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Operational Seakeeping Considerations in LCU Deployment

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Operational Seakeeping Considerations in LCU Deployment

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Excellence Through Knowledge

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



LCU 1610 Class

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



- 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



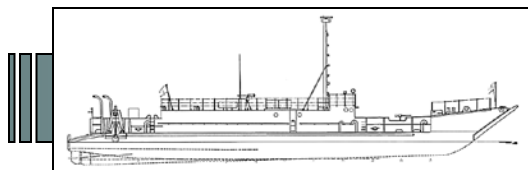
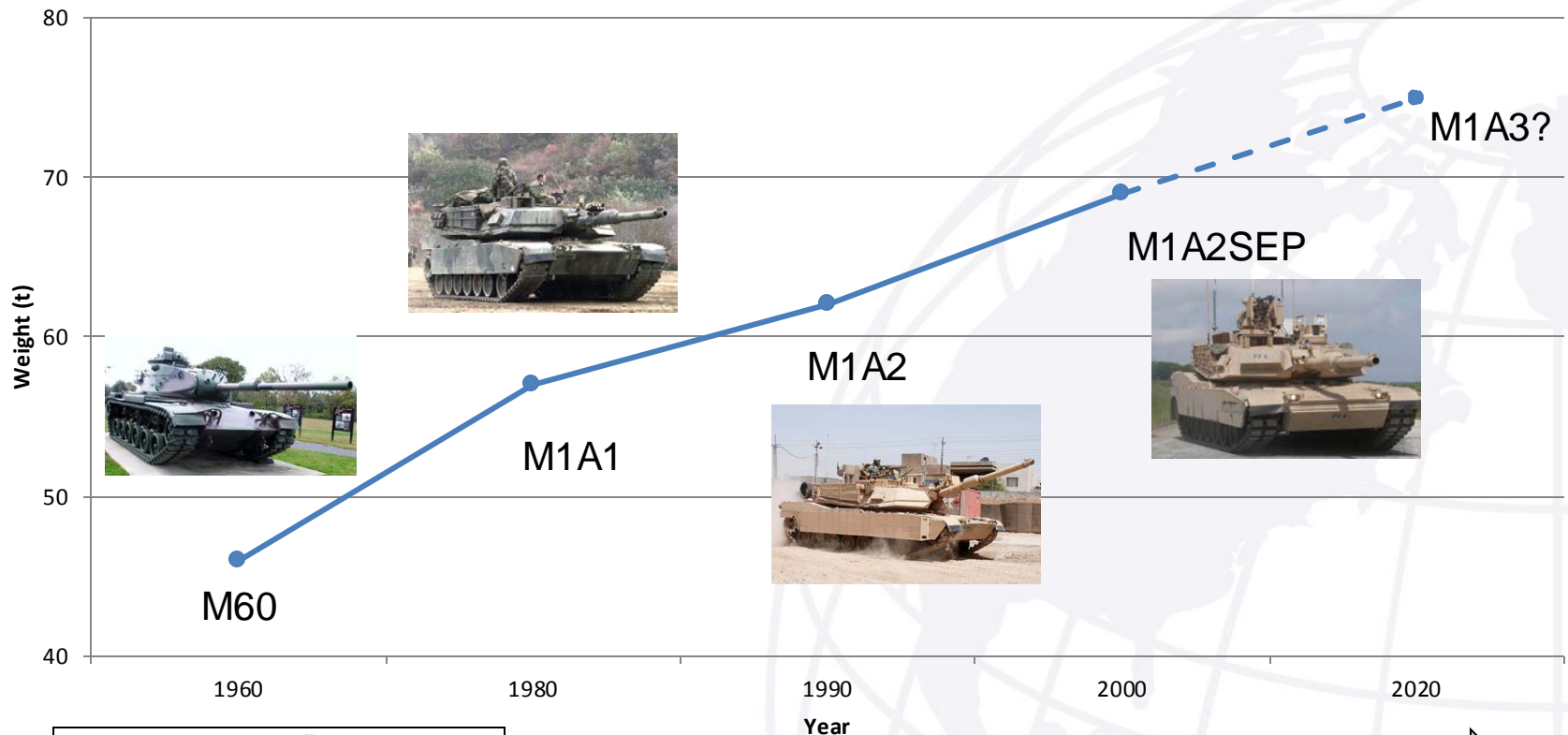
- Objective
 - Provide revised operational recommendations for LCU operating in coastal mission areas
- Approach
 - Categorize current LCU stability criteria
 - Model expected coastal seas
 - Determine static and dynamic stability ranges
 - Evaluate desired payload/cargo loading cases
 - Explore safe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



