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Operational Seakeeping Considerations in LCU Deployment

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Excellence Through Knowledge

Outline

- Background
- Objective
- Analysis Methods
- Findings
- Future Work

LCU 1610 Class
http://cs.finescale.com/fsm/general_discussion/f/50/t/152216.aspx?page=67

Background

- LCU Operational Concerns
  - Primary payload has experienced significant weight creep since the LCU was initially designed
    - LCU mission potentially impacted by payload weight
    - Maximum load at design limit for stability
  - Current stability criteria may be overly conservative for typical LCU coastal missions
    - Ferrying from ship to shore
    - Transiting parallel to shore

Objective

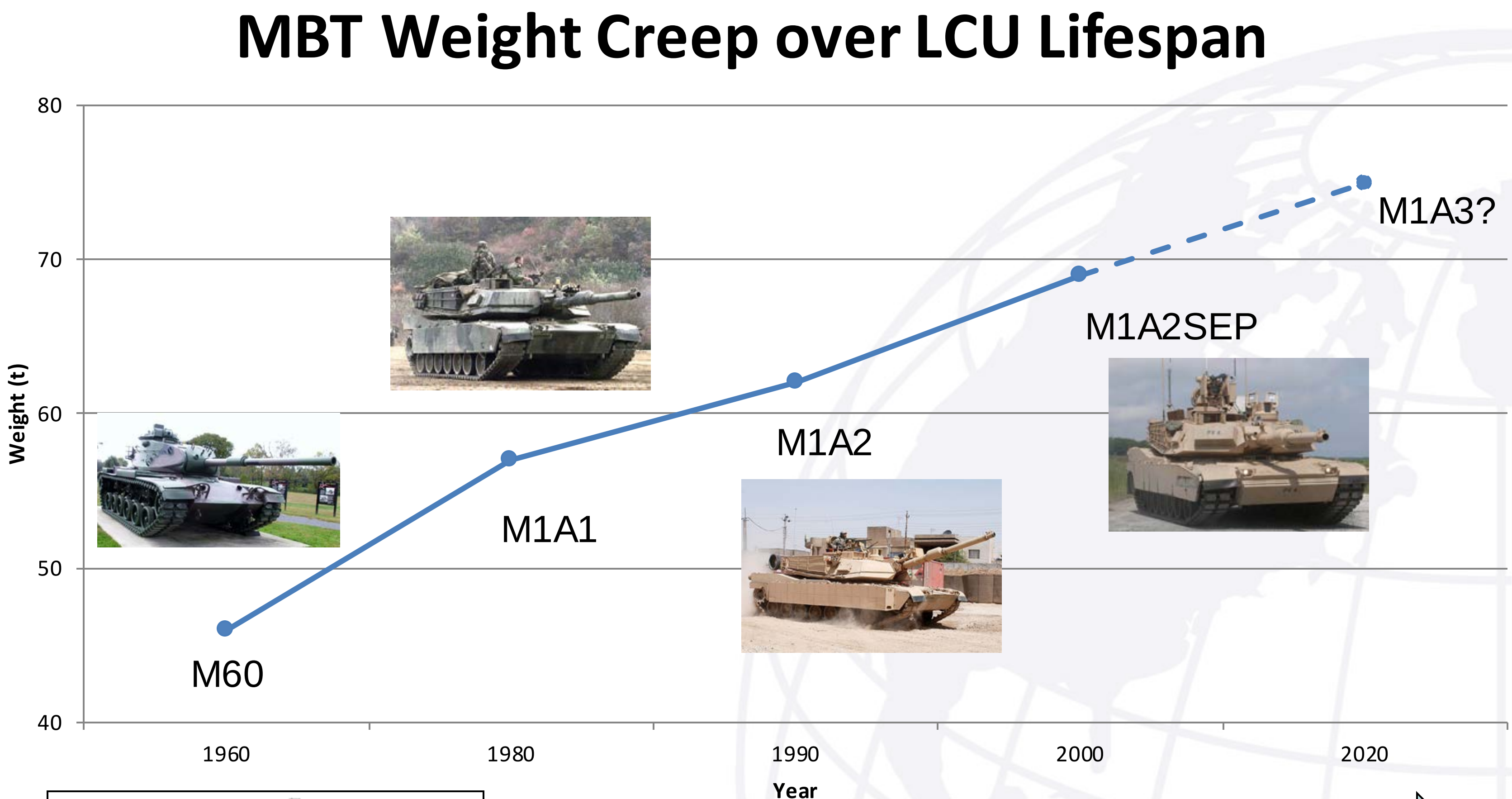
- Objective
  - Provide revised operational recommendations for LCU operating in coastal mission areas
- Approach
  - Categorize current LCU stability criteria
  - Model expected coastal seas
  - Determine static and dynamic stability ranges
  - Evaluate desired payload/cargo loading cases
  - Explore safe operating envelopes

