Risk-Based Deep-Draft Channel Design

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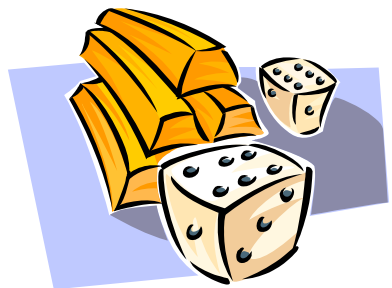
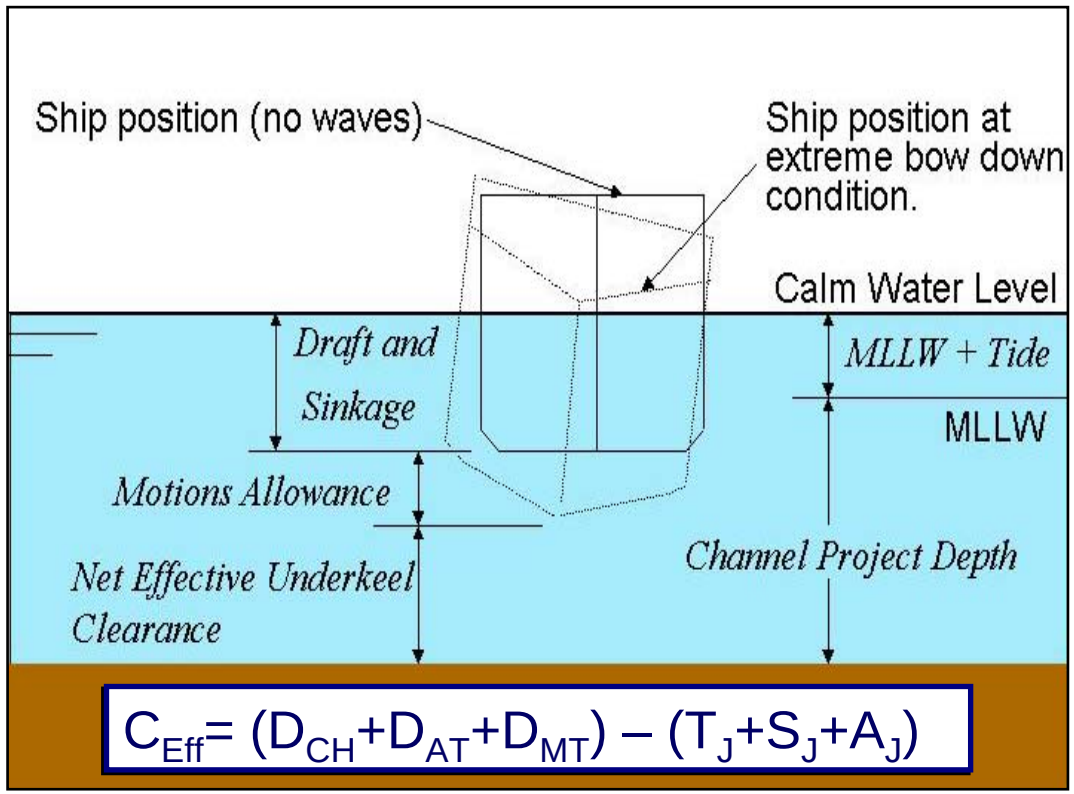


Problem

- **Bigger and faster ships**
- **Require deeper and wider entrance channels**
- **Corps > $500M/yr on dredging**
- **Dredging can cost $150K/vertical ft/acre, $1M/ft**
- **Minimize dredging, insure safe navigation, acceptable underkeel clearance**

Underkeel Clearance (UKC)

- **Net effective underkeel clearance C_{Eff}**
- **Channel project depth D_{CH}**
  - **Advance maintenance**
  - **Variability from horizontal**
- **Tide Stage**
  - **Astronomical D_{AT}**
  - **Meteorological D_{MT}**
- **Ship**
  - **Draft T_J (brackish)**
  - **Sinkage (Squat) S_J**
- **Motions allowance A_J**

