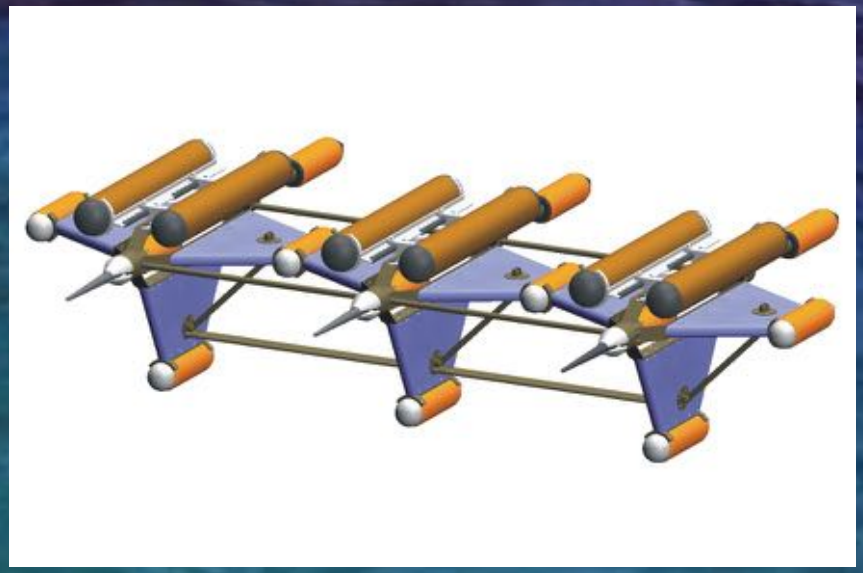
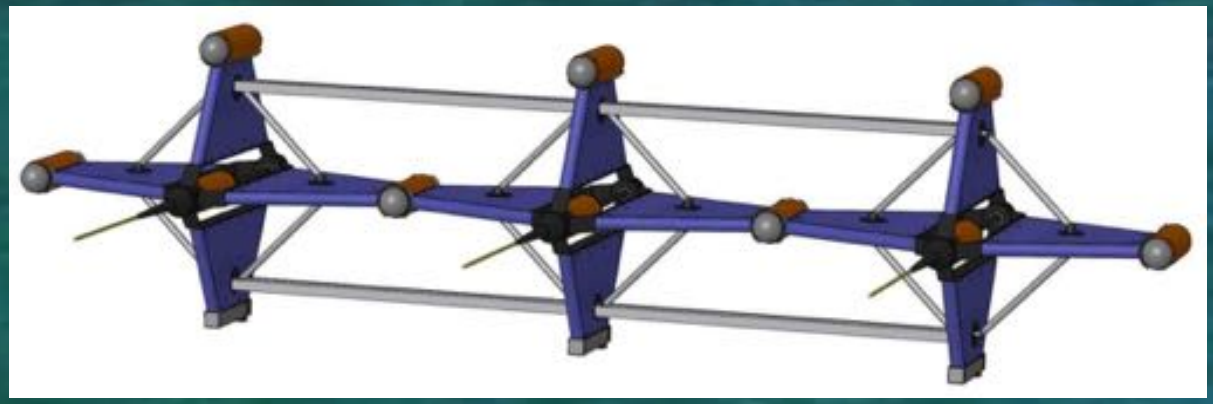


Reconfigured to allow lower flight height



or for surface and shallow towing



Original 10 Magnetometer Design

Other modifications include addition of removable wheels to allow for bottom towing ("towed crawler")