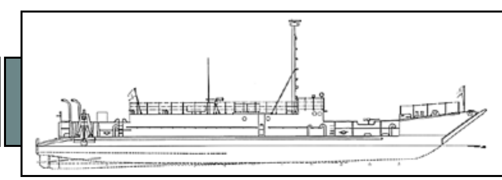
Landing Craft Utility (LCU)

- Amphibious Operations Craft
  - Launched by amphibious assault ships
  - Transports troops, military equipment and vehicles ashore
- General Characteristics (LCU1627)
  - Length (LOA): 41.1 m (134.8 ft)
  - Beam: 8.8 m (28.9 ft)
  - Depth: 2.44 m (7.8 ft)
  - Draft: 1.1 – 2.1 m (3.5-6.8 ft)
  - Displacement: 392 t (386 LT)
  - $Speed_{Max}$: 11 knots (5.66 m/sec)
  - $Range_{Max}$: 1200 nautical miles
  - $Load_{Max}$: 127 metric tones (125 LT)
  - Design/Built: 1950s/1960-70s

http://www.navsource.org/archives/10/18/181644.htm

Payload Weight

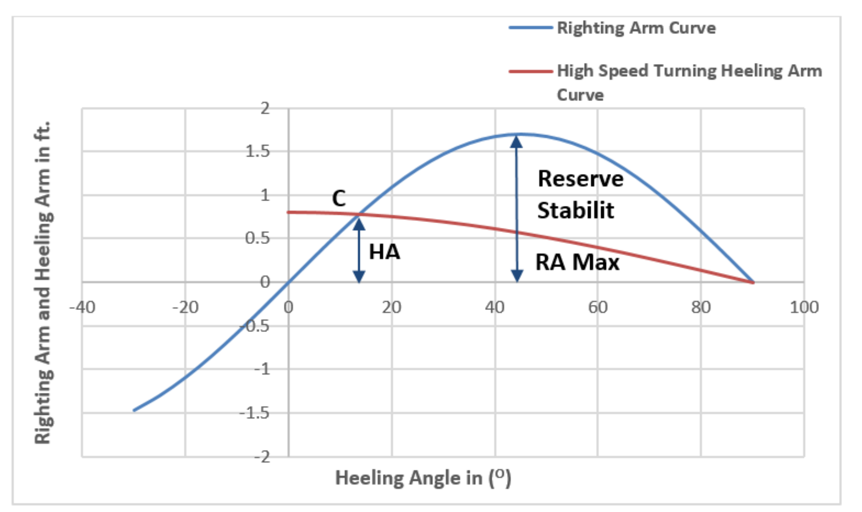




Not a failure of ship design margin

Static Stability Criteria

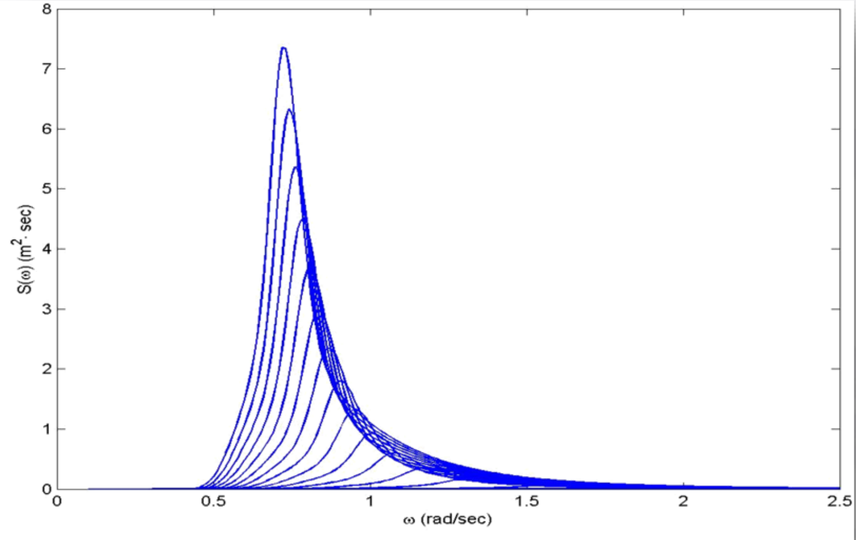
- Stability Criteria are based on GZ Curves
  - Righting arm (GZ)
  - Applied forces' heeling arms
  - Heeling angles
  - Areas under GZ curves
- General Stability Criteria
  - Wind Action and Rolling
  - Lifting Weights over the Side
  - Crowding Passengers to One Side
  - High Speed Turning
  - Topside Icing