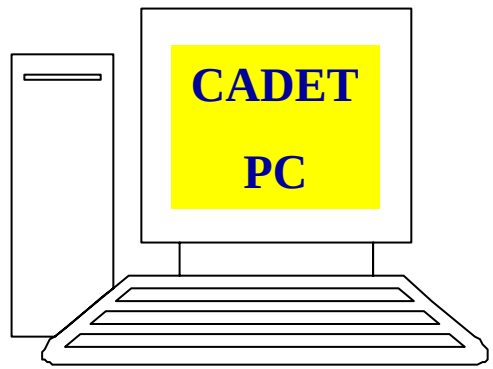


Background

- Corps responsible for navigation safety
- Underkeel clearance (UKC) major factor
- No consistent guidelines for channel design
  - Corps
  - States
  - PIANC
- Ship motion data scarce
  - Physical model
  - Field measurements
- Analytical/numerical models
  - Few available
  - Little verification
  - Need probabilistic or risk-based models

Overview

- **Creation of a PC-based entrance channel design tool**
  - **Channel Analysis and Design Evaluation Tool (CADET)**
- **Based on Navy's Environmental Monitoring and Operator Guidance System (EMOGS)**
  - **Operationally assist deep draft Navy ships transiting shallow channels**
  - **Predicts underkeel clearance before the ship transits the channel**
- **Flexible to accept any commercial ship and any entrance channel design**
- **Bundle with software that calculates sinkage (squat) and trim and ship response amplitude operators (RAO's) for shallow water**
- **Fortran and C**
- **Operational in FY05**
- **Revisions in FY07, plans to market CADET**



History of EMOGS Development

- **1989: Kings Bay for OHIO class submarine & wave buoys**
- **1992: VANGUARD class submarines**
- **1994: PC-based and pressure array**
- **1995: installed at Port Canaveral using wave buoys from Kings Bay**

Channel Design Methodology

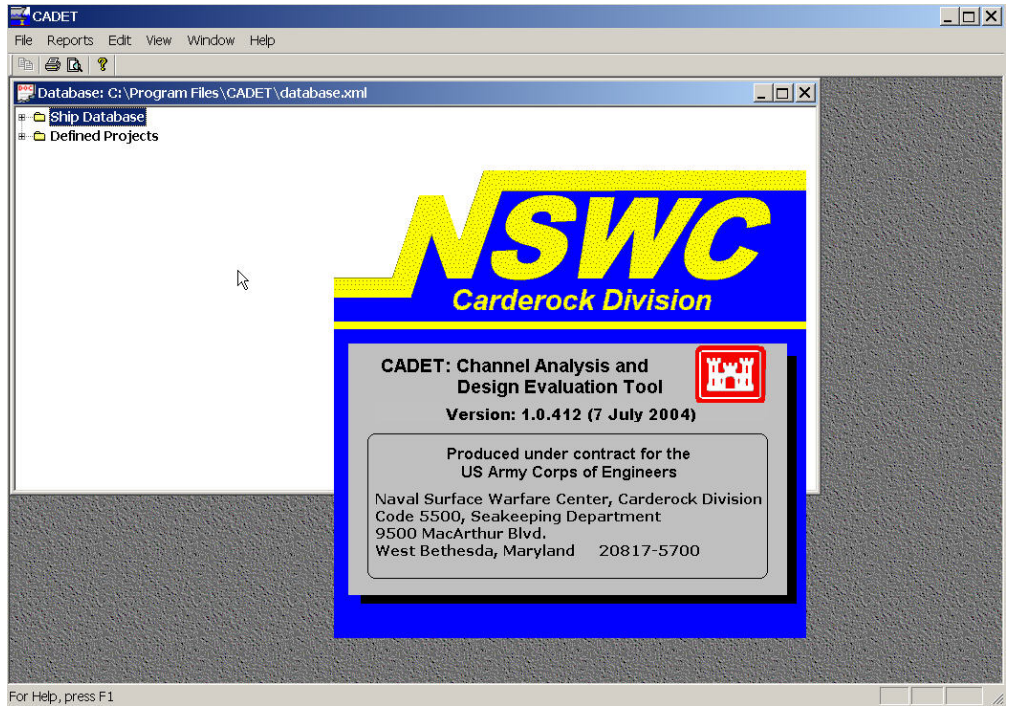
- **Deterministic approach**
  - **Required channel depth is calculated**
  - **100% accessibility**
- **Probabilistic risk-based approach**
  - **Predictions of net effective underkeel clearance**
  - **Analysis of associated risk of touching channel bottom for interpreting clearance output**
- **Accessibility Comparison – San Diego**
  - **Deterministic: Recommended channel depth 61 feet**
  - **EMOGS San Diego: Recommended channel depth 55 feet**
    - **90% accessibility with EMOGS channel operation guidance**
    - **62% accessibility without EMOGS channel operation guidance**
    - **Economic benefits of risk-based approach vs. deterministic**

