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Overview - Environmental Effects of Underwater Unexploded Ordnance (UXO) & Munitions Constituents (MC)

IR Conference
Port Hueneme, CA
February 11, 2004

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Sponsors

- **Chief of Naval Operations (N-45)**

  Mr. Geoffrey Cullison

  Ms. Cindy Turlington

- **Naval Facilities Engineering Command (NAVFAC)**

  Mr. Andy Del Collo

Performers

Engineering Service Center

- **Naval Facilities Engineering Service Center - Port Hueneme, CA**
  - Barbara Sugiyama – Project Manager
  - Warren Bartel
  - Alexandra DeVisser
  - Dan Polly
- **Space and Naval Warfare Systems Center – San Diego, CA**
  - Bill Wild
  - Rob George
  - Chip Johnson
  - Gunther Rosen
  - Dr. P.F. Wang
- **U.S. Army Engineer Research and Development Center – Vicksburg, MS**
  - Dr. Judy Pennington
  - Dr. Gui Lotufo
  - Dr. Mark Dortch

Background

Initial Decision Report (IDR) Objectives

1. **Define the Problem**
   - Underwater UXO sources and munitions constituents (MC)
   - Fate and effects of MC in water

     Leave-in-Place (LIP)
   - Fate and effects associated with underwater detonations

     Blow-in-Place (BIP) (no further effort)

2. **Assess Current and Future Technology**
   - Previous and current R&D Efforts
   - Emerging Technologies and Assessment

3. **Provide Recommendations**
   - Data Gaps / Future RDT&E options (Decision matrix)

Underwater UXO Risk Determination- Navy *Initial Decision Report* (IDR)

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BLAST SAFETY - **Human safety**

IDR Discussion

PROBLEM FORMULATION

- Munitions Constituent (MC)
- Route of Potential Exposure

ANALYSIS

(HAZARD AND EXPOSURE ASSESSMENT)

- Degradation and breakdown products
- Marine environmental fate/transport
- Toxicity to marine organisms
- Bioavailability to marine organisms
- Exposure from:
  - Quantity and distribution
  - Potential release rate (*i.e.* corrosion rate, leach rate)

Data Gaps / Future RDT&E options to support:

RISK CHARACTERIZATION

- Risk Estimation and Description

UXO Underwater Site Conceptual Model

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Block 1: Source Quantification

-how much UXO?

-% dud, cracked/breached, low order detonation

-% buried on impact, or uncovered

-net vertical/horizontal movement/transport

-% corrosion/concretion with time

-% buried with time

Block 2: MC Transport / Degradation Pathway

-Dissolution

-Adsorption/desorption

-Photolysis

-Irreversible binding

-Microbial transformation

-Advection from original location

Block 3: Exposure Pathway

-Water and/or sediment

-Mode: surface water contact, ingestion
sediment contact, ingestion

-Receptors: benthic infauna,
benthic epifauna,
pelagic fish,
waterfowl

UXO Underwater Site Conceptual Model

Block 1: Source Quantification

UXO INPUT (UXO type expected, quantity per unit time, location)

-Historical records, range or operational reports, anecdotal stories, other information

- UXO Subpopulation #1 (*ex. Aerial bombs > 500-lb*)
- UXO Subpopulation #2 (*ex. Lg. Projectiles >5-inch/38*)
- UXO Subpopulation #3 (*ex. Sm. Projectiles < 40mm*)
- UXO Subpopulation #x

OUTPUT

ARRIVAL ANALYSIS

-Delivery Mode by *each* UXO Subpopulation (Speed, Trajectory, Impact angle)

-Non-high order Detonation for *each* UXO Subpopulation

OUTPUT

- % Dud Rate (*i.e.* intact)
- % Cracked / Damaged Casing
- % Low-order Detonation

- % buried intact
- % uncovered intact
- % uncovered exposed
- % buried exposed

Exit to "CM Block 2"

OUTPUT OUTPUT

UXO MOBILITY ANALYSIS

TIME

Transport with Time

Corrosion with Time

Biofouling with Time

- Military Activities
  - ranges
  - loading facilities
  - rogue activities
- Site Influences
- Met/Ocean Data
  - Extreme waves
  - Tides
  - Run-off events
- Orientation
- Burial Depth & Location
- Entombment Depth

