Meeting Agenda

Wednesday:
1:30 PM  Introduction and project review
Bob Bea

2:00  ULSLEA updates (fatigue, earthquake, additional configurations)
Jim Stear

3:00  Discussion

3:15  Break

3:30  Sponsor Presentations

4:00  Discussion

4:30 PM  Conclude

Thursday:
8:00 AM  Review issues from previous day
Bob Bea

8:30  ULSLEA enhancements, demonstration
Jim Stear

9:30  Future work plan
Bob Bea, Jim Stear

10:00  Discussion, sponsor's directions

11:00 AM  Adjourn
1997 - 1998

MARINE TECHNOLOGY & MANAGEMENT GROUP

INDUSTRY & GOVERNMENT AGENCIES SPONSORED RESEARCH PROJECTS SUMMARIES

Professor Robert Bea
College of Engineering
Tel: (510) 642-0967
Fax: (510) 643-8919
e-mail: rgb@euler.berkeley.edu

Professor Karlene Roberts
Haas School of Business
Tel: (510) 642-5221
Fax: (510) 631-0150
e-mail: karlene@haas.berkeley.edu

215 McLaughlin Hall
UNIVERSITY OF CALIFORNIA
Berkeley, CA 94720-1712

Goal: Develop engineering and management technology that will help improve the QUALITY (safety, serviceability, durability, compatibility - economy) of marine systems

QUALITY

RESEARCH AREAS
Human & Organization Factors
Ships & Floating Systems
Platforms & Pipelines
<table>
<thead>
<tr>
<th>Human and Organization Factors</th>
<th>Researcher</th>
<th>Goals and Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLAIM II (with Prof. Williamson, Prof. Roberts, Paragon Engineering Inc.)</td>
<td>Derek Hee</td>
<td>Develop a comprehensive system to evaluate the life-cycle reliability characteristics of ships including human factors considerations. Validate system with Estonia accident analysis.</td>
</tr>
<tr>
<td>Management of Rapidly Developing Crises: A Multi-Community Study</td>
<td>Bob Bea, Karlene Roberts</td>
<td>Develop a real-time system to assist in arresting rapidly developing sequences of events that can lead to catastrophic accidents.</td>
</tr>
<tr>
<td>Human &amp; organization factors in diving operations</td>
<td>Shawn Cullen</td>
<td>Promote dive safety through identification, analysis, and management of human and organization factors in diving operations.</td>
</tr>
<tr>
<td>Human &amp; organization error risk reduction assessment instrument - SMAS</td>
<td>Brant Pickrell</td>
<td>Develop, code, and verify a computer program for use in assessing the risks of human and organization errors in operations of offshore platforms and marine terminals.</td>
</tr>
<tr>
<td>Human &amp; organization factors in quality of offshore platforms (with Atkins, Ramboll, and MSL Eng.)</td>
<td>Rich Lawson</td>
<td>Develop a computer program to facilitate analyses of human and organizational factors in the life-cycle quality performance of offshore platforms.</td>
</tr>
<tr>
<td>Human and Organizational Factors in Emergency Medicine</td>
<td>Karlene Roberts</td>
<td>Develop and implement research in seven medical units, ranging from paramedic units in fire departments to adult and child critical care units. This research tests a model of risk mitigation. Other investigators participating in this research include...</td>
</tr>
<tr>
<td>Center for Risk Mitigation - CRM</td>
<td>Bob Bea, Karlene Roberts</td>
<td>Organize a research center that will provide a forum for research and information exchange among diverse industries to improve the safety of high technology systems.</td>
</tr>
</tbody>
</table>