Risk Analysis

- **Engineering Approach**
- **Model uncertainty with Gaussian distribution**
  - **Channel depth**
  - **Static ship draft**
  - **Sinkage (squat) and trim**
- **Model uncertainty with Rayleigh distribution**
  - **Motions allowance**
- **Risk of touching project depth**
  - **Proportion of all transits, under statistically constant conditions, where the minimum instantaneous clearance is less than zero**
  - **Probability density of the largest motion excursion in a given duration of transit considering uncertainty in estimates of channel depth and ship motion and velocity**
  - **Probability density obtained numerically**

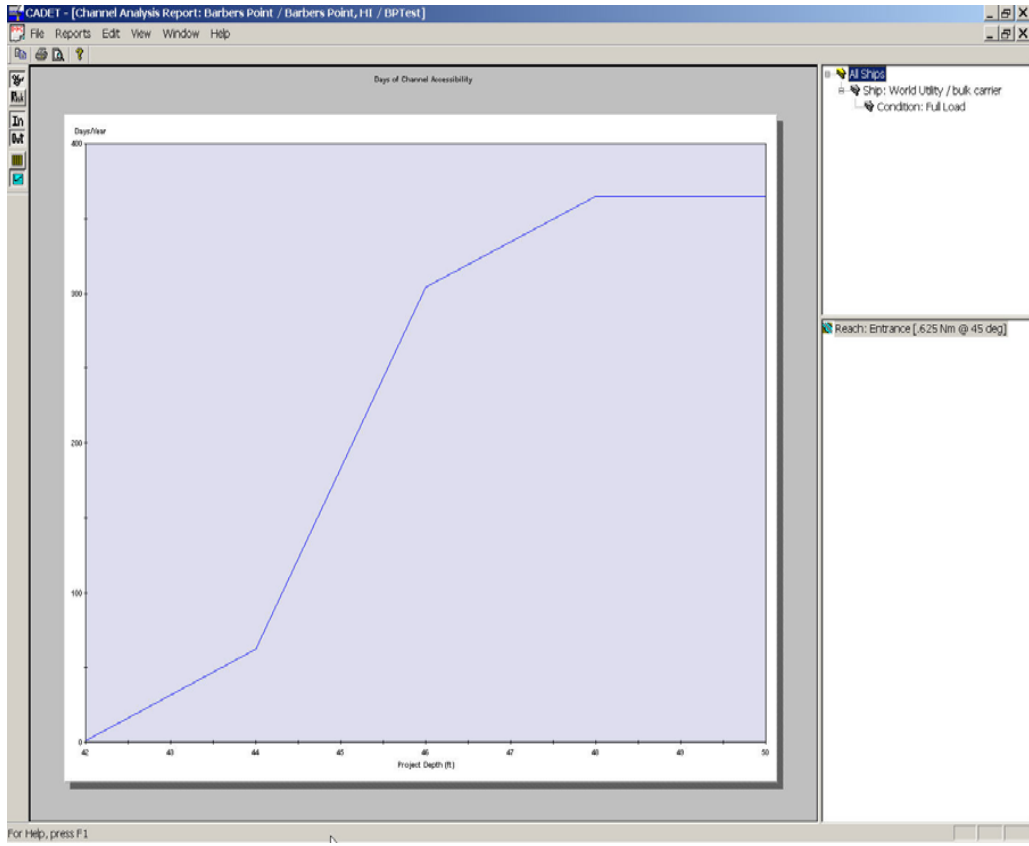
CADET Capabilities

- Ship type and number
  - Containership
  - Bulk carrier
- Ship loading
  - Static draft and trim
  - Ship speed
  - CG
  - Roll damping
  - Roll and pitch gyradii
  - Sinkage (Squat)
  - 6 DOF RAO's
- Inbound and outbound transits
- Any channel configuration
  - Channel segment length
  - Depth
  - Orientation
- Any wave conditions
  - Wave Spectra
  - Probabilities of occurrence