Task 4

OUTPUT

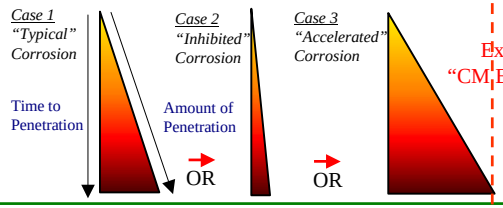
CORROSION ANALYSIS

% buried + uncovered *intact*

% buried + uncovered *exposed*

Task 3

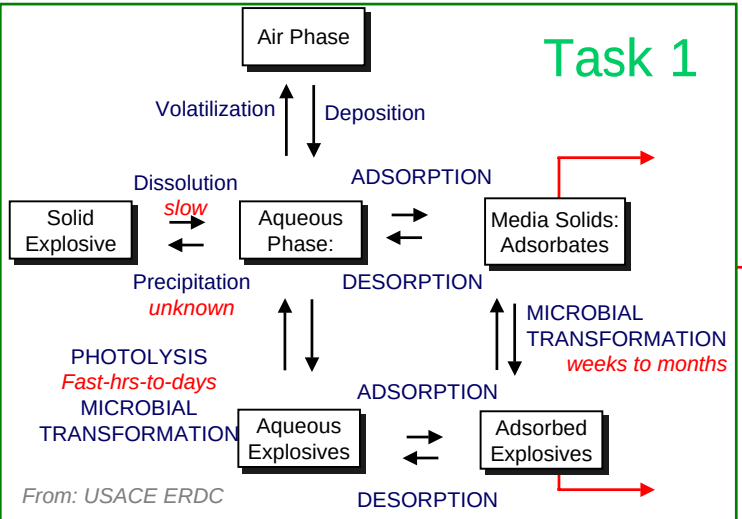
Corrosion Potential with Time



Exit to "CM Block 2"

Block 2: Degradation Pathway

Task 1



From: USACE ERDC

Block 3: Exposure Pathways

Task 2

Explosive Blast Safety

Receptors

- Humans
- Waterfowl/ Pelagic
- Benthic Epifauna
- Benthic Infauna

Water

- Parent MC compound
- Degradation products
- Adsorbed particles

Surface Water Contact
Water Ingestion
Sediment Ingestion
Sediment Contact

Sediment

- Parent MC compound
- Degradation products
- Adsorbed particles

Surface Water Contact
Water Ingestion
Sediment Ingestion
Sediment Contact

Surface Water Contact
Interstitial Water Contact
Sediment Contact
Sediment Ingestion

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Ongoing Projects

- **TASK 1**: Munitions Constituents in Marine Matrices (SEDIMENT and WATER) Degradation Research
- **TASK 2:** Multi-species Marine Sediment Toxicity/Bioaccumulation Research
- **TASK 3**: U/W Ordnance Casing Corrosion Research
- **TASK 4**: U/W Ordnance Mobility and Burial
- **TASK 5**: ARAMS Support and Integration

Navy Funded R&D Efforts - Physical Degradation

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TASK 1: MC IN MARINE SEDIMENT, WATER: DISSOLUTION, TRANSFORMATION, SORPTION, PARTITIONING PROCESSES **Milestones**
(1) Fractionation of *TNT* in Marine Sediments (FY02)
(2) Dissolution Rates of *TNT, RDX, HMX* in Salt Water (FY02)
(3) Transformation Rates, Adsorption Coefficients of *TNT, RDX, HMX (FY02)*
(4) Transformation Rates, Adsorption Coefficients of TNT Degradation Products - Part 1 *(2ADNT/ 4ADNT/ 2,4DANT/ 2,6DANT)* (FY03)
(5) Fractionation of RDX in Marine Sediments (FY03)
(6) Transformation Rates, Adsorption Coefficients of TNT Degradation Products - Part 2 *(TNB/ DNB/ 2,4DNT/ 2,6DNT)* (FY04)
(7) Fractionation of *HMX* in Marine Sediments (FY04?)
(8) Transformation Rates for *Picric Acid* In Fresh and Salt Water (FY05)
(9) Final Report- Integration of Previous Results (FY06)

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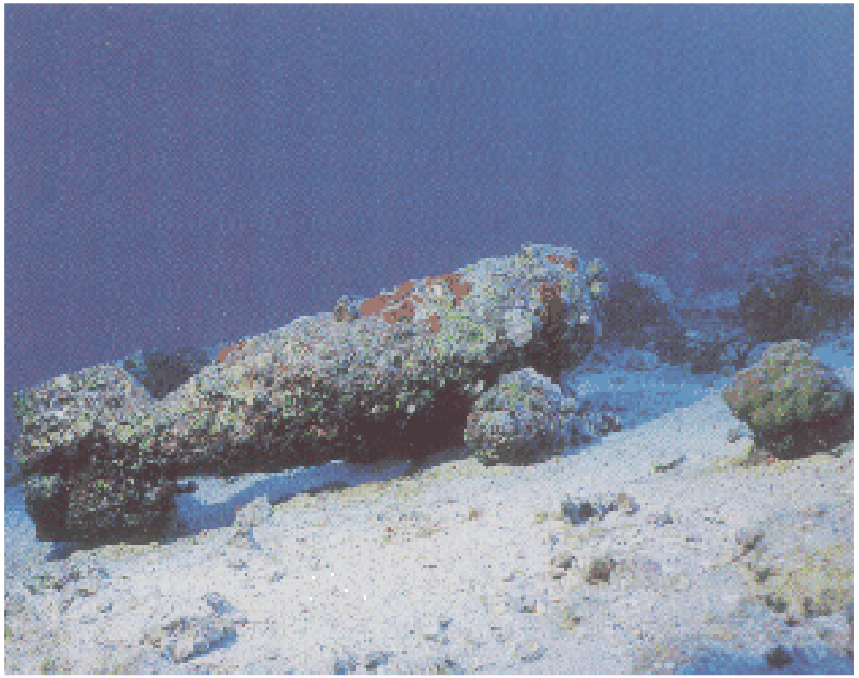
Navy Funded R&D Efforts-Toxicity