Technical Approach

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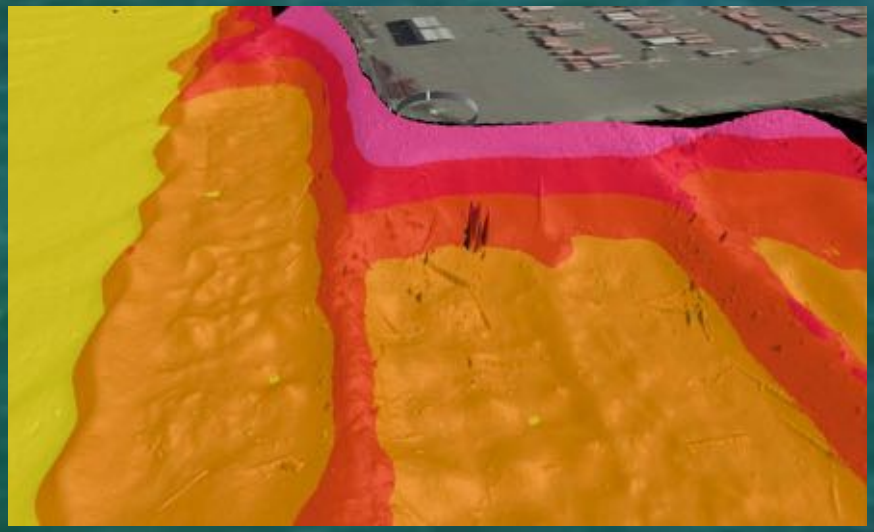
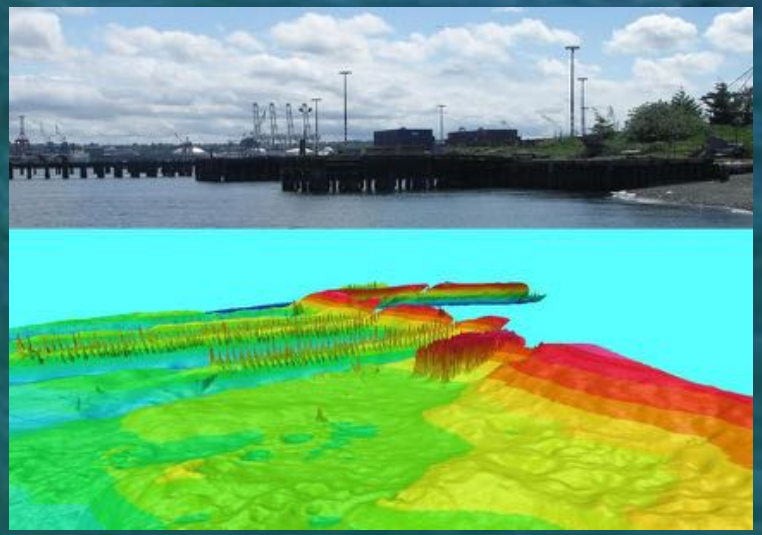
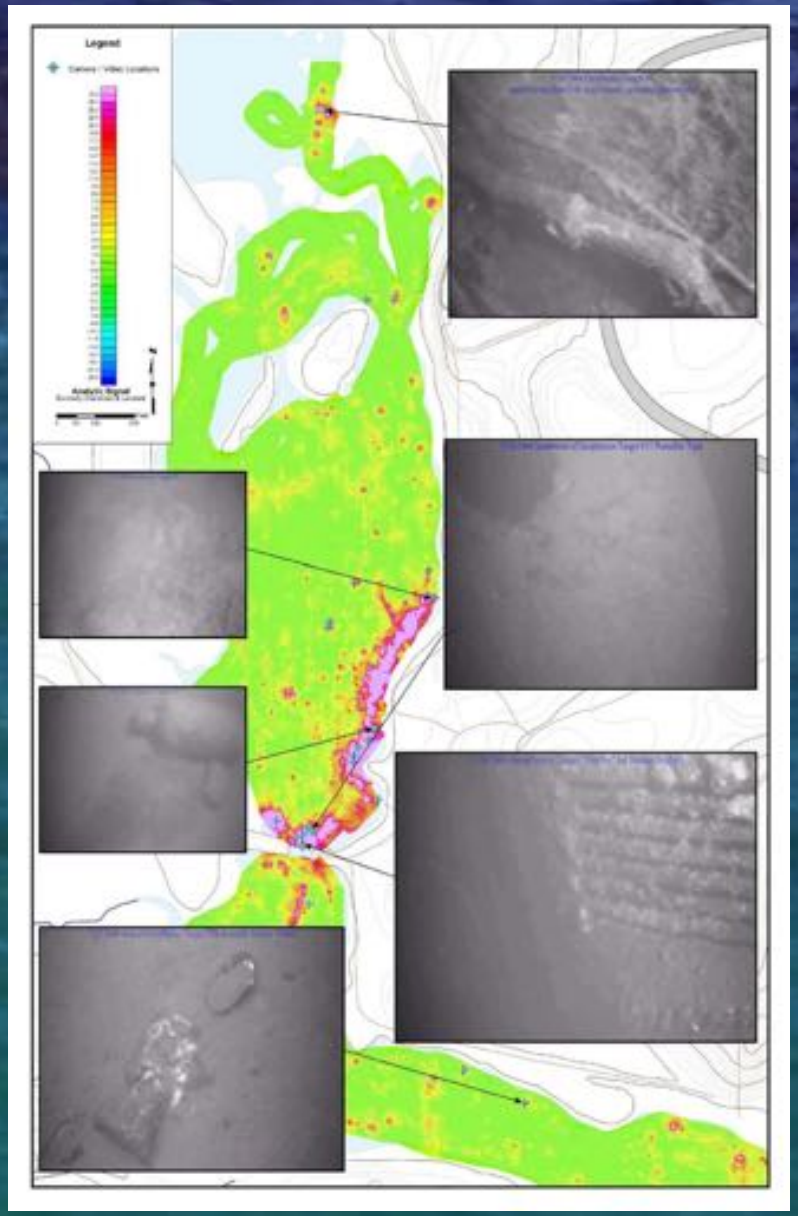
- Conduct high-resolution multibeam sonar survey with sidescan (or interferometric sidescan) and chirp subbottom profiling concurrently
- Utilize sidescan and subbottom profile data to refine MGA survey approach to maximize efficiency and reduce cost
  - Optimize survey patterns
  - Avoid obstructions and debris which are proud of surface





Technical Approach

- Conduct magnetometer survey using MGA and appropriate positioning systems for anticipated water depths
- Process data and identify MEC/UXO-like anomalies and related features, as well as debris field (if present)
- Conduct Anomaly Evaluation Using High Resolution Video and Imagery Sonar on ROVs and/or visual inspection by Divers



High-Resolution Multi-beam and Interferometric Sidescan Sonar Survey

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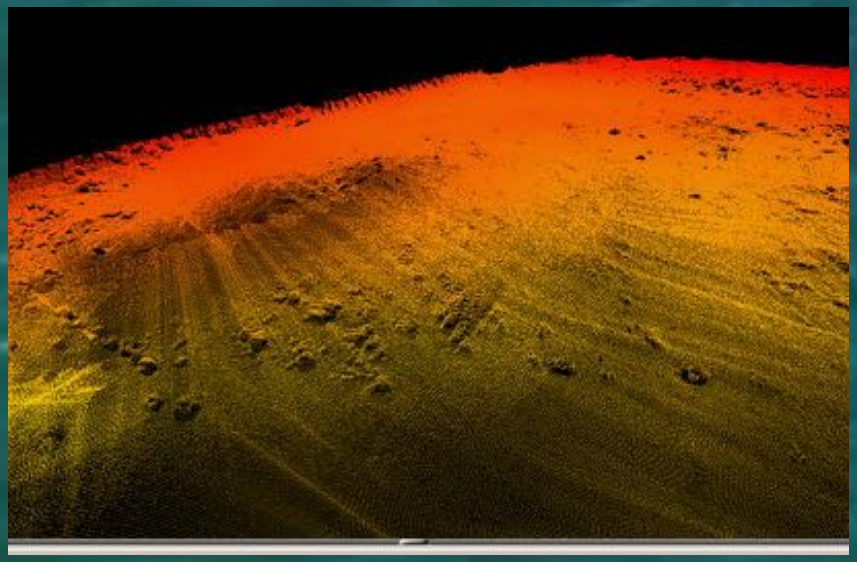
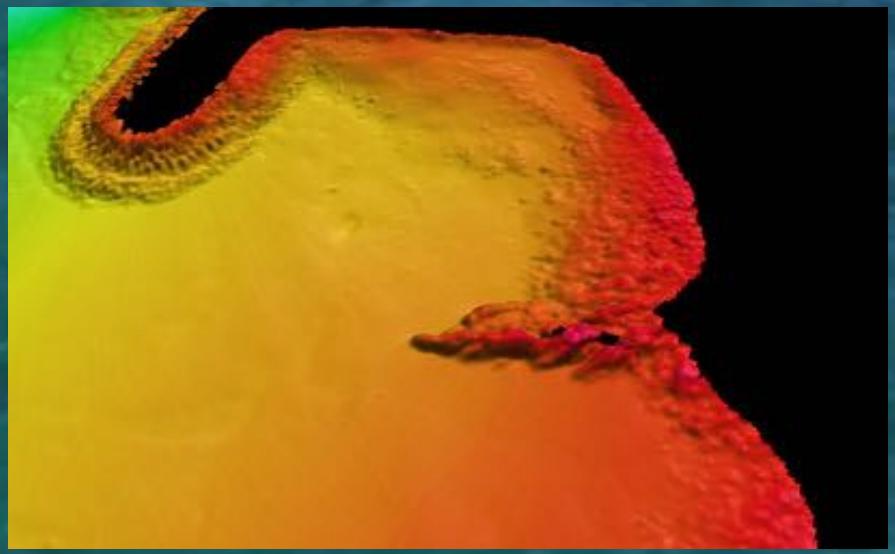
- Map site bathymetry and identify areas of interest
- Identify debris fields and become aware of obstructions to maintaining magnetometer array flight height
- Acquire multibeam snippet data to assist with classification of bottom type and items of interest
- Refine MGA survey approach based on analysis of data