SMAS - SAFETY MANAGEMENT ASSESSMENT SYSTEM
<table>
<thead>
<tr>
<th>Ships, Platforms, Pipelines</th>
<th>Researcher</th>
<th>Goals and Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship Structural Integrity Information System - SSIIIS III</td>
<td>Henry Reeve</td>
<td>Develop and verify one component of a comprehensive ship quality information system that addresses the structural aspects of ships over their life.</td>
</tr>
<tr>
<td>Design and construction of long-life marine composite structures</td>
<td>Paul Miller</td>
<td>Develop and test panels of marine composites subjected to repeated loadings in submerged conditions. Develop and verify an analytical procedure to allow the evaluation of the long-term performance characteristics of marine composite panels.</td>
</tr>
<tr>
<td>Optimal strategies for the inspections of ships and offshore platforms for fatigue and corrosion damage (with Martec, Inc.)</td>
<td>Tao Xu</td>
<td>Develop procedures and strategies to optimize the inspection and repair of ship and offshore platform structures. The inspection strategies will address predictable damage (e.g. fatigue of critical structural details) and unpredictable damage (e.g. due to accidents and errors).</td>
</tr>
<tr>
<td>Reassessment &amp; Requalification system for offshore platforms (Prof. Bill Ibbs, Principal Investigator)</td>
<td>Steve Stanef</td>
<td>Develop a computer based information and data management system for the reassessment and requalification of fleets of offshore platforms.</td>
</tr>
<tr>
<td>Ultimate Limit State Limit Equilibrium Analyses of template-type offshore platforms - ULSLEA Phases 3 and 4</td>
<td>Jim Stear, Zhaohui-Jin, Pending Assignment</td>
<td>Continue development and verification of a simplified procedure to characterize the ultimate limit state loadings and capacities of offshore platforms and their reliabilities for extreme condition storms and earthquakes.</td>
</tr>
<tr>
<td>Analyses of the nonlinear performance of platforms and caissons subjected to hurricanes</td>
<td>John Kareolis, James Wiseman</td>
<td>Continue study of the performance characteristics of platform and caisson systems when the storm loadings force the structures to their ultimate limit states.</td>
</tr>
<tr>
<td>Performance of pile foundations subjected to earthquake excitations (Profs. Seed, Bray, Pestana)</td>
<td>Philip Meymand, Thomas Lok, Chris Hunt</td>
<td>Develop and verify analytical models to assess the performance characteristics of groups of piles supporting structures subjected to intense earthquake excitations. Perform shaking tests on model pile groups to provide test data to verify the analytical models.</td>
</tr>
<tr>
<td>Pipeline Integrity and Maintenance Information System - PIMPIS</td>
<td>Tarek Elsayed</td>
<td>Develop and verify an inspection and maintenance decision support system for submarine pipelines using a knowledge-based approach. PIMPIS will provide a means of embedding expert knowledge to help select options for pipeline inspections and maintenance.</td>
</tr>
<tr>
<td>Platform, pipeline, and floating systems design and requalification criteria for the Bay of Campeche</td>
<td>Tao Xu, Zhaohui-Jin, Pending Assignment</td>
<td>Develop and verify a general platform and pipeline design and reassessment - requalification system tailored to the unique environmental, operational, and economic characteristics of PEMEX operations in the Bay of Campeche.</td>
</tr>
<tr>
<td>ISO earthquake guidelines for design and reassessment of offshore platforms</td>
<td>Bob Bea, Pending Assignment</td>
<td>Continue development of reliability based platform earthquake design and reassessment guidelines for the International Standards Organization.</td>
</tr>
<tr>
<td>Reliability based earthquake LRFD design guidelines for offshore Indonesia</td>
<td>Bob Bea, Pending Assignment</td>
<td>Develop platform load and resistance factor design guidelines for offshore Indonesia.</td>
</tr>
<tr>
<td>Decommissioning and re-use of offshore platforms</td>
<td>James Wiseman, Brian Collins</td>
<td>Develop a general process for the assessment and evaluation of alternative procedures for the decommissioning of offshore platforms. Assist in conduct of MMS / CSLC workshop on decommissioning.</td>
</tr>
</tbody>
</table>
Screening Methodologies for Use in Offshore Platform Assessments and Requalifications