TASK 2: MULTI-SPECIES MARINE TOXICITY AND BIOACCUMULATION Milestones
(1) Toxicity of TNT and TNT Breakdown Products in Water Exposures (FY02)
(2) Bioaccumulation of TNT and TNT Breakdown Products (FY02)
(3) Multi-species Marine Sediment Toxicity Studies (FY02/03) *(SSC-SD Lead)*
(4) Toxicity of TNT with Sediment Exposures (FY03)
(5) Toxicity and Bioaccumulation of RDX/HMX in Water Exposures (FY03)
(6) MC Distribution in Invertebrate and Fish Tissues (FY04)
(7) Dietary Uptake of TNT (FY04)
(8) Mollusk Food Chain Bioassay (FY05) *(SSC-SD Lead)*
(9) Toxicity of Contaminant Mixtures Containing MC to Marine Inverts (FY05)
(10) Toxicity of Contaminant Mixtures containing MC to Marine Fish (FY05)
(11) Final Report- Integrating Navy-funded Research on MC in the Marine Environment (FY06)

Task 3 – Underwater Ordnance Casing Corrosion

Technical POC:
Warren Bartel, NFESC

Other Performers:
Dan Polly (NFESC)
Jim Jenkins (MAR Inc.)



Underwater Exposure

Depending on environmental factors, for shell casings NOT breached on impact; the quantity and amount of individual shell corrosion will affect exposure area and potential risk.

Casings will corrode -

- Corrosion at slow rates,developing pinhole/ seal leaks over time

Corrosion rates can vary-

- State of burial
- Location of site

TASK 3: U/W Ordnance Casing Corrosion

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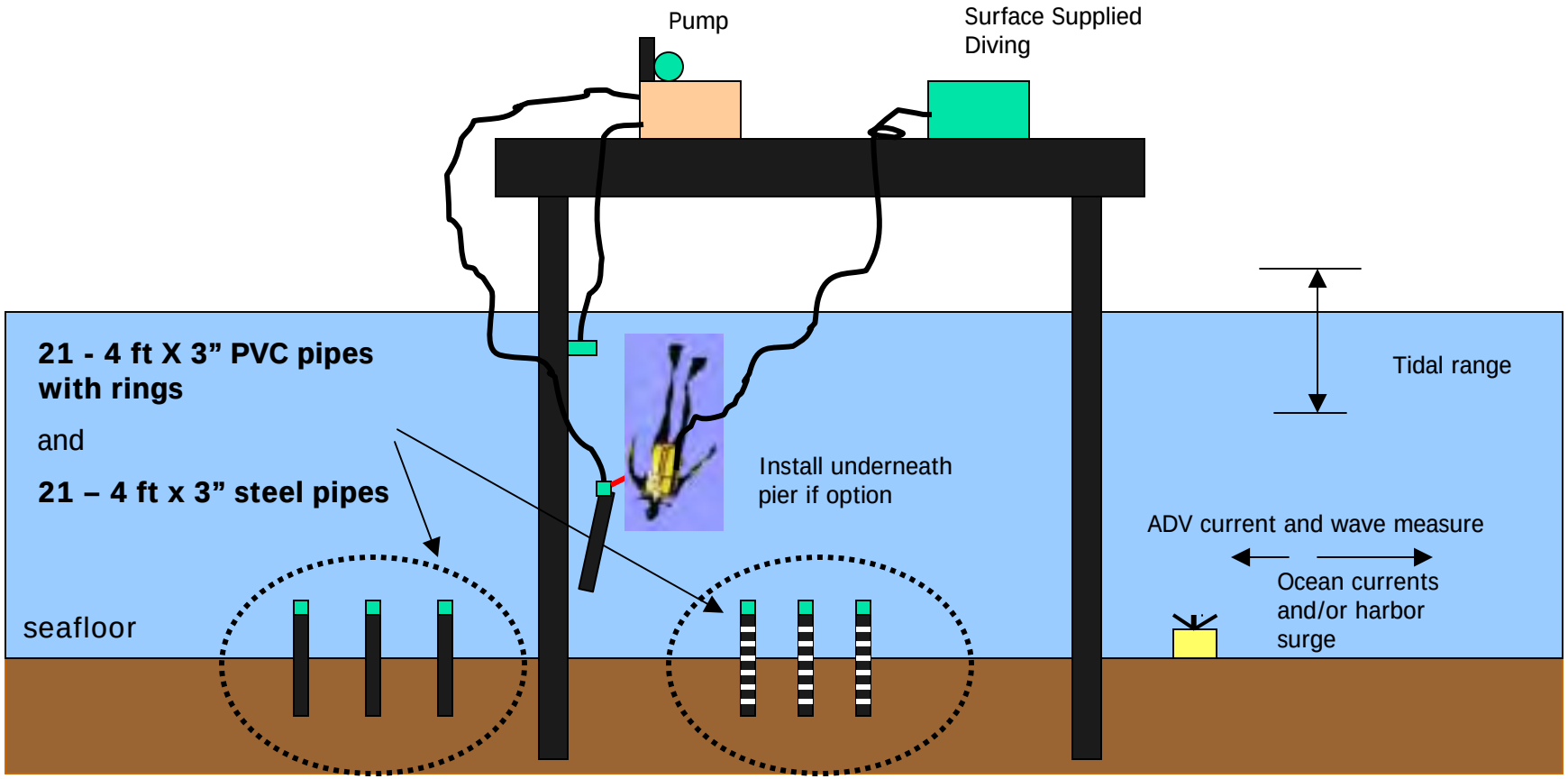
- Identify Corrosion Data Gaps
- Develop U/W Ordnance Corrosion Prediction Model Capability
  - Start with Basic Model of Steel in Seawater
  - Test Data Integration
  - Modify Basic Model to Include (location, UXO type, buried/unburied, abrasion, galvanic, etc.)
- Collect Generalized and Localized Corrosion Data to Update Coefficients in Model
  - Generalized Rates will be determined in Field Tests
  - Localized Rates will be determined in Laboratory Tests
- Implement Model Software and User Guide
  - C Program or Excel Spreadsheet (TBD)
  - Integrate with Risk Assessment Model