Example RESON SeaBat Multibeam Data

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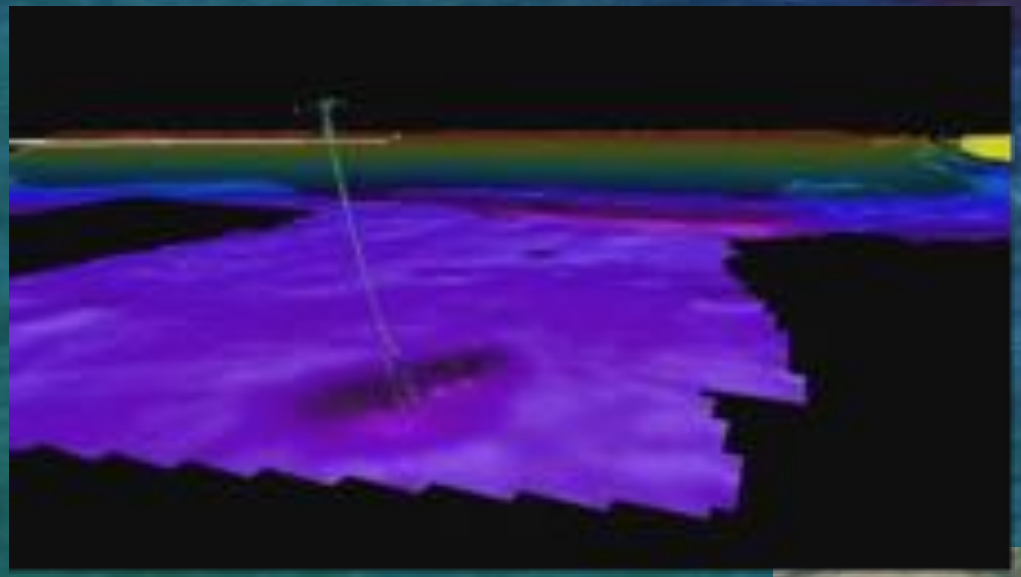
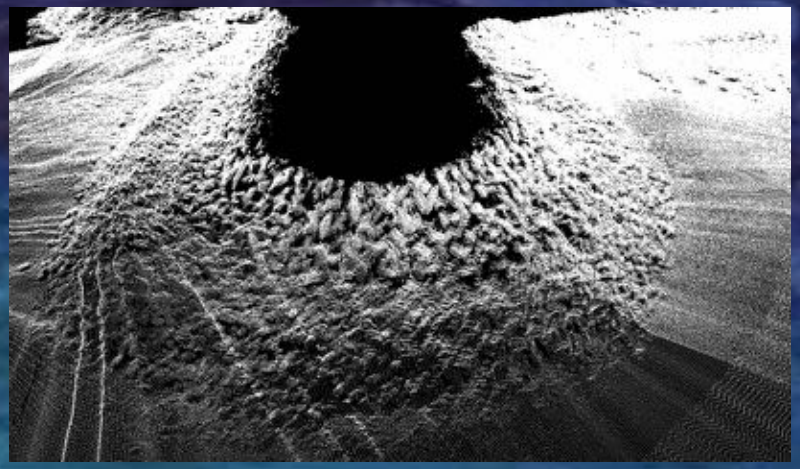
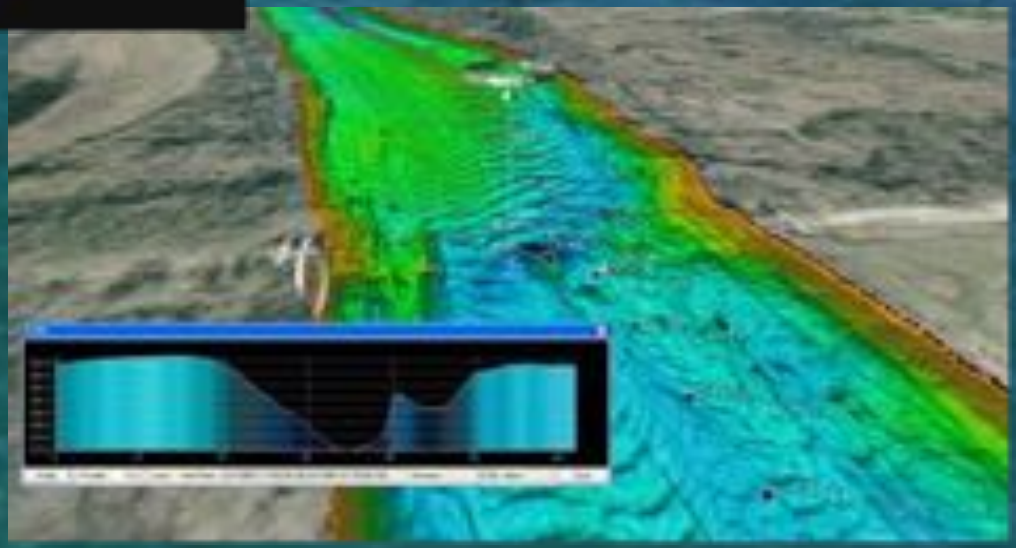