- 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

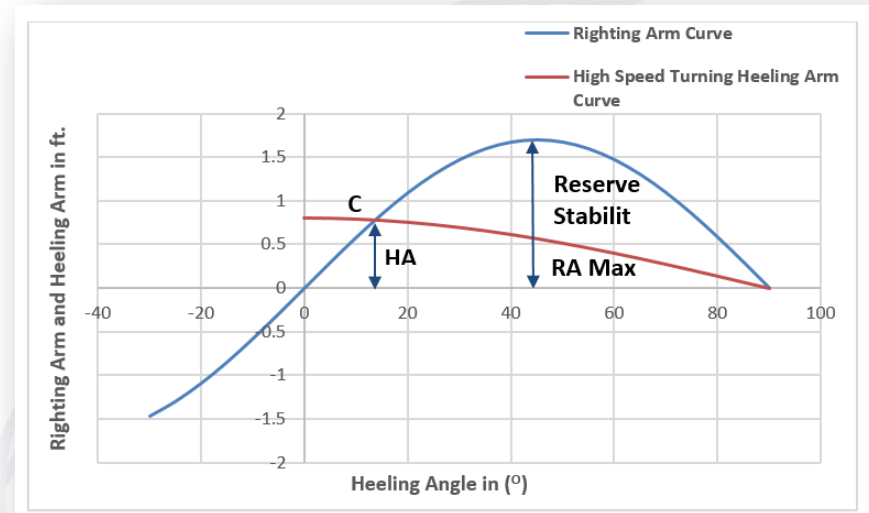


MBT Weight Creep over LCU Lifespan



Not a failure of ship design margin

- 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

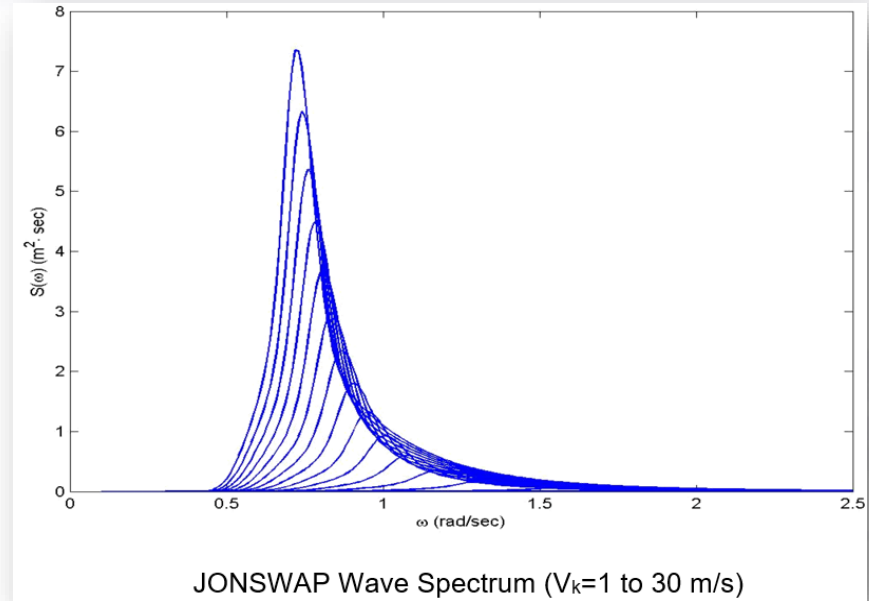


Righting Arm and Heeling Arm

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

- Commonly Used Wave Spectra

- Pierson-Moskowitz