Generalized Tests

- Categorize with 2 Site Types
  - Temperate (Southern California Climate)
  - Cold Water (Washington State Climate)
- Collect Data
  - Buried/Unburied/Partially Buried
  - Abrasive Corrosion and Ocean Currents/Waves
  - Temperature, Salinity, O_2 , pH, Resistivity
  - Lab Analysis

Generalized Tests: Pier-side



Sample of Test Articles before and after

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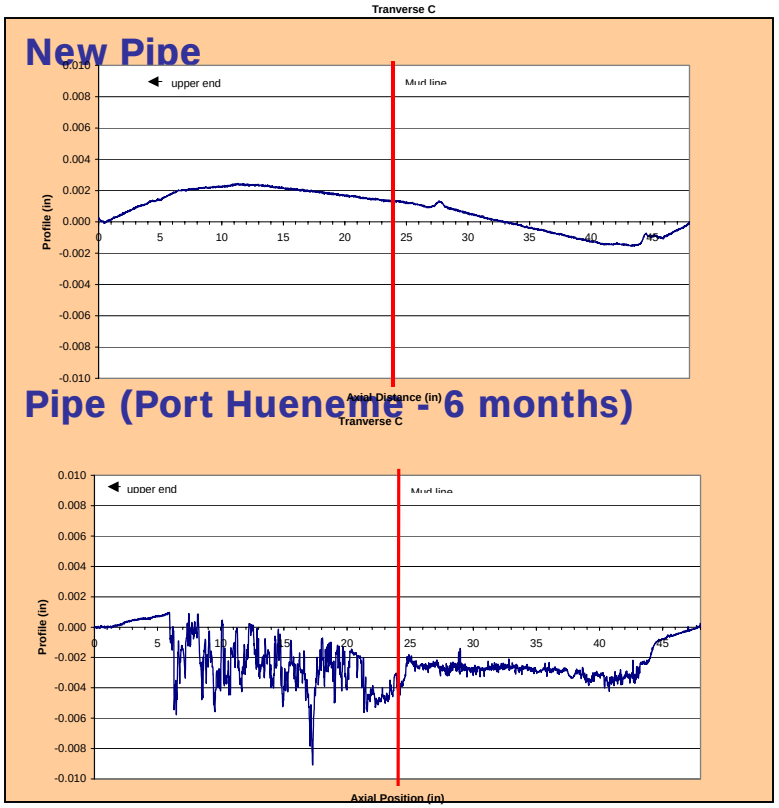
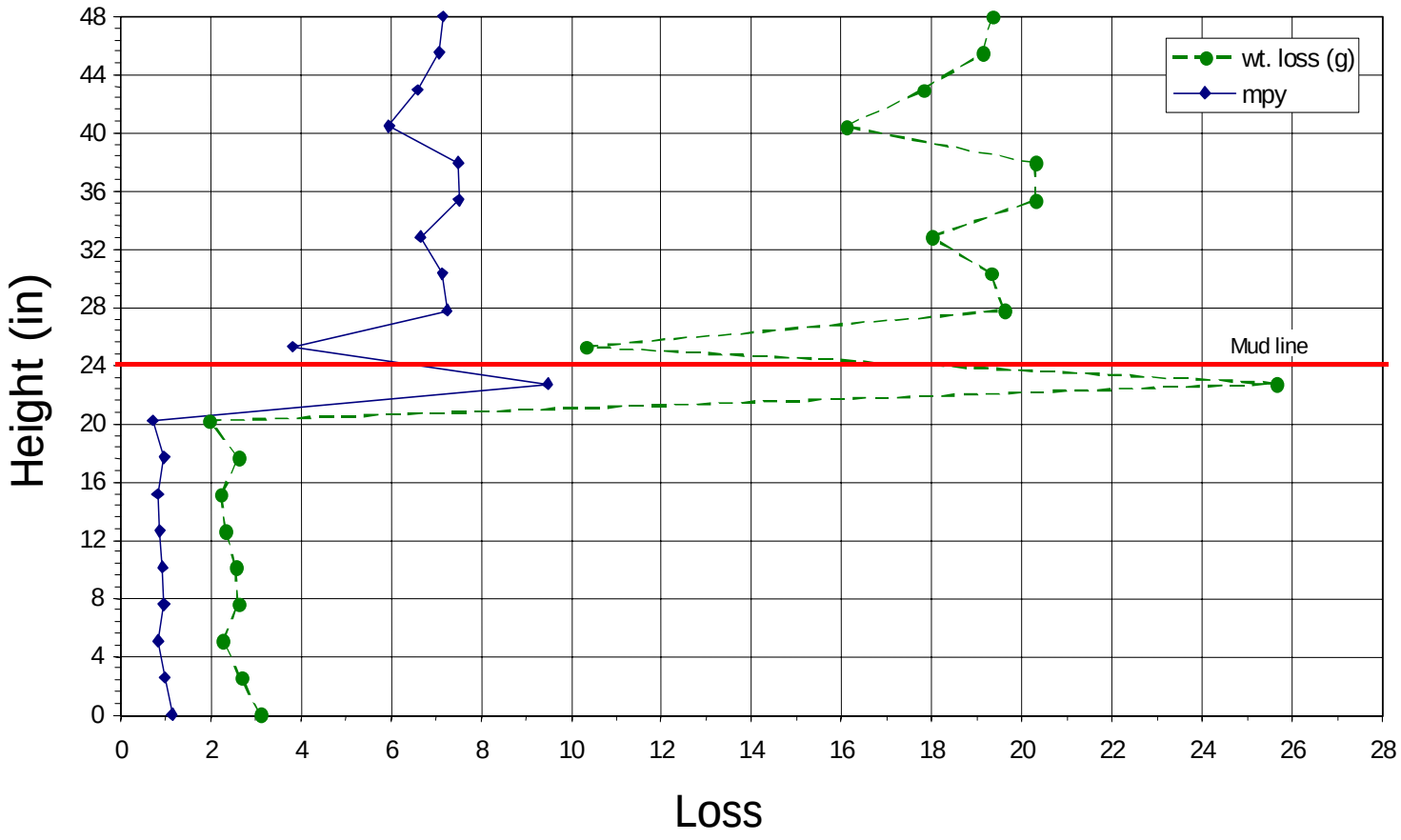
Profilometer Measurements (Four Orthogonal Traverses per Pipe)



Preliminary Results Port Hueneme Ring Segments After 6 Months



Buried rings: weight loss ≈ 2.5 grams (1mil/yr)

Seawater rings: weight loss 16 - 20 grams (7 mil/yr)

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Milestones and Major Deliverables

Milestone	Estimated Completion Date	Status
Gather Existing Data	March FY02	Complete
Identify Data Gaps	May FY02	Complete
Develop Corrosion Model	August FY02	Complete
Develop Test Plans	November FY02	Complete
Conduct Prototype Tests	March FY03	Complete
Conduct Generalized Corrosion Tests	March FY03- October FY04	In-progress
- Temperate Climate - Cold Water Climate	October FY04 ... FY09 (opt) October FY04 ... FY09 (opt)	Tests Started Tests Started
Conduct Localized Corrosion Tests	October FY04	In Progress (collecting Samples)
Write Computer Model/Software Development	October FY04	Not started
Summarize Corrosion Data and Corrosion Model	October FY04 – FY05 (opt)	Not started