Mooring Line with
Associated Scour Hole



Breakwater and
associated rip rap/debris

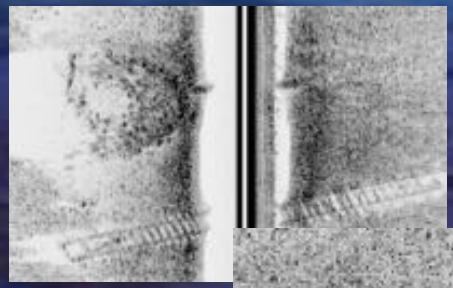


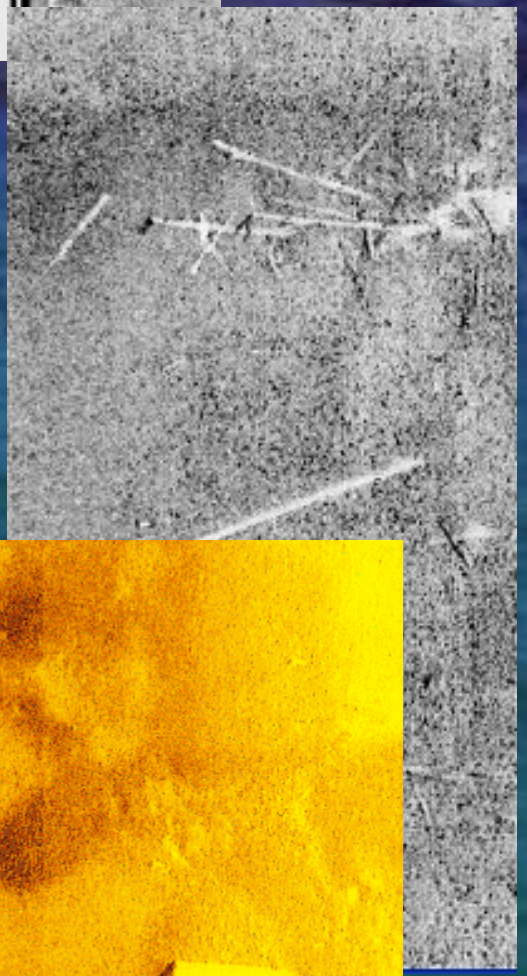
Mega Ripples in
River Channel

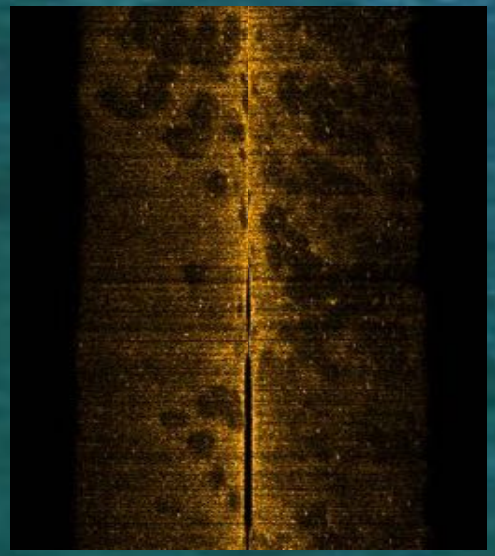
Sidescan Sonar Survey

Including Interferometric

- Further define debris fields and obstructions to maintaining magnetometer array flight height
- Complement classification of bottom type and items of interest
- Drape over multibeam surface







Subbottom Profiling

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- Identify, quantify, and delineate areas with sediment that could contain buried MEC/UXO and to approximately what depth MEC/UXO may be found
- Identify scour and deposition patterns that may assist in evaluation of MEC/UXO transport (sediment facies analysis)
- Refine MGA survey approach based on analysis of data

Data Fusion - Examples of Subbottom Profile Data Co-registered with Multibeam Data

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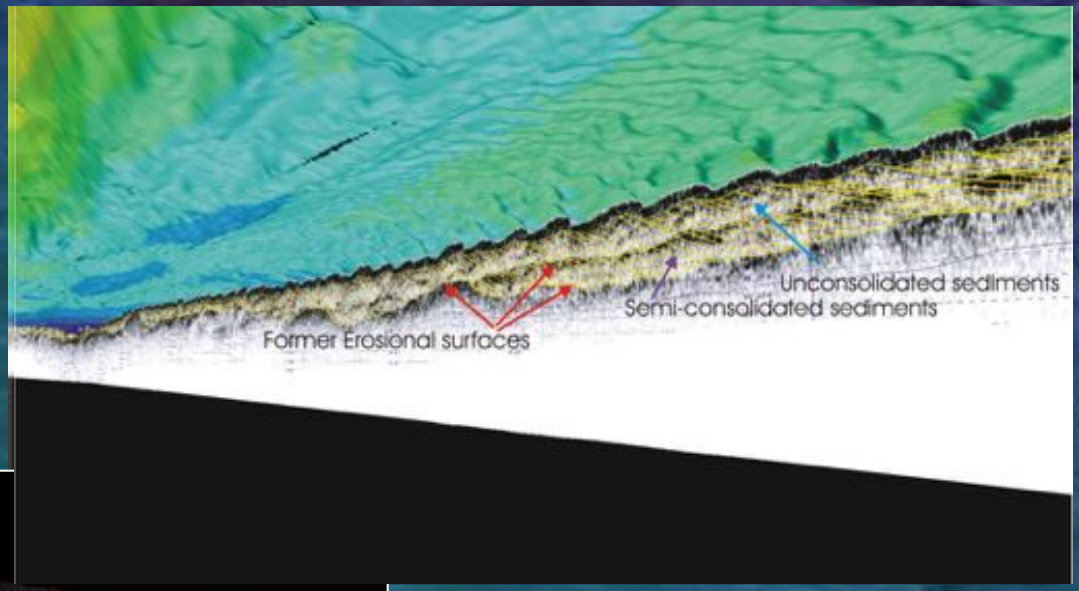
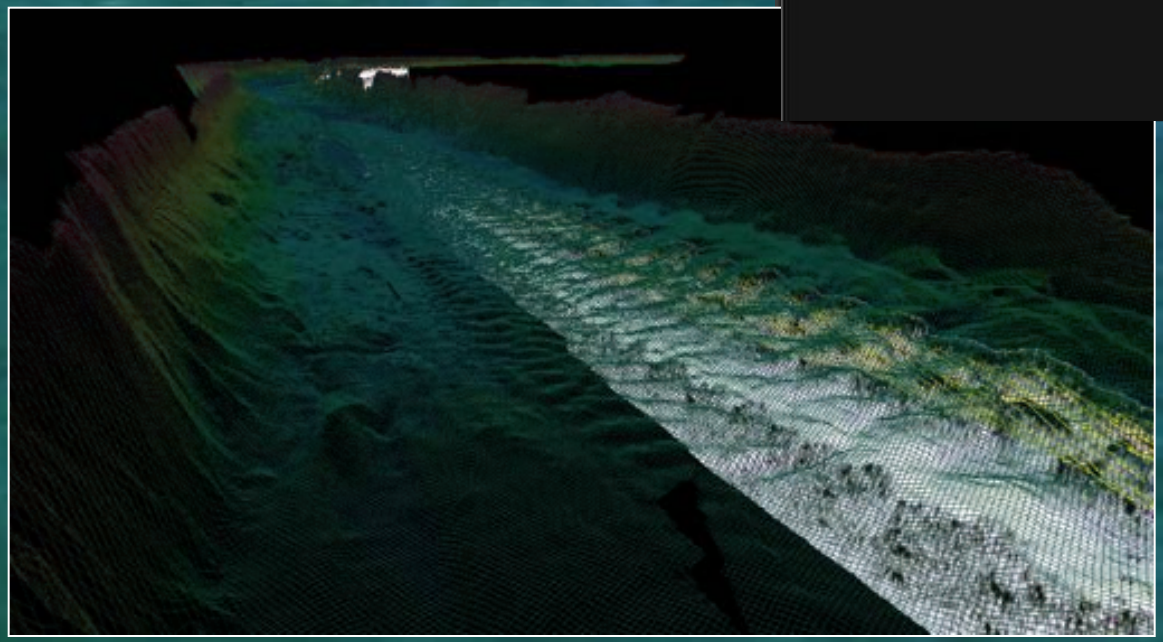
Sub-bottom Profile Seen from Below River Bottom Multibeam Bathymetry