Righting Arm and Heeling Arm
Source: G. Koelbel. "Procedures manual, dynamic stability analysis for U.S. Navy small craft," 1977.

Wave Spectra

- Commonly Used Wave Spectra
  - Pierson-Moskowitz
  - JONSWAP
  - Bretschneider
  - Ochi-Hubble



JONSWAP Wave Spectrum (V_K=1 to 30 m/s)

- LCU Stability Research
  - Focused on Bretschneider and Ochi-Hubble spectra
  - Identified as most appropriate for the typical operational environment (coastal waters)

- Wave significant Height

Average value of the 30% highest waves

$$H_{1/3} \equiv \zeta = 4(m_o)^{1/2}$$

- Modal frequency

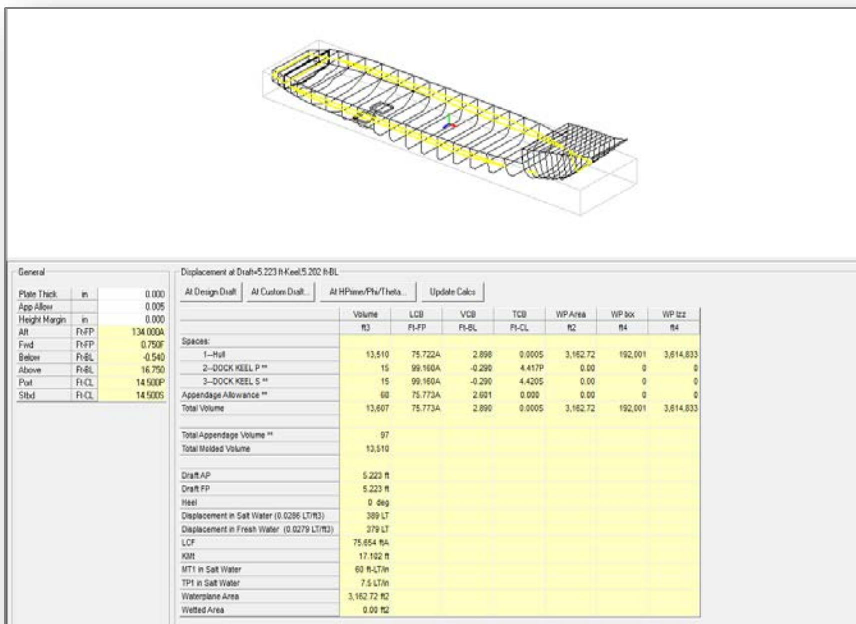
The frequency at which the spectrum reaches maximum value