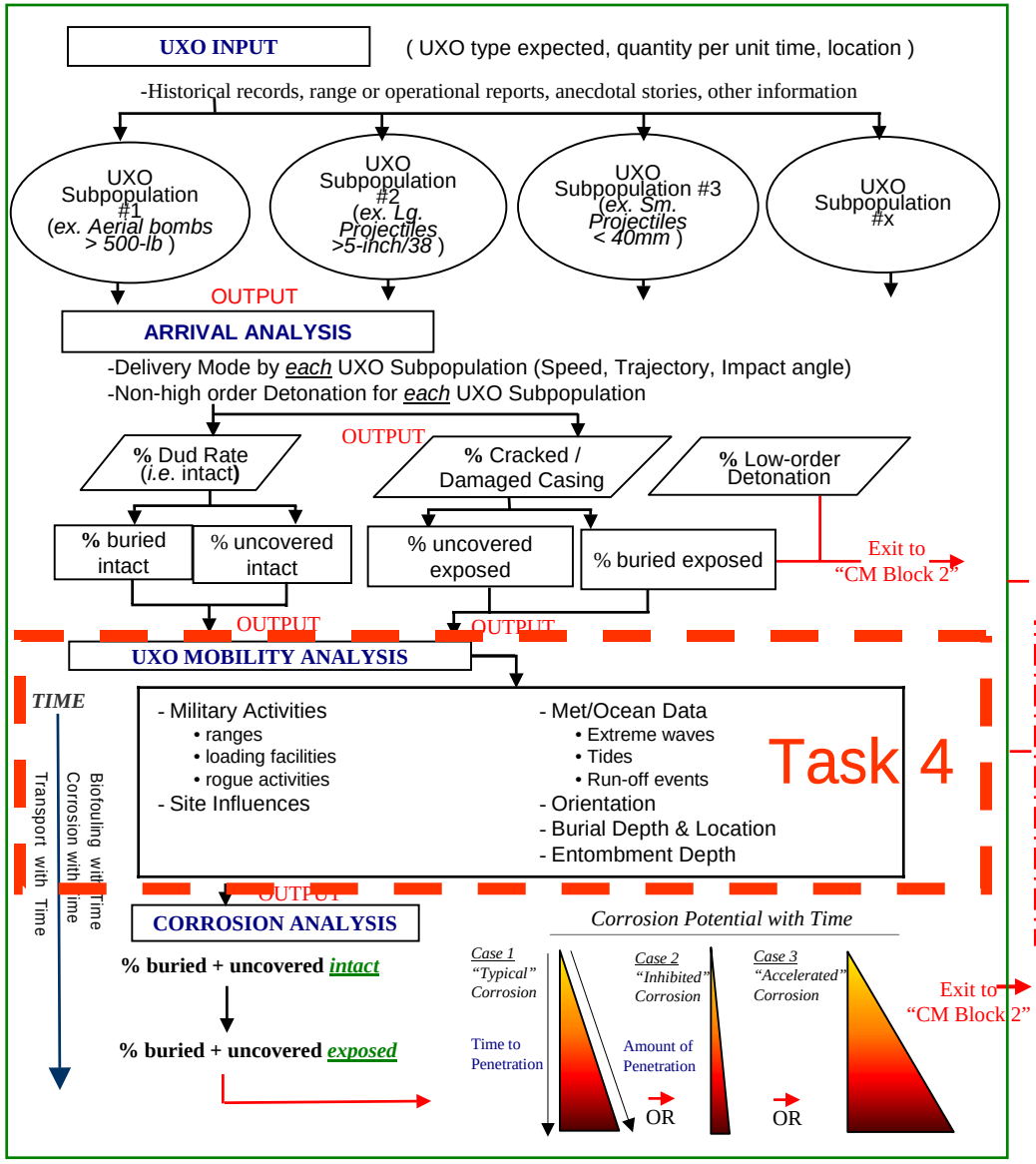
Task 4 – Underwater Ordnance Physical Transport and Burial

Technical POC:
Alexandra De Visser, NFESC

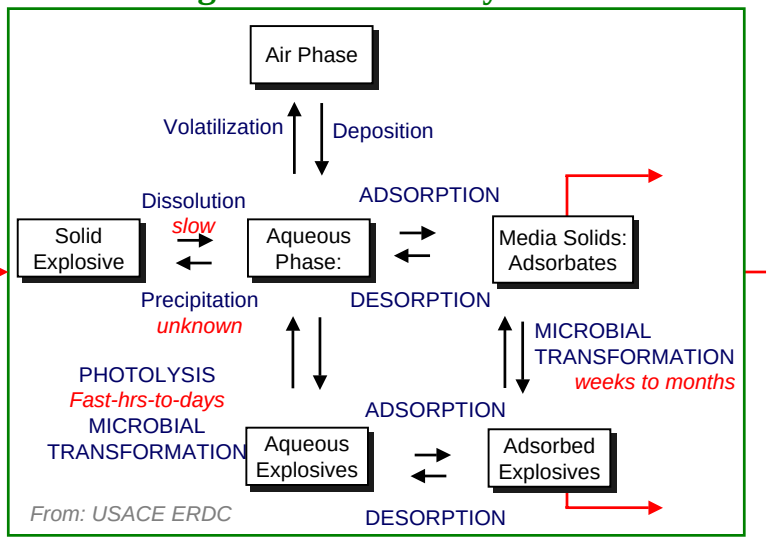
Other Performers:
Sound and Sea Technology
Scott A. Jenkins Consulting

