1st Annual
Atlantic Petroleum
R&D Forum

Ice Management and
Impact Oil and Gas
Developments on the
Grand Banks

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Grand Banks Region
Historical Iceberg Distribution
Ice Management

- Ice and metocean conditions
- Protection – structural integrity
  - Iceberg design loads
  - Disconnection
  - Excavation / Burial
- Risk mitigation
  - Detection and towing
Ice Load Analysis

- **Ice - Structure Interaction**
  - Failure mechanisms
    - (crushing, spalling, fracture),
  - Ice strength, contact area
  - Interaction geometry

- **Impact Loads**
  - **Global** - kinetic energy, eccentricity, ice pressure, crushing, contact area, penetration
  - **Local** – HP zone, impact duration
Iceberg Seabed/Facility Interaction

- Subsea systems
- pipelines
Iceberg Seabed/Facility Interaction

- Gouge Characterization
Technical Program

- Subsea Infrastructure Protection
  - risk mitigation strategies
    - Alternative protection concepts
    - Ice contact/loads/wellhead damage
    - Consequences
    - Safety class considerations
- If, contact/damage ... re-entry
- Construction issues
- Intervention issues
Iceberg Seabed/Facility Interaction

- Subgouge soil displacement
  - Keel geometry
  - Keel strength
  - Soil strength

- Pipeline response
  - Large deformation
  - Strain
Ice Management Framework

Iceberg Observed

Detection, Tracking & Classification

Physical Management

Data Management

Forecasting

Threat Evaluation & Decision Making

Weather, Operational Status, etc.

Iceberg Leaving Zone
Iceberg Detection

- **Systems**
  - Marine Radar
  - Satellite Radar
  - HF Radar
  - Aerial & Vessel Reconnaissance

- **DATA FUSION**
  - Detections vary in space and time

- **Ship / iceberg classification**
Iceberg Detection

- Ship Ice Classification
- Polarimetric discrimination potential
  - ENVISAT ASAR AP Mode provides extra channel of information
  - Different multi-polarimetric signatures for ships and icebergs
Iceberg Detection

- SHIP TARGETS
- May 19\textsuperscript{th}, 2004
  - 2 Ship Targets, Provincial Airlines Ltd. (PAL)
Iceberg Detection

- ICEBERG TARGETS
- May 2\textsuperscript{nd}, 2003
  - Iceberg Target, C-CORE
    - 150 x 50 m Large Tabular
Iceberg Forecasting

- Iceberg Drift Prediction (CIS)

Iceberg Profiling
Iceberg Towing

- Iceberg net design
- Iceberg tow stability
- Towing catenary
- Towing in pack ice
- High seas towing
- Multiple vessel towing
- Performance
Iceberg Stability Under Tow

- Icebergs may be unstable (tendency to roll)
  - Iceberg geometry, shape
  - Iceberg size relative to applied power
- Increased length of tow hawser ...
  - Reduced slippage
  - Reduced roll
Iceberg Stability Under Tow

Non-Tabular Icebergs

Tabular Icebergs

Plan Aspect Ratio Range from 1:1 to 3:1 (L:W)
**Towing Catenary Toolbox**

**Iceberg stability**

**Inputs**
- Tow force
- Tow speed
- Water depth
- Allowable cable depth
- Tow cable and iceberg rope properties

**Output (given tow force)**
- Length of tow cable to deploy
- Distance from the ship to the iceberg
Pack Ice Management

- Relieve pressures in confining pack conditions
- Towing icebergs through pack
- Prevent disconnection
Decision Making Toolbox
Ice Management Simulation
Tactical Avoidance - Shipping

- Detection

Scan Averaging
Marine Radar
Tactical Avoidance

- Ship Maneuvering

\[ R_A = f(y, V, L) \]

\( R_A \) = offset from original track or avoidance range

\( y \) = distance traveled
\( V \) = vessel velocity
\( L \) = iceberg length
Effect of Tactical Avoidance

Generic Population
Mean length = 44m

Population that Hit
Mean length = 6.63m

Larger icebergs that give higher loads are avoided
Risk Mitigation - Design Loads

- Global Loads \((10^{-4} \text{ exceedence})\)
- Reduced risk ... reduced load
  - The longer you fish ... the bigger fish you will catch.
**Risk Mitigation - Design Loads**

- Global Loads ($10^{-4}$ exceedence)
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![Probability of Exceedence vs. Iceberg Design Load Graph](image)
Risk Mitigation - Design Loads

- Global Loads ($10^{-4}$ exceedence)
- Reduced risk ... reduced load
  - The longer you fish ... the bigger fish you will catch.
Other Benefits

• Design for Hibernia considerably different from Terra Nova and White Rose facilities

• Hebron Concept uniquely different due to better understanding of the ice conditions and loads

• With more experience and confidence in IM, we saw jackups on the Grand Banks
Future Ice Management R&D

- Iceberg strength
  - Pressure area effects
  - Fracture analysis

- Continued improvements of ice management on the Grand Banks
  - Towing in high seas
  - Towing in pack ice
  - Subsea protection

- Further development of iceberg drift forecasting capability
  - Improved current modeling
  - Iceberg drift data collection with detailed profiles to enhance drift coefficients
Future Ice Management R&D

- Satellite monitoring in remote areas
  - Orphan Basin
- Implementation of Data Fusion into operations
- Implementation of decision-making toolbox into operations
- Continued development of simulation training
- Development of subsea protection alternatives
The End