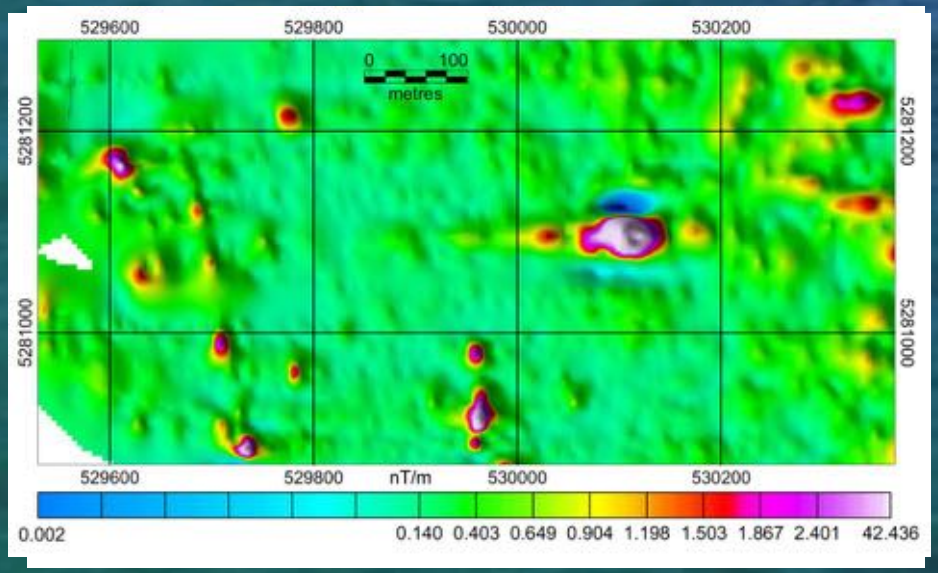


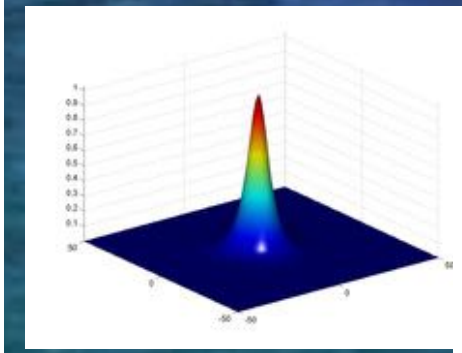


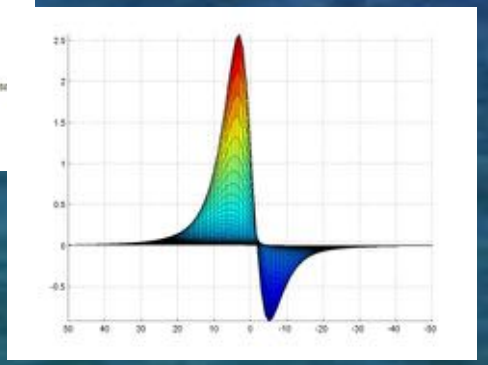
Sub-bottom Profile with Water Column Removed, Seen from Above River Bottom Through Wireframe of Bathymetry Surface

MGA Survey

- Identify ferrous anomalies that may be MEC/UXO or MEC/UXO-related (individual items or clusters)
- Identify other anomalies of interest (sunken ships or barges, pipelines, etc.