- JONSWAP
- Bretschneider
- Ochi-Hubble



- 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

$$\omega_m$$

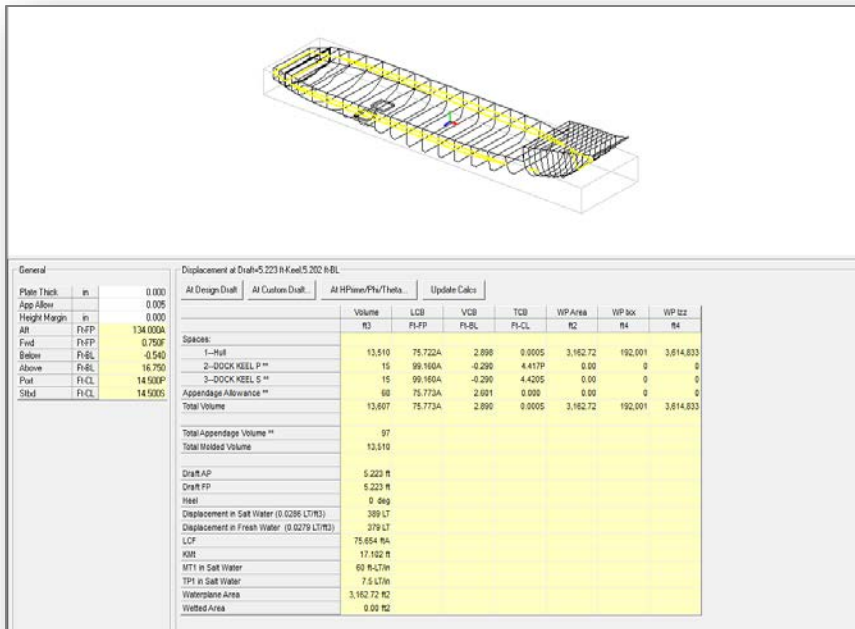
- Modal period

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

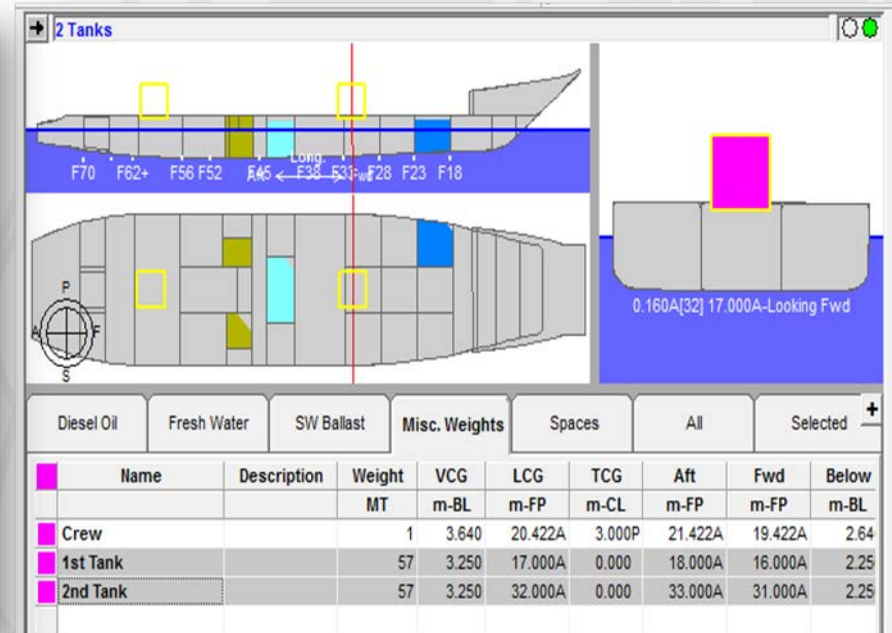


• POSSE Capabilities

- 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

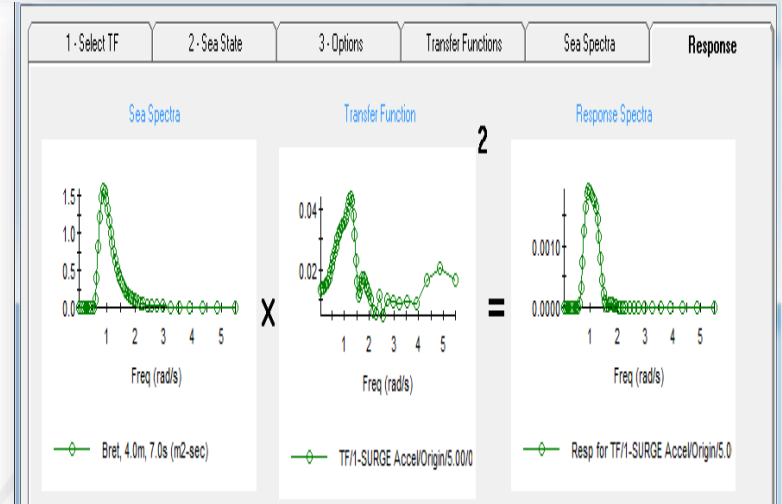


LCU Loading Entry Table