UXO Underwater Site Conceptual Model

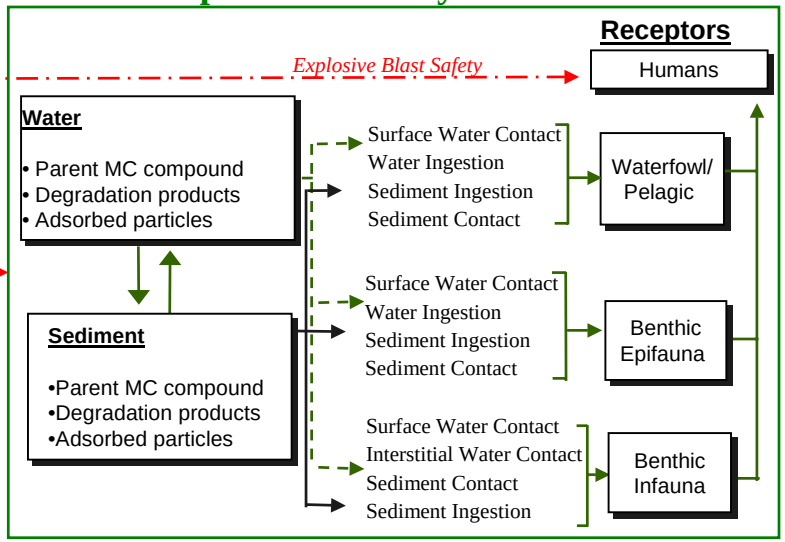
Block 1: Source Quantification



Block 2: Degradation Pathway



Block 3: Exposure Pathways



Objective/Approach

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Objective: Predict displacement and burial of UXO in littoral waters from introduction to final entombment.

Approach:

- Based on VORTEX/LATTICE Model developed for ONR by SIO to predict Mine Burial in worldwide generic coastal waters
- The existing model mine model is being adapted to produce a “UXO Mobility Model” (UXO sizes from heavy bombs to small, light munitions)
- Demonstration will cover the gamut of seasonal shoreline changes
- Model will run in deterministic modes for direct comparison with observations using both in situ bottom current measurements and local wave observations

Underwater UXO Mobility and Burial Model

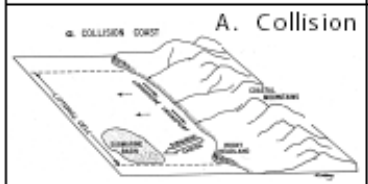
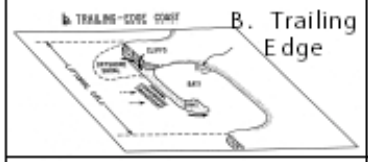
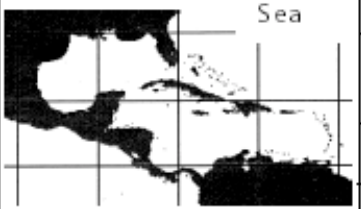
Input

- Calibrated generic coastal site classification: provides shore profile, sediment types, and selectable seasonal forcing environment options
- Sub-category: adapts for sheltered water with tidal prism and captured runoff (deposition environment)
- UXO site coordinates provide local bathymetry and major coastal runoff locations
- Current meter time series data for calibration

Output

- Time variable UXO displacement and burial depth
- UXO migration rates and distances