Project Objective:

Further develop and verify simplified quantitative screening methodologies for Level 2 platform assessments so these methodologies may be used in practice

Phase I: June 1993 to May 1995
Phase II: June 1995 to May 1996
Phase III: June 1996 to May 1997
Phase IV: June 1997 to May 1998
Phase IV Project Sponsors

ARCO Exploration and Production Technology

Exxon Production Research Company

Mobil Technology Company

Shell Offshore Incorporated

Unocal Corporation

New Sponsors:

US Minerals Management Service

PeMEX/IMP

Potential Sponsors:

Chevron Petroleum Technology Company

Phillips Petroleum Company

Saudi Arabian Oil Company
Phase IV Deliverables

#1
Documentation of ULSLEA program enhancements, comparisons, developments, evaluations, and verifications

#2
Updating of ULSLEA user and modeling guide, including updated software and coding

#3
Two meetings
• Aero and hydrodynamic loadings ✓
• Unbraced deck legs capacity ✓
• Jacket capacity (legs, braces, joints) ✓
• Foundation capacity ✓
• Deterministic ULS analysis ✓
• Probabilistic ULS analysis ✓
• Damaged and grout-repaired members ✓
• Verification case studies (5) ✓
• ULSLEA program documentation ✓
• Meetings (2) ✓
ULSLEA Phase II

- Modeling enhancements ✓
- Code updating and enhancement ✓
- Preliminary design of braces ✓
- Jacket horizontal framing effects ✓
- Additional verifications (2) ✓
- Linear analysis comparisons ✓
- User - modeling guide ✓
- Reporting and documentation ✓
- Meetings (2) ✓
ULSLEA Phase III

- Fatigue analysis algorithms ✓
- Earthquake analysis algorithms ✓
- Verifications of earthquake analysis (3) ✓
- Earthquake deck spectra ✓
- Additional configurations ✓
- Platform strength and robustness studies ✓
- Code updating ✓
- Reporting and documentation ✓
- Meetings (2) ✓
Fatigue Analysis with ULSLEA

Long-term wave heights

Correlate wave loads to joint stresses

Compute fatigue damage

\[ Y_0 = \frac{N_0}{T_{\text{spectrum}}} H_0^{8\text{ave}m} \left( \ln N_0 \right)^{\frac{8\text{ave}m}{\xi}} \Gamma \left( 1 + \frac{\xi \text{stress}}{\xi_0} \right) \]

\[ Y_1 = \frac{N_1}{T_{\text{spectrum}}} H_1^{8\text{ave}m} \left( \ln N_1 \right)^{\frac{8\text{ave}m}{\xi}} \Gamma \left( 1 + \frac{\xi \text{stress}}{\xi_1} \right) \]

Find \( S_p \) for \( H_f \)

\[ D_d = \frac{T_d}{K} \left( \frac{S_p(1-R)}{H_f^{8\text{stress}}} \right)^m (Y_0 + Y_1) \]
Fatigue Analysis with ULSLEA

API Wave Height Distribution

<table>
<thead>
<tr>
<th>Connection</th>
<th>Axial SCF</th>
<th>In-Plane Bending SCF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chord K</td>
<td>$1.8\sqrt{\gamma \tau \sin \theta}$</td>
<td>$1.2\sqrt{\gamma \tau \sin \theta}$</td>
</tr>
<tr>
<td>Chord T and Y</td>
<td>$3.06\sqrt{\gamma \tau \sin \theta}$</td>
<td>$2.04\sqrt{\gamma \tau \sin \theta}$</td>
</tr>
<tr>
<td>Chord X, $\beta &lt; 0.98$</td>
<td>$4.32\sqrt{\gamma \tau \sin \theta}$</td>
<td>$2.88\sqrt{\gamma \tau \sin \theta}$</td>
</tr>
<tr>
<td>Chord X, $\beta \geq 0.98$</td>
<td>$3.06\sqrt{\gamma \tau \sin \theta}$</td>
<td>$2.04\sqrt{\gamma \tau \sin \theta}$</td>
</tr>
<tr>
<td>All Braces</td>
<td>$10 + 0.375(1 + \sqrt{\frac{\tau}{\beta SCF_{chord}}}) \geq 18$</td>
<td></td>
</tr>
</tbody>
</table>