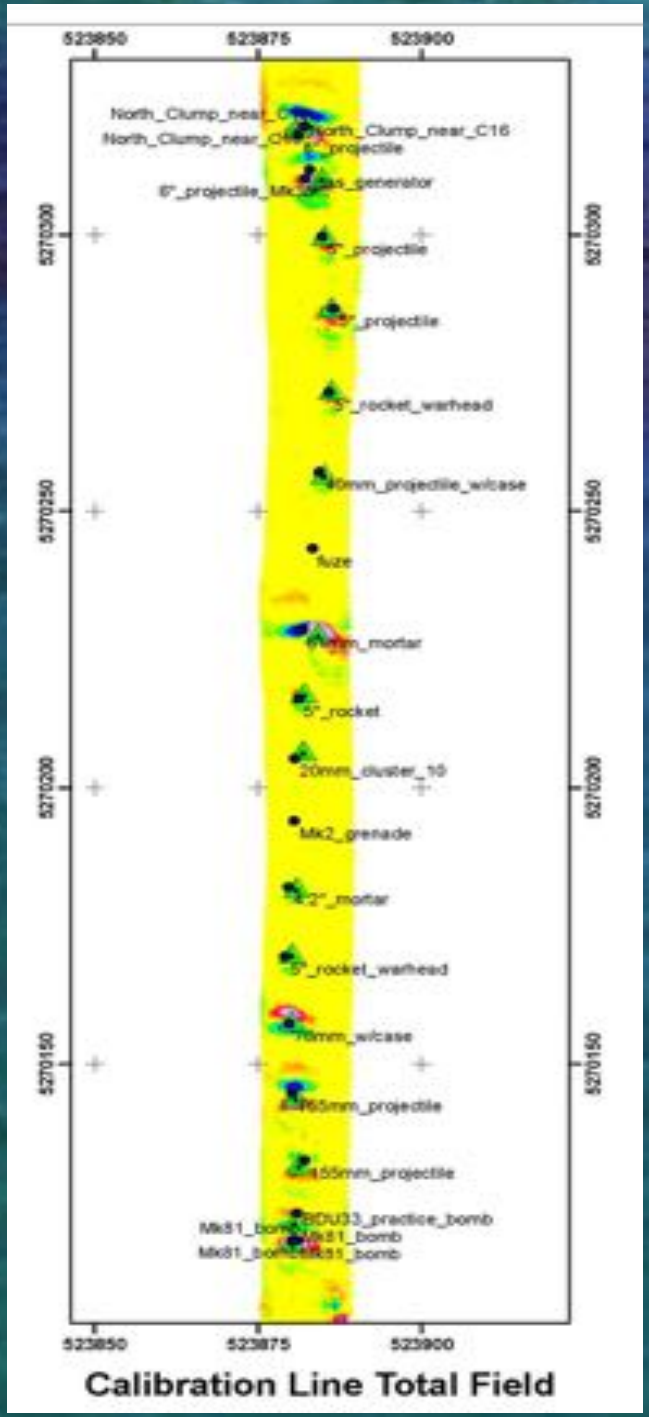
- Commercially proven 3-D gradiometer re-engineered for optimum MEC/UXO detection
  - Used commercially to depths of >1000m for pipeline, cable route mapping, and deep sea mining
  - In use by US Navy for mapping and other applications*

*Naval Sea Systems Command, Undersea Warfare Center, Mapping Marine Ferrous Targets Using the SeaQuest Gradiometer System, 2003

Example Total Field Results from MGA

- Both total field and analytic signal are acquired while surveying with a 3-D gradiometer, therefore data from both are used during data interpretation.

- Geologically -sourced anomalies (topographically complex 'bumpy' bedrock, boulders, etc.) can mask smaller ferrous targets



Calibration Line Total Field

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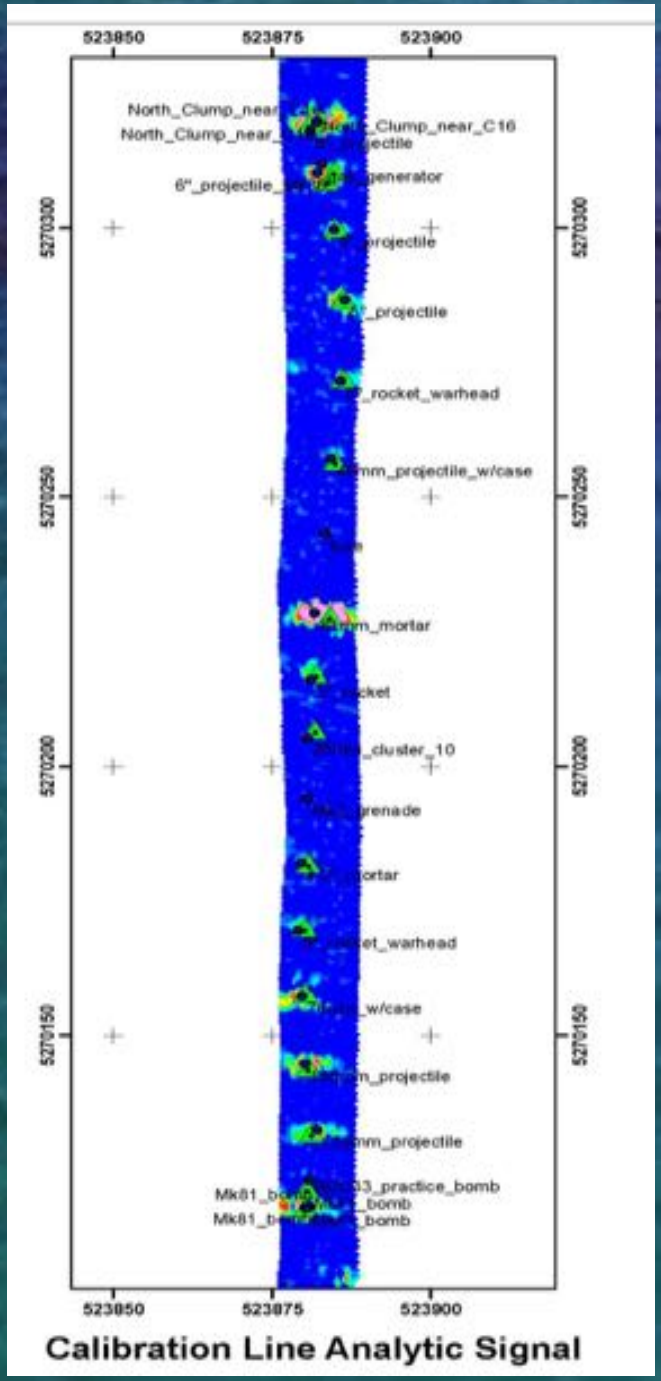
Example Analytic Signal Results from MGA

- True 3-D Analytic Sign
  - Eliminates solar interference (i.e. diurnal variations)
  - Suppresses geological interference
  - Results independent of survey line direction
- Analytic Signal yields a clear peak for each target even when the objects are close together. This simplifies data interpretation.