$$\omega_m$$

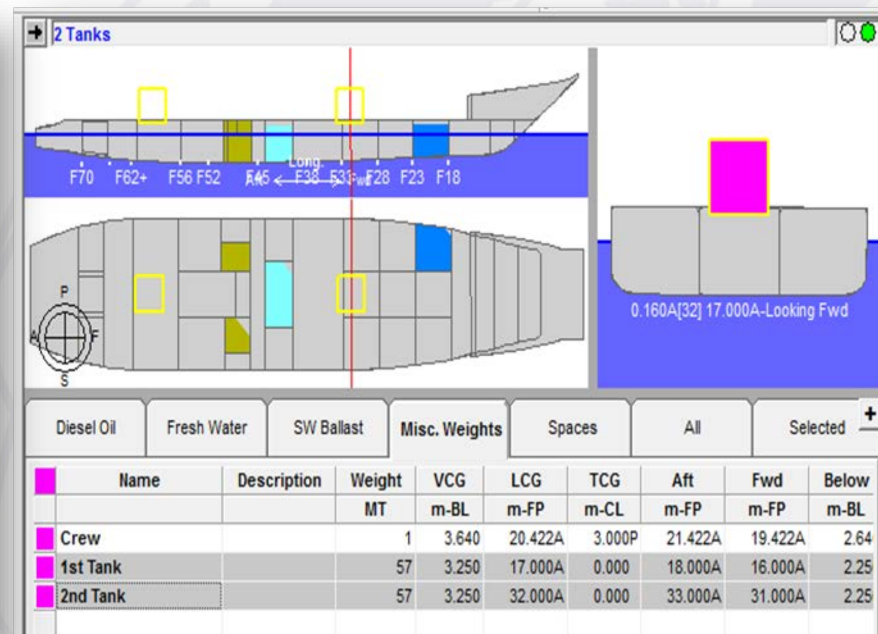
- Modal period

$$T_m = \frac{2\pi}{\omega_m}$$

- POSSE Capabilities
  - Prediction of intact stability based on selectable criteria
  - Flooding, Stranding, Dry-dock, Heavy lift & other analyses
  - Evaluation of ship’s strength, damage, corrosion properties



LCU Hull Geometry Definition



LCU Loading Entry Table

Standard Ship Motion Program (SMP)

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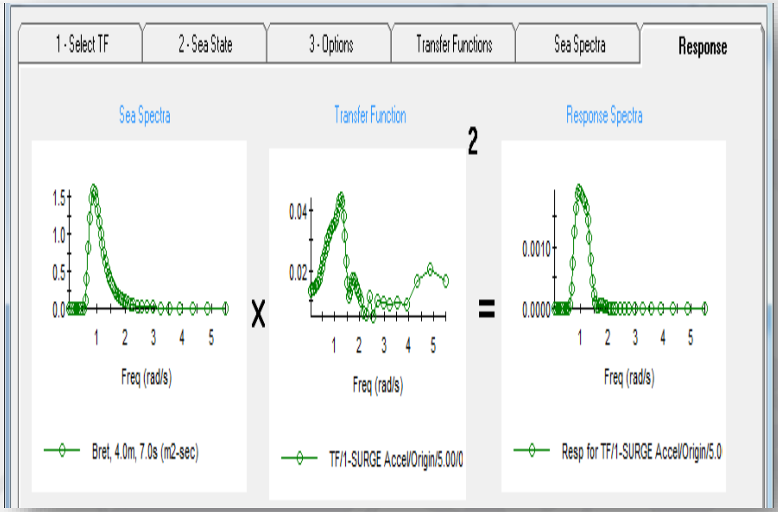
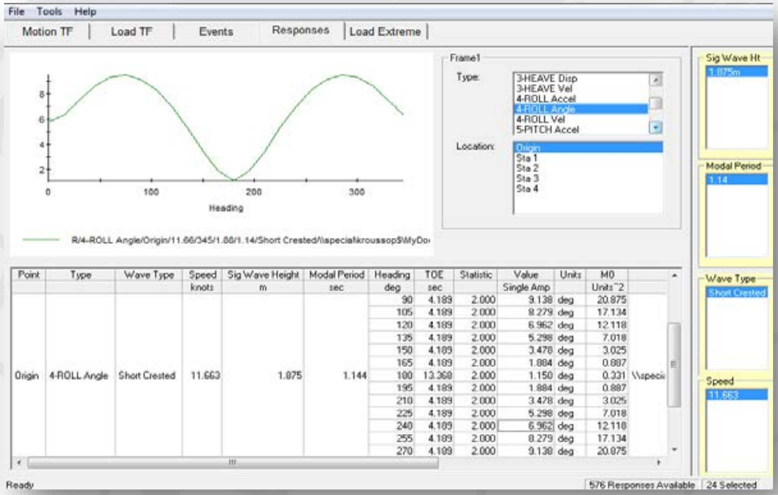
- SMP Capabilities
  - Predicts ship motions (a, v, d)
  - Computes Structural loads (bending)
  - Probability of slamming and submerging
- Basic Assumptions
  - Customary sea headings
  - Weights treated as lumped mass
- Methods
  - Utilizes various wave Spectra inputs
  - Generates transfer function
  - Derives ship response spectra
- Results
  - Outputs ship body responses in six degrees of freedom against relative sea headings