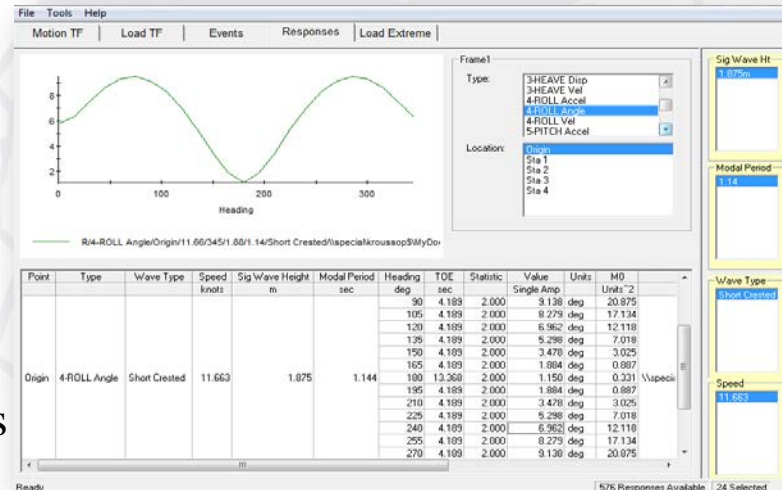


Standard Ship Motion Program (SMP)

- **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



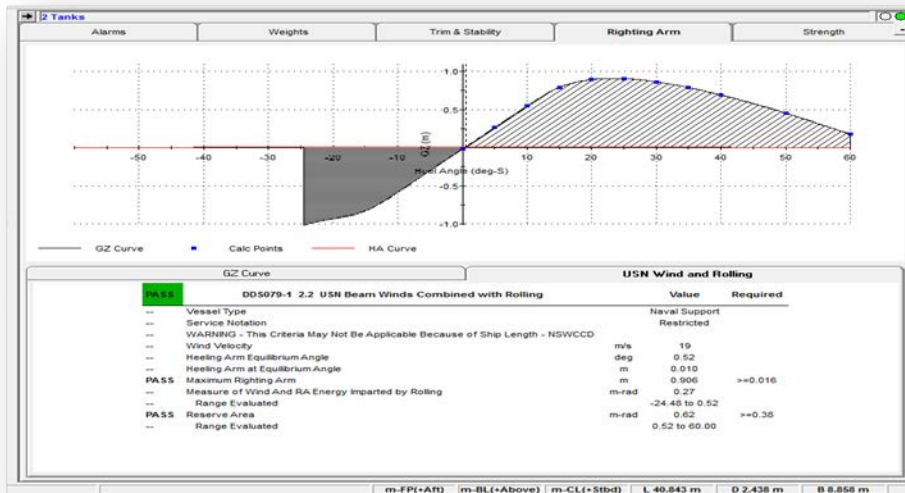
SMP Structure-Ship's Responses Calculator



SMP Results-Ship responses 10

- **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	9.77	19.29
	(8.49 Knots)	(18.99 Knots)	(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.