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MGA Detection Capability

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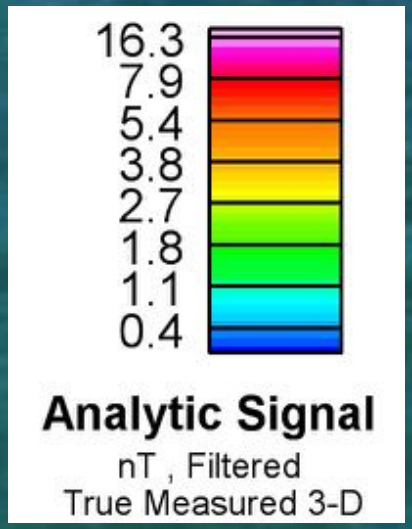

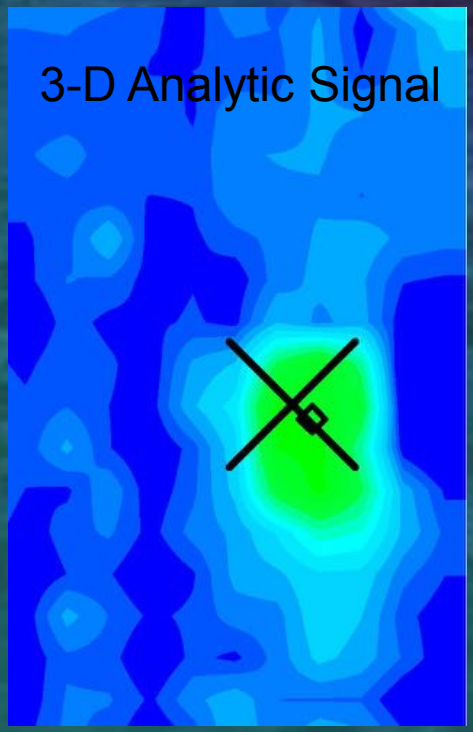

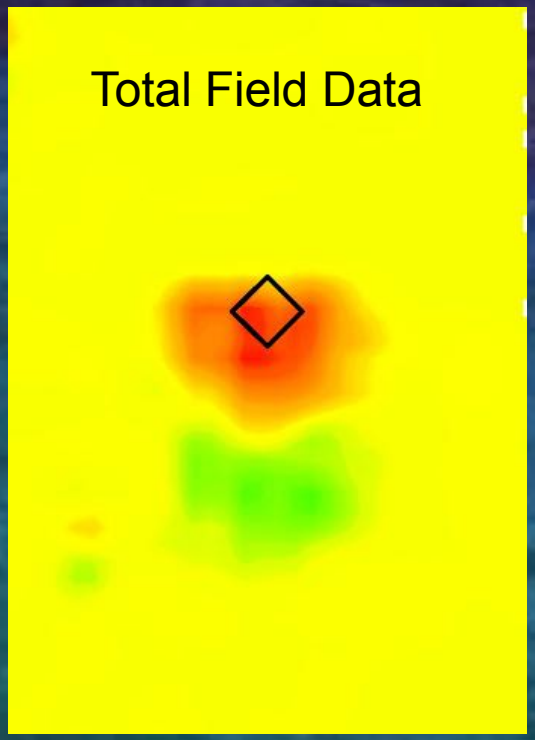

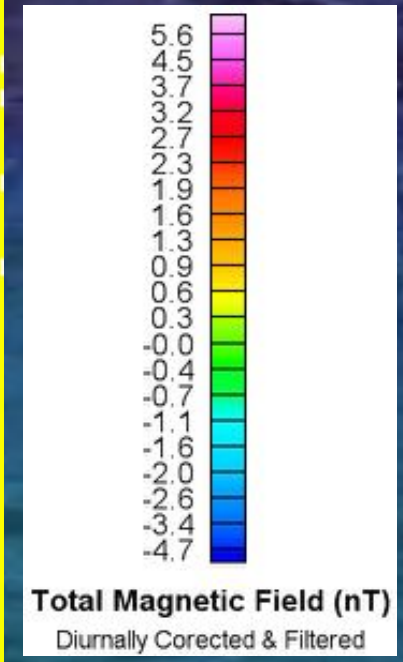

- Single 40 mm projectile with case (full round)
- 3 nT analytic signal peak & 3 nT total field peak (pos)
- Reported burial depth – 10-12 inches
- MGA flight altitude 1.6 to 2 meters

Summary

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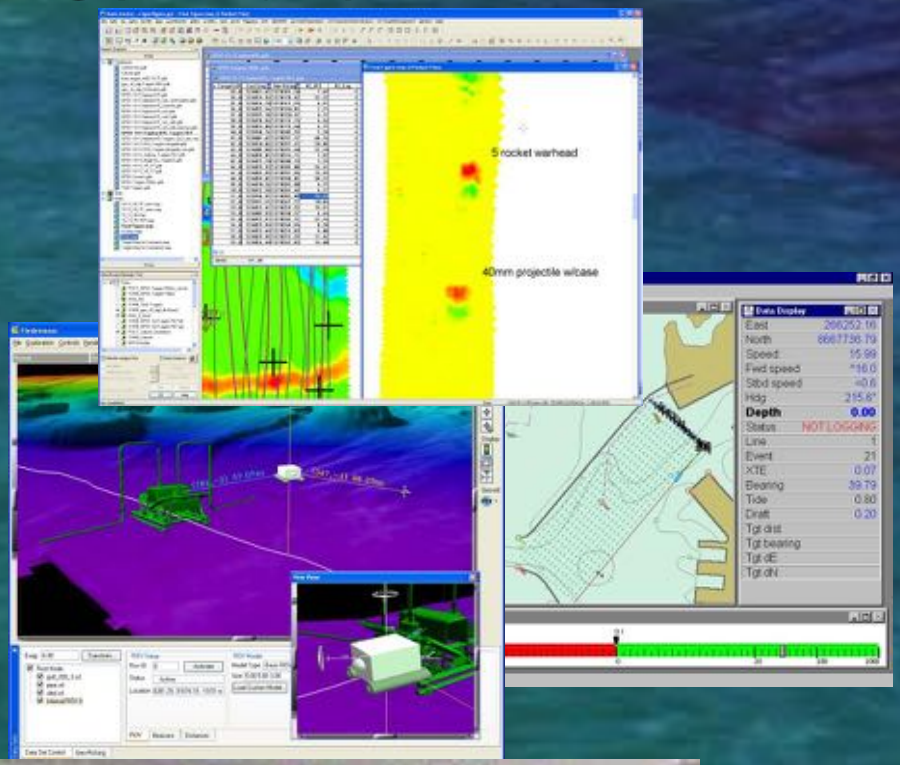
- The Tetra Tech data collection and analysis system was developed by integrating and modifying commercially available equipment, developing a customized system for MEC/UXO detection and mapping
- The system is scalable/modular & reconfigurable to facilitate adaptation to a broad variety of site conditions and data needs
- The system collects data over a much broader area than other available systems and in a broader range of water depths, increasing production and reducing cost
- The system is field proven to be reliable and effective
- The system provides detailed, high-quality data that will support the most accurate discrimination and location of subsurface ferrous anomalies, foot print reduction, and effective planning