SMP Structure-Ship's Responses Calculator



SMP Results-Ship responses

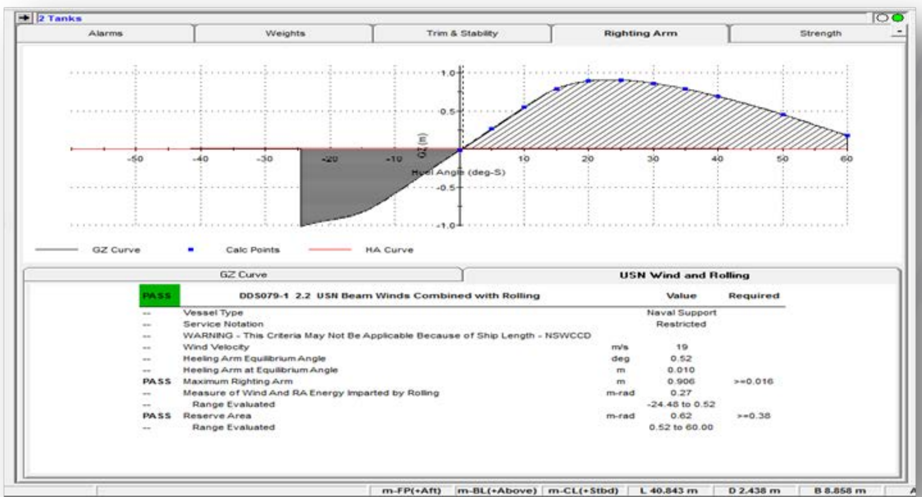
Static Stability Results

- Static Stability
  - Based on standard U.S. Navy criteria
  - Focused on wind-rolling and found GZ to be much greater than WHA
  - Both Reserve Area and Max Wind Heel Angle requirements are satisfied for all loading cases and sea states
  - Adequate in all loading cases

Sea State	2	4	6
Wind Velocity (m/s)	4.37 (8.49 Knots)	9.77 (18.99 Knots)	19.29 (37.49 Knots)

Wind Velocity for Sea States 2, 4, and 6

K. McCreight, "A Note on Selection of Wave Spectra for Design Evaluation," 1998.



<u>Sea State 6</u>

- Loading Case: **Full Payload**
- Criterion: **"Passed"**
- Heeling angle: **0.52 deg.**
- Max righting arm**: 0.096m**

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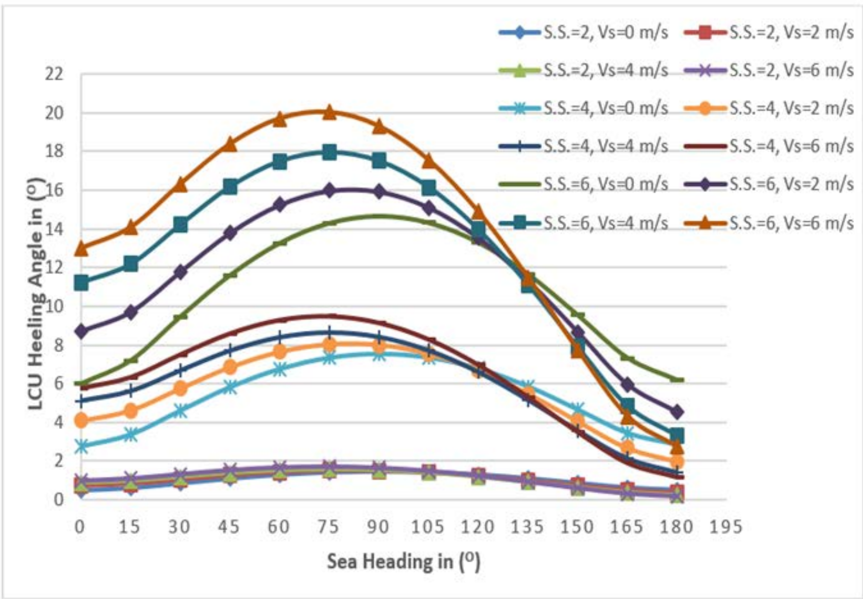
Dynamic Stability Results

- Dynamic Stability
  - Based on ship responses to random wave exciting forces
  - Ship responses are derived by SMP simulations
  - Ship rolling angles plotted against relative sea heading



Heeling Angle vs Sea Heading in Ochi-Hubble Short-Crested Waves for LCU Carrying Two M1A1 Tanks