API Stress Concentration Factors
Fatigue Analysis with ULSLEA

Fatigue Damage Input

- Exposure Period
  - Td: 30
- S-N Curve
  - m: 3.74
  - K: 1790000000
- Stress
  - q: 1.2
  - R: 0.5

Average
- H0: 40
- Eta0: 1
- NO: 1000000

Extreme
- H1: 75
- Eta1: 1
- N1: 1000000000

FATIGUE ASSESSMENT
Fatigue Damage Ratings for End-On Tubular Joints

jacket bay # | brace # | joint i | joint j | Ts (years) |
-------------|---------|---------|---------|------------|
1            | 1       | 0.0317  | 0.0317  | 30         |
2            | 2       | 0.0317  | 0.0317  | 30         |
3            | 3       | 0.0317  | 0.0317  | 30         |
4            | 4       | 0.0317  | 0.0317  | 30         |
2            | 1       | 3.5171  | 3.5171  | 9          |
2            | 2       | 3.5171  | 3.5171  | 9          |
3            | 3       | 3.5171  | 3.5171  | 9          |
4            | 4       | 3.5171  | 3.5171  | 9          |
3            | 1       | 3.1499  | 3.1499  | 10         |
2            | 2       | 3.1499  | 3.1499  | 10         |
3            | 3       | 3.1499  | 3.1499  | 10         |
4            | 4       | 3.1499  | 3.1499  | 10         |
Earthquake Analysis with ULSLEA

Modal analysis to get vibration properties

Consult response spectrum to get modal accelerations

Find demands associated with each mode

Combine modal responses

Compare to ULSLEA lower bound
Earthquake Analysis with ULSLEA

Discrete Models:

Added Mass:

\[ m_{\text{added}} = \rho_w \pi r^2 \sin \theta \]

Period Lengthening:

\[ \tilde{T}_1 = T_1 \sqrt{1 + \frac{k_1^*}{K_x} \left[ \frac{1}{1 - (T_o / \tilde{T}_1)^2} + \frac{K_x h_1^{*2}}{K_\theta} \right]} \]
Earthquake Analysis with ULSLEA

Pile head stiffnesses:

\[
k_z = \frac{x E A}{L} \quad \text{and} \quad k_x = 18.2Gr \frac{(1 - \nu^2)}{(2 - \nu)^2}
\]

Foundation Effects on 1st Mode Period
Earthquake Analysis with ULSLEA

Earthquake Analysis Parameters

- **Model Comb.**
  - SRSS
  - ABS Sum

- **Hydrodynamic Mass**
  - CM = 0.8

- **API Spectrum**
  - Soil A: ZPA (g) = 0.25
  - Soil B: Spectrum COV = 0.8

- **Soil Parameters**
  - Shear Modulus (ksi): 2.5
  - Poisson's Ratio: 0.5

- **Pile Stiffness Biases**
  - Axial: 1
  - Lateral: 1

Periods and Mode Shapes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Broadside</th>
<th>Deck</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1  2  3</td>
<td>1  1 2  3</td>
</tr>
<tr>
<td>Period (sec)</td>
<td>1.5 0.17 0.09</td>
<td>0.122 0.121 0.122</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.9 -0.122 -1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.369 -1 0.161</td>
</tr>
</tbody>
</table>
Verification 1: Southern California Test Structure

Hypothetical 4-leg platform
Structure is A36 steel
Main diagonals are 24" and 30" diameter
Legs are grouted
72" diameter piles designed for 150’ penetration in medium to stiff clay