Coastal Classification System with Synthesized Model Input Parameters

Coastal Type	Boundary Conditions					Model Parameters		
	Morphology (Example)	Sediment Source	Sediment Sink	Closure Depth	Littoral Cell Dimensions	Grid Cell	Grain Size	Bed Roughness, η_0
 A. Collision	Narrow-Shelf Mountainous Coastal Bluffs (Cailfornia)	Rivers & Bluff Erosion	Submarine Canyons	15 - 18 m	Longshore: 50 km Cross Shore: 1 - 5 km	Farfield: 70 - 90 m Nearfield: 1 - 4 cm	Beach: 0.2 - 0.3 mm Shelf: 0.06 - 0.10 mm	0.5 - 3 cm
 B. Trailing Edge	Wide-Shelf Plains (Duck, NC)	Headlands & Shelves	Roll-Over Shoals Spit-Extension	10 -13 m	Longshore: 100 km Cross Shore: 30 - 50 km	Farfield: 40 - 80 m Nearfield: 2 - 7 cm	Beach: 0.2 - 0.4 mm Shelf: 0.06 - 0.15 mm	0.8 - 5 cm
 C. Marginal Sea	a) Narrow-Shelf Mountainous (Korea) b) Wide-Shelf Plains (Corpus Christi) c) Deltaic tideless (Mississippi) d) Deltaic tidal (Bangladesh) Wide-Shelf	Rivers & Deltas	a) Canyons b) Beaches & Barriers c) Delta & Shelf d) Delta Islands, flats, canyons	Narrow shelf: 7 - 10 m Wide shelf: 4 - 7 m Delta: 3 m	Longshore: a) 5-10 km b) 100 km c) 5-200 km d) var Cross Shore: a) 1 - 5 km b) 50 km c) 20-80 km d) var	Farfield: 10 - 20 m Nearfield: 1 - 3 cm	Beach: 0.06 - 0.21 mm Shelf: 0.01 - 0.09 mm Delta: .005 - .05 mm	a-d) 0.1 - 1 cm d) sand waves
 E. Coral Reef Form of Biogenic	Coral Reef Island (Hawaii)	Carbonate Reef Material Volcanic Headlands	Pocket Beaches & Awa Channels to the Shelf	Reef Platform	Longshore: ~2 km Cross Shore: 0.5 km	Farfield: 100 - 150 m Nearfield: 1 - 20 cm	Beach: 0.2 - 0.4 mm Shelf: 0.03 - 0.1 mm	Reef Platform ~1 m Offshore 1 - 15 cm

Initial Vortex/Lattice Model Calibration and Verification Testing

- Model calibration and validation required for each generic category of critical UXO sites
- Test planned for highest priority Collision Coastline Coastal Classification
- Pt. Mugu, CA, Drifter Field Test

- Inert UXO surrogates (20mm) deployed in surf zone (8-30 ft)
- Lagrangian Drifter Technique used to determine horizontal and vertical divergence
- Direct deterministic comparison with model predictions
- Comparisons of model/observations made wrt season

UXO Test Objects

- **Small Caliber Shells (< 1 in. dia.): primarily 30/50 cal. & 20mm rounds**

- **Large Caliber Projectiles (> 1 in. dia.): primarily Navy 5” (21’ to 26’ long)**

- **Aerial bomb shapes, small caliber UXO in cases and similar shapes will be tested in follow-on work under the ESTCP program**

Y0817 Field Tests

- Lagrangian Drifter Tests (Point Mugu, CA) Collision Coastal
  - Many samples (100), steep Collision Coastal beach
  - Only tracked by date and location found on the beach
  - Inexpensive but only gives broad statistics and requires high-energy storm to beach samples (long-term test).
- Measurement Method Field Test (Pacific Beach, WA)
  - Direct measurement of individual large samples by both acoustic and tether tracking
  - Conducted on high-energy, high tide range, flat beach (Collision Coastal)
  - Compares tracking methods and refines measurement process.
  - Gives rapid results (one tide cycle), direct validation of model for the surf transit phase of movement. Fully instrumented waves.

ESTCP Dem/Val Field Tests

ESTCP Dem/Val

- Atlantic (Duck, NC) and Hawaiian (TBD)
- Uses both Lagrangian and best direct-measure methods
- Calibrates model for remaining major coastal conditions (trailing edge, biogenic)

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Milestones

- **Rank Navy UXO sites (operational/BRAC/FUDS) and categorize them by hydrodynamic and sediment types (FY03)**
- **Adapt VORTEX model for UXO and near field grid transitions (FY03). Draft report Feb 04**
- **Acquire/Fabricate dummy ordnance (FY03-FY04)**
- **Calibrate VORTEX model for selected test site and deploy and track ordnance movement over seasonal and storm driven mobility/burial sequences (FY03-04)**
- **Compare model predictions with measured data (FY04)**
- **Document deterministic results for collision coastal category (FY04)**

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Accomplishments to Date

- **Completed survey of representative Navy MEC sites Grouped sites into geomorphic coastal categories**
- **Completed VORTEX model adaptation plan**
- **Completed following VORTEX model adaptation:**
  - **Develop code modification to run model backwards from initial state of complete burial.**
  - **Develop I/O file structures to accommodate short time step simulations for small caliber munitions.**
  - **Develop codes for movable nearfield gridding schemes for small caliber munitions.**
  - **Modified code to initialize population density of UXO according to layers of impact burial**

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Accomplishments to Date

- **Specified dummy ordnance procurement/fabrication requirements**
- **Initial field test / model calibration plan**
- **UXO Measurement Method Field Test (MMFT) planning for Pacific Beach, WA (FY04).**
  - **Permits in progress**
  - **Surrogates designed**
  - **Instrumentation procurement in progress**
- **ESTCP proposal accepted for outyear efforts**

Questions and POCs

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