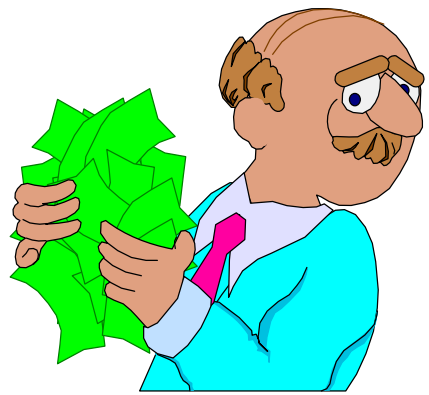
CADET Accessibility

- Days per year can safely transit channel for given depth
- Based on percent occurrence of wave conditions per year yielding less than α risk of touching specified project depth
- Selected ship and project
- Inbound and/or outbound transits
- Graph or table



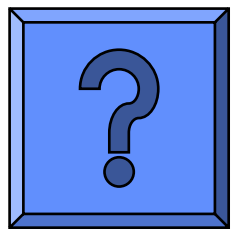
CADET Benefits

- **Planning & design for navigation studies**
- **Improved channel design for depth and alignment**
- **Predictive tool for squat, trim, RAO's, and UKC**
- **Operational tool for Corps, USCG and Port Authorities**
- **Minimum channel depth with maximum accessibility**
  - **Project depth can be minimized**
- **Improved operational efficiency**
  - **Determine when the environmental conditions in the channel are unsafe for transit**
- **Integrated models into NAV/MTS 2020 Vision**



Workshop Questions

- **Define and Prioritize Problems/Issues**
- **Data Assembly Questions**
- **Short and Long Term Goals**
- **Action Steps for High Priority Goals**



Problem Statement

- **Need good ship response data from field and laboratory for validation and verification of CADET and other numerical models**