Analyzed by Gates, et al., using both time-history and RSA

Verification uses API spectrum, 5% damping, soil B, ZPA = 0.25 g
Verification 1: Results

Comparison of Shear Demands

Modal Contributions
Verification 2: Platform Ellen

8-leg drilling platform

Majority of structure is 36 ksi, with 50 ksi piles

Main diagonals range 20” to 30” diameter

Legs are ungrouted

48” and 66” diameter piles driven to 232’ and 264’ in medium to stiff clays and silts

Verification uses API spectrum, 5% damping, soil C, ZPA = 0.25 g
Verification 2: Broadside Response

Broadside Shear Demands

Modal Contributions to Broadside Demands
Verification 2: End-On Response

End-On Shear Demands

Modal Contributions to End-On Demands
Verification 3: Platform Elly

12-leg drilling platform

Majority of structure is 36 ksi, with 42 ksi piles

Main diagonals range 24” to 36” diameter

Legs are ungrouted

42” and 48” diameter piles driven to 200’ to 252’ in medium to stiff clays and silts

Verification uses API spectrum, 5% damping, soil C, $ZPA = 0.25$ g
Verification 3: Broadside Response

Broadside Shear Demands

Modal Contributions to Broadside Demands
Verification 3: End-On Response

End-On Shear Demands

Modal Contributions to End-On Demands
Reliability and Earthquakes

Uncertainty in Response Spectrum Ordinates

Safety index formulation:

$$\beta = \frac{\mu_M}{\sigma_M}$$

$$\mu_M = \ln \left( \frac{\mu_R}{\mu_S} \sqrt{\frac{1+V_S^2}{1+V_R^2}} \right)$$

$$\sigma_M^2 = \ln(1+V_R^2) + \ln(1+V_S^2) - 2 \ln(1 + \rho_{RS} V_R V_S)$$

If spectrum is deterministic:

$$\sigma_T^2 = \sigma_M^2 \left( \frac{\partial T}{\partial T_M} \right)^2 + \sigma_{Kx}^2 \left( \frac{\partial T}{\partial K_x} \right)^2 + \sigma_{Kg}^2 \left( \frac{\partial T}{\partial K_g} \right)^2$$
Accelerations for Equipment

Amplification Ratio

\[
\begin{align*}
T_{e_f}/T_{s_i} < 1.25 & \quad & T_{e_f}/T_{s_i} \geq 1.25 \\
\bar{u}_{ij} ' &= \left( \frac{A_{ej}}{A_{si}} \right) \bar{u}_{xi} & \bar{u}_y '' &= \left( \frac{A_{ej}}{A_{si}} \right) SA_j \\
\ddot{u}_j &= \sqrt{\sum_{i \text{ over all } \bar{u}} (\bar{u}_{ij} ')^2 + \sum_{i \text{ over all } \ddot{u}} \left( \Gamma_i \phi_{xi} \ddot{u}_{ij} '' \right)^2} \\
&\quad \frac{\sum_{i \text{ over all structure modes}} \left( \Gamma_i \phi_{xi} \right)^2}{\sum_{i \text{ over all structure modes}} \left( \Gamma_i \phi_{xi} \right)^2}
\end{align*}
\]
Ductility-Level Analysis

Northridge Newhall

Northridge Sylmar

Hanshin Miyagi Ken-Oki

Diagram showing the ductility-level analysis for different events.
Additional Configurations

Multi 4-leg jackets:

Platform Deck

4-Leg Jackets

Platform Deck Plan

4-Leg Jacket Plans

Multi-jacket Behavior
Additional Configurations

Tripod Jackets:

Broadside Load

End-On Load

Broadside Jacket Capacity:

\[
P_{uH_{boj}} = P_{uH_{MLTF Frame 1}} + \left( \frac{P_{uH_{MLTF Frame 1}}}{k_{H_{MLTF Frame 1}}} \right) k_{H_{Frames 1}} + \sum \left( \frac{P_{uH_{MLTF Frame 1}}}{k_{H_{MLTF Frame 1}}} \right) k_{H_{Frames 2,3}} \cos^2 \theta
\]