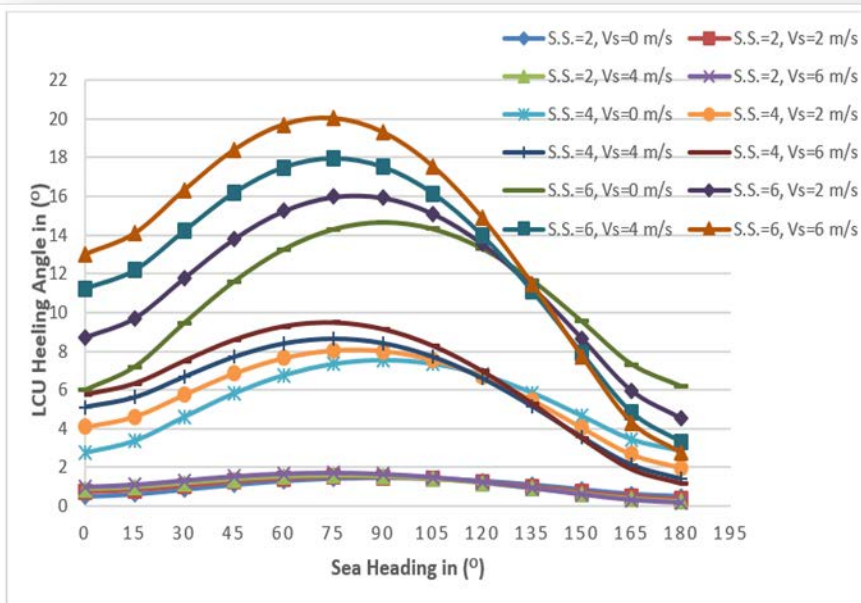
Sea State 6

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

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
Lightship with Full Cargo Deadweight	6	6		Bretschneider	15

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

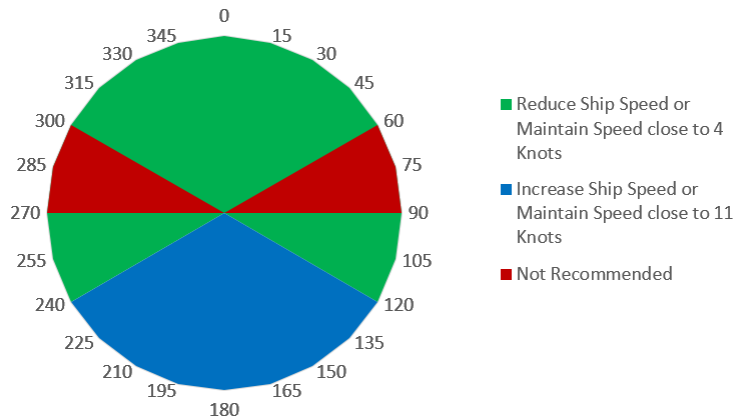
Wind Velocity and Significant Wave Height for Sea States 2, 4, and 6



- 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 $+30^\circ$ (fwd) of beam
 - LCU undergoes higher heeling angles
 - Adjust speed as recommended by operational envelopes

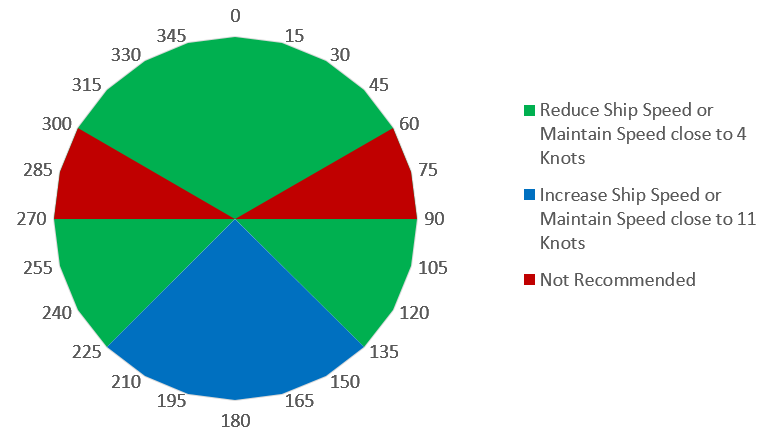


Lightship and One M1A1 Tank



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



- 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