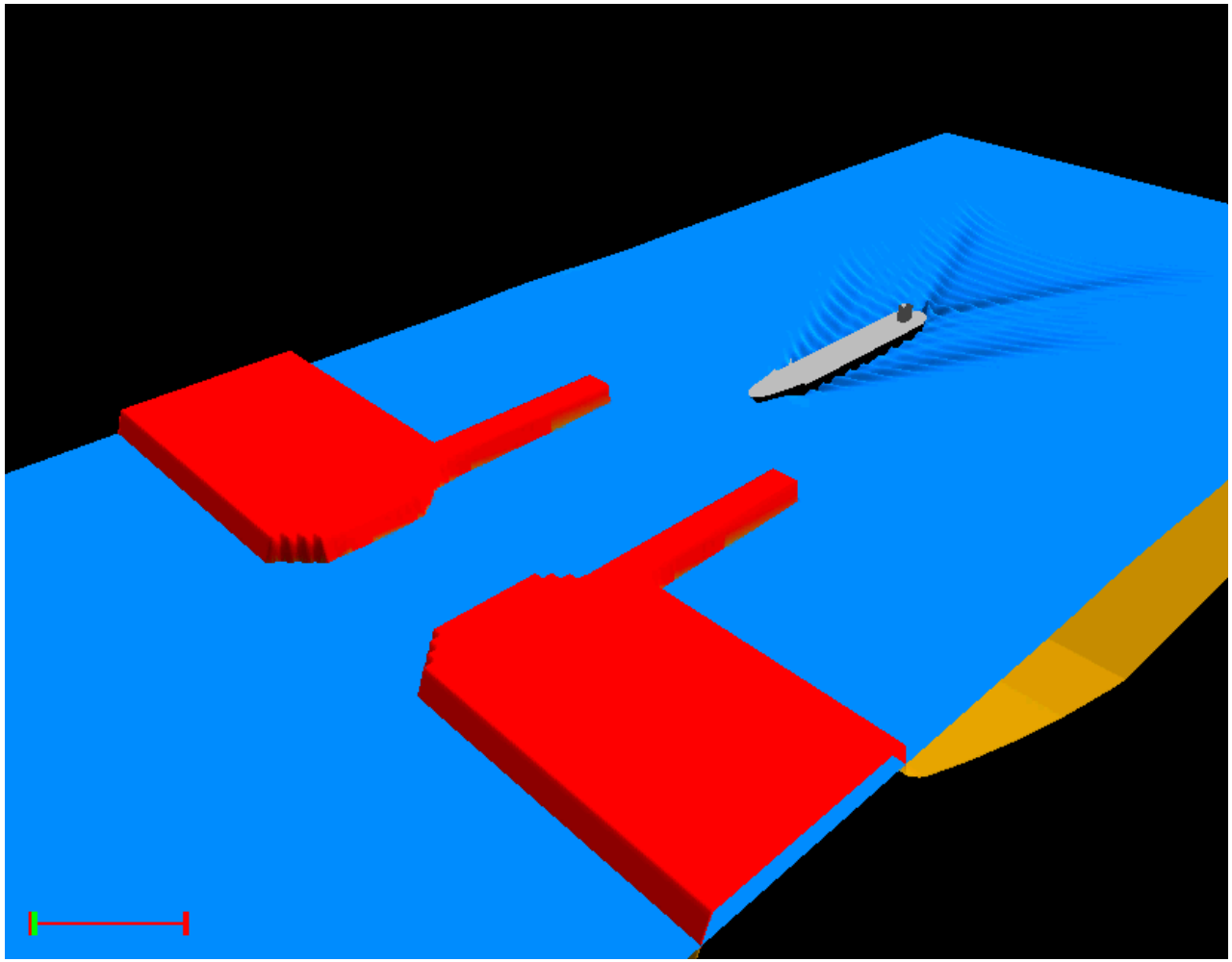
Data Assembly

- **What are data requirements?**
  - **Ship motions in 6 degrees of freedom to waves and currents**
  - **Ship sinkage or squat for new mega containerships coming on line**
- **What do we know and what do we need to know?**
  - **Have lots of empirical formulas for sinkage and squat, but are they accurate for larger vessels**
  - **Have RAOs for limited set of ships, but are the accurate for larger, commercial vessels**
  - **Can numerical models predict accurately or will they also need updated data from field or laboratory?**
  - **New 6 DOF models, Boussinesq models, RANS models for predictions**
    - **Phase-resolving wave modeling technology to predict waves and currents**
    - **Accurate and reliable estimate of waves at inlets and navigation channels, and wave runup and overtopping at inlet structures (jetties, breakwaters, piers**
  - **Field data is best (especially with GPS), but not always easy to obtain (weather, waves, ships, timing, etc.) and expensive to gather**

Short and Long Term Goals

- **1 Year Goals**
  - **Revised CADET Program**
  - **Continue validation studies**
- **5 Year Goals**
  - **Better data on ship response including heave, pitch, roll, and squat**
  - **Better ship motion response programs for horizontal and vertical motions**
  - **RANS and Boussinesq models of ship response**
    - **A new finite-volume Boussinesq-type wave model with unstructured finite element grid**
  - **More comparisons with field and laboratory data**
  - **Active marketing of CADET**

Ship-wake Effects at a Coastal Inlet



Action Steps

- **Collect accurate ship sinkage and motion data from field and/or laboratory**
- **Data required**
  - **Range of wave conditions including periods, heights, and directional spread**
  - **Range of ship types, drafts, speeds, and angle of ship approach to waves**
  - **Range of current conditions**
  - **Range of channel conditions including restricted and unrestricted, channel side slopes, underkeel clearance**
- **Collaborators**
  - **ERDC, CHL**
    - **Navigation R&D**
    - **CIRP**
  - **IWR, NETS**
  - **NSWC, Carderock**
- **Consequences/Benefits**
  - **Better estimates of ship response to waves and currents**
  - **Inability to validate and verify model predictions**
- **Obstacles/Road Blocks**
  - **Funding**

Summary and Conclusions

- **CADET: Channel Analysis and Design Evaluation Tool**
  - **Ship type, number, and loading**
  - **Inbound and outbound transits**
  - **Any channel configuration**
  - **Any wave conditions**
- **Determine when the environmental conditions in the channel are unsafe for transit**
  - **Minimum channel depth with maximum accessibility**
  - **Predictive tool for squat, trim, RAO's, and UKC**
- **Workshop Questions**
  - **Problem/Issue Statement**
  - **Data Assembly**
  - **Short and Long Term Goals**
  - **Action Steps**

Questions

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