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# Energy Efficient Operations of Warships

Perspective of the Indian Navy

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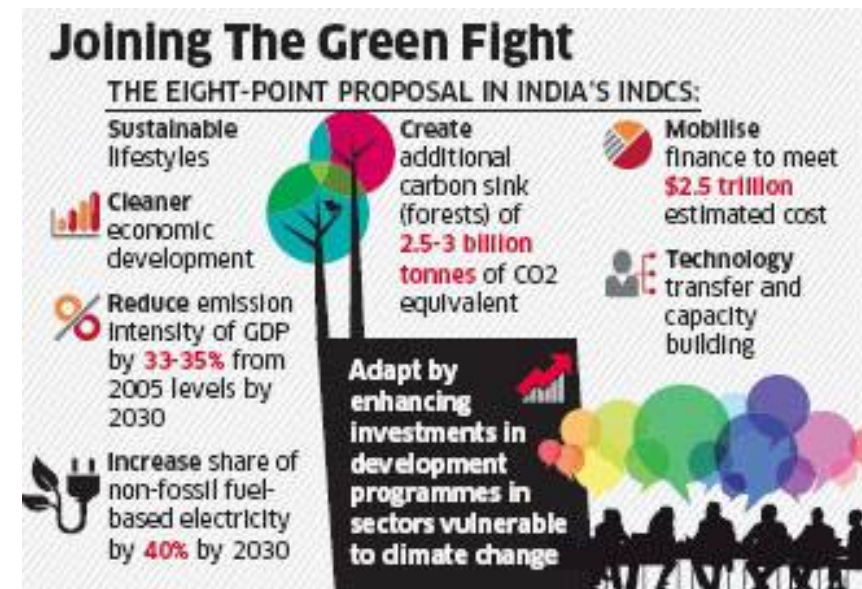
# Content

- ▶ Introduction
- ▶ Drivers for Change
- ▶ IN's Green Initiatives Programme
- ▶ Current Practices
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- ▶ Conclusion



# Introduction

- ▶ Current global scenario
  - Climate change concerns
  - Environment sustainability
- ▶ India's climate change goals
  - Intended Nationally Determined Contribution
    - Core Principle: Sustainable Development
- ▶ Implementation requires all-inclusive efforts





# Introduction

- ▶ Indian Navy : Aligned to the national mission
  - Global maritime force
    - Blue water capabilities
    - 200 ship Fleet by 2027
  - Green Initiatives Program (2014)
    - Energy and resource efficient
    - Environmentally responsible
  - IN Environment Conservation Roadmap
    - Reduce
    - Diversify
    - Clean technologies

**Green Footprint to blue water capabilities**

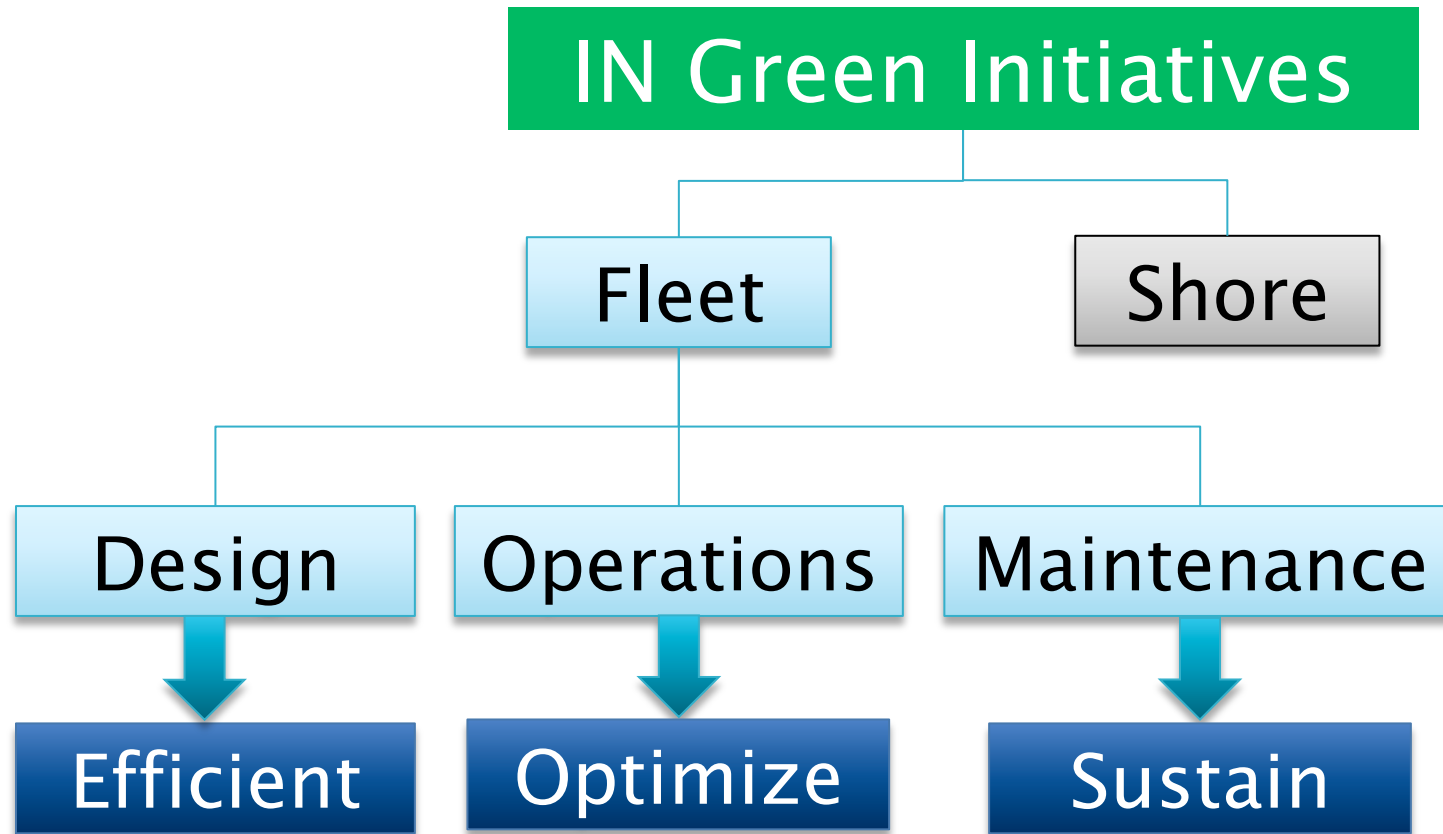


# Drivers for Change

- ▶ Drivers
  - Global climate change concerns
  - Alignment with national policy
  - Reduce running costs
  - Enhanced operational reach
  
- ▶ Emerging challenges
  - High CAPEX – Planned acquisitions/ship building program
  - Availability of mature technology
  - Cultural issues – traditional warship practices
  
- ▶ Implementation
  - Acquisition
  - Fleet procedures
  - Behavioral changes



# IN 'Go Green' Objectives



# Overall IN 'Go Green' Philosophy

## IN Green Initiatives

Fleet

Shore

Cultural Shift

Design

Operations

Maintenance

Acquisition

Retrofit

Doctrine

Fleet Plans

Fleet Operations

Condition Monitoring

Corrective Maintenance



# O&M: Current Practices