End-On Jacket Capacity:

\[
P_{uH_{boj}} = P_{uH_{MLTF Frames 2,3}} \sin \theta + \sum \left( \frac{P_{uH_{MLTF Frames 2,3}}}{k_{H_{MLTF Frames 2,3}}} \right) k_{H_{Frames 2,3}} \sin \theta
\]
Additional Configurations

Braced Monopods (Caissons):

Capacity of unsupported section:

\[ P_{uH} = \frac{(M_u - Q\Delta)}{H_d} \]

Capacity of brace:

\[ P_{uH} = P_{uHbrace} + \frac{P_{uHbrace}}{k_{Hbrace}} k_{Hmain pile} + \frac{3M}{2H_u} \]
Additional Configurations

Guyed Monopods (Caissons):

Capacity of guy wire system:

\[ P_{uH} = P_{uH_{guy\ wire}} + \frac{P_{uH_{guy\ wire}}}{k_{H_{guy\ wire}}} k_{H_{main\ pile}} - \frac{3M}{2H_u} - F_{pretension} \cos \theta \]
ULSLEA Program Development

- Coding finished for Phase III commitments

- v3.0 runs with MS Excel 5.0 in MS Windows environment (Win95 and Office97 recommended)

- Machine requirements are 32 MB RAM and Pentium/90 processor or better
Basic Program Enhancements

- Drag/added mass coefficient scaling
- Grouting of legs
- Corner skirt piles
- Braced deck bay
Drag Coefficient Scaling: SP 62 A

BROADSIDE LOADING

BROADSIDE LOADING

\[ \text{STORM SHEAR / PLATFORM SHEAR CAPACITY (KIPS)} \]

\[ \text{PLATFORM ELEVATION (FT)} \]

\[ \text{C_d SCALING} \]

NO SCALING
Phase IV Project Goals

- Parameter studies (3 platforms)
- Development of ductility-level earthquake analysis routines
- Diagonal loading formulations and capacity formulations for elements sensitive to diagonal loads
- Adaptation of the program to allow for the analysis of 4-leg structures with one vertical face, and tripod structures with one vertical leg
- Developing and documenting updated biases and uncertainties for joints, braces, and piles
- Adapting the program interface to allow for the input of separate yield strengths for individual components of the structure (joint cans, braces)
- Improved graphical and printed output
- Foundation elements allowing for layered soils, and contributions to stiffness and capacity from mud mats, mudline braces, and conductors
- Algorithms allowing a user to calculate reliability sensitivity factors
- Spatial variation of wave forces for platforms with large dimensions
- Shallow water wave kinematics
- Vertical loads and loading capacities for deck structures
# Phase IV Project Plan

<table>
<thead>
<tr>
<th>Task/Description/G</th>
<th>SR</th>
<th>1997</th>
<th>1998</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Damage studies</td>
<td>New</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>2 - Dynamics</td>
<td>Stear</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>3 - Diagonal loads</td>
<td>Stear, Jin</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>4 - Configurations</td>
<td>Stear</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>5 - Uncertainties</td>
<td>Jin, Xu</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>6 - Joints</td>
<td>Stear</td>
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<td>------</td>
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<tr>
<td>7 - Improved output</td>
<td>Stear, Jin</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>8 - Foundations</td>
<td>Stear, Jin</td>
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<tr>
<td>9 - Reliability</td>
<td>Jin</td>
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<tr>
<td>10 - Wave spatial</td>
<td>New</td>
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<td>-x</td>
</tr>
<tr>
<td>11 - Kinematics</td>
<td>Jin</td>
<td>------</td>
<td>-x</td>
</tr>
<tr>
<td>12 - Deck elements</td>
<td>New</td>
<td>------</td>
<td>------</td>
</tr>
</tbody>
</table>

Meetings: x x x