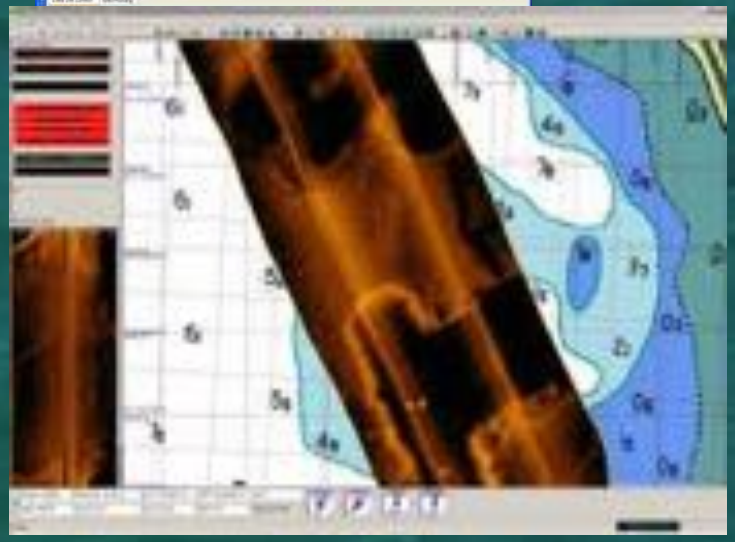
Any Questions?

- It’s nice when it all comes together

Additional Information

Software





- Oasis Montaj
  - Filtering, gridding, target picking 3-D Voxel gridding
- Hypack/HySweep
  - Survey Vessel Navigation
  - Single/multibeam sonar acquisition and editing
- Fledermaus
  - Multibeam sonar data processing/editing.
  - 3D presentations of multibeam, sidescan, subbottom profiler and magnetometer data
  - Simulations with flights (including movies).
  - Real-time Tow fish tracking in 3D.
- SonarWiz.Map
  - Sidescan/Subbottom Sonar Playback & Processing
  - Site/route mosaics
  - Identification of debris fields
- Custom Sonar Software
  - Experienced sonar software developer
- GIS – ArcInfo, Arc Map, ERDAS Imagine, AutoCAD
  - Charts produced and presented electronically and/or as hardcopy

Positioning Components

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- The Vessel
  - RTK GPS (~2 cm on x, y and z) or DGPS offshore (~20 cm)
  - Vessel IMU (heave, pitch, roll, yaw)
  - Data Acquisition Computers

- The Towfish
  - USBL / LBL
  - Digital Cable Counter
  - Altimeter, pitch, roll and depth sensors
  - Heading sensor

Multibeam Sonar Components

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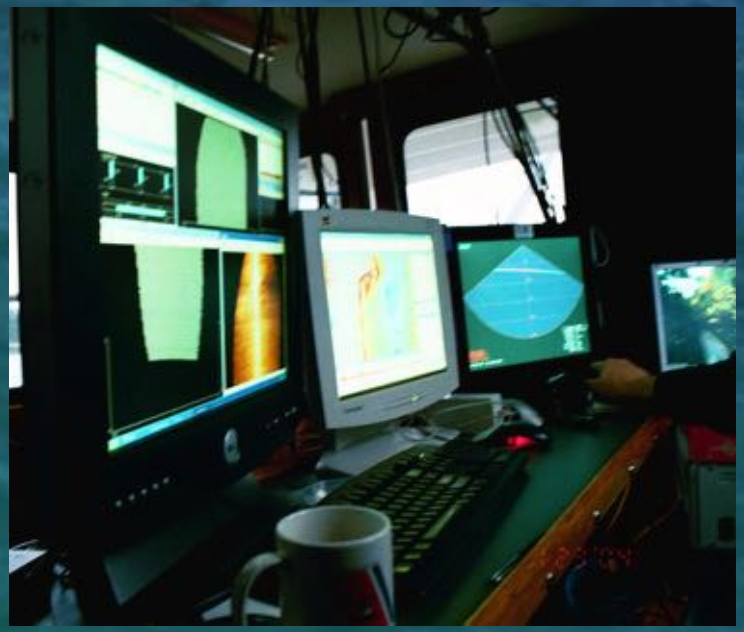
- RESON SeaBat 8125 multi-beam echo sounder (MBE)
  - Provides detailed bathymetry data
  - Highest resolution commercial multi-beam sonar currently available
- Integrated inertial system (Applanix POS-MV / WaveMaster)
  - Determines heading and vessel roll, heave and pitch to allow compensation of bathymetry data for vessel motion induced by wave action & other vessel dynamics.
- Seabird SBE-19 / MicroCat Sound Velocity Meter (MBE support system)
  - Data used to model and correct refraction and path length effects from sound speed changes through the water column



Sidescan Options

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- EdgeTech 4200, 4300, Klein 5000, or equivalent
  - Sidescan data to compliment and improve the resolution of multibeam sonar data (drape mosaic on multibeam surface)
  - Provides photo-like imagery which is used to identify areas of interest
  - Benthos C-3D Interferometric Sidescan System (optional)
    - May be used to supplement the MBE in any areas that are too shallow to be safely or efficiently surveyed (~>1-2 meters)

3D Gradiometer Array with Longitudinal Sensors

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7 Magnetometer MGA System