Loading Condition	Sea State	Ship Speed (m/s)	Wave Type	Wave Spectrum	Bretschneider Spectrum Modal Period Tm (sec)
Lightship	2	0	Short-Crested	Ochi-Hubble	7
Lightship with Half Cargo Deadweight	4	2		Bretschneider	11
		4			
Lightship with Full Cargo Deadweight	6	6			15

LCU Dynamic Stability Parameter Values

Sea State	2	4	6
Wind Velocity (m/s)	4.37 (8.49 Knots)	9.77 (18.99 Knots)	19.29 (37.49 Knots)
Significant Wave Height ($H_{1/3}$) (m)	0.3	1.875	5

Wind Velocity and Significant Wave Height for Sea States 2, 4, and 6

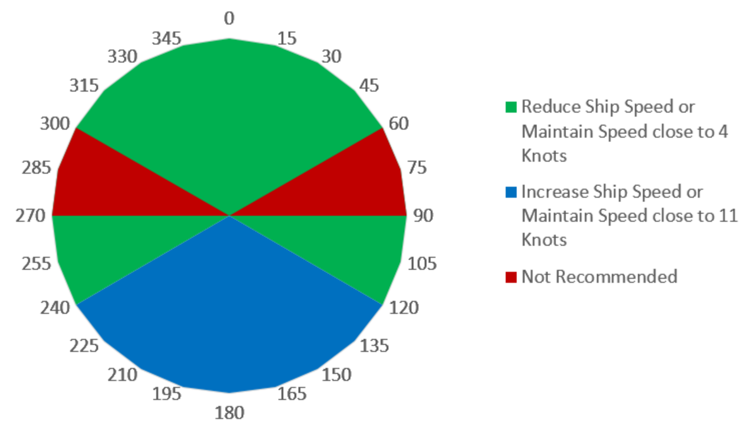
K. McCreight, "A Note on Selection of Wave Spectra for Design Evaluation,"

Operational Recommendations

- Findings
  - Increasing displacement results in greater heeling angle for all headings
  - Greater displacement and/or high sea state amplify the speed effects
- Recommendations
  - Sea State 2
    - All loading conditions and speeds
    - Use experience to transit in a seakindly manner
  - Sea States 4 and 6
    - Prefer following seas rather than head seas
      - Reduces heeling angles
    - Avoid sea headings within +30° (fwd) of beam
      - LCU undergoes higher heeling angles
    - Adjust speed as recommended by operational envelopes

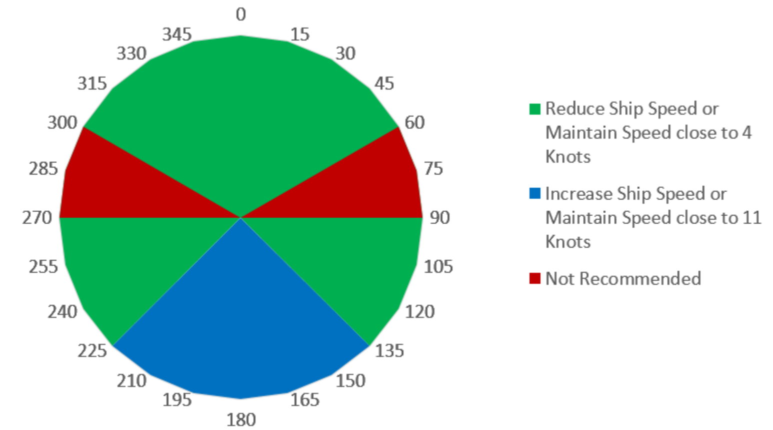
Operational Recommendations for the LCU

Lightship and One M1A1 Tank



Sea Headings Based Operational Polar Diagram for LCU Lightship and Carrying One M1A1 Tank in Sea States 4 and 6

Two M1A1 Tanks



Sea Headings Based Operational Polar Diagram for LCU Carrying Two M1A1 Tanks in Sea States 4 and 6

Future Work

- Investigation of hull appendages effects on stability
- Examination of damaged craft stability
- In situ testing using current LCU and progressive loading cases to validate simulation results
- Refine operational guidance as a function of:
  - Chosen loading condition
  - Given sea state (wind speed and wave height)
  - Observed wave heading
  - Desired transit heading

FILE US NAVY 060604-N-8547M-011 LANDING CRAFT UTILITY LCU 1658

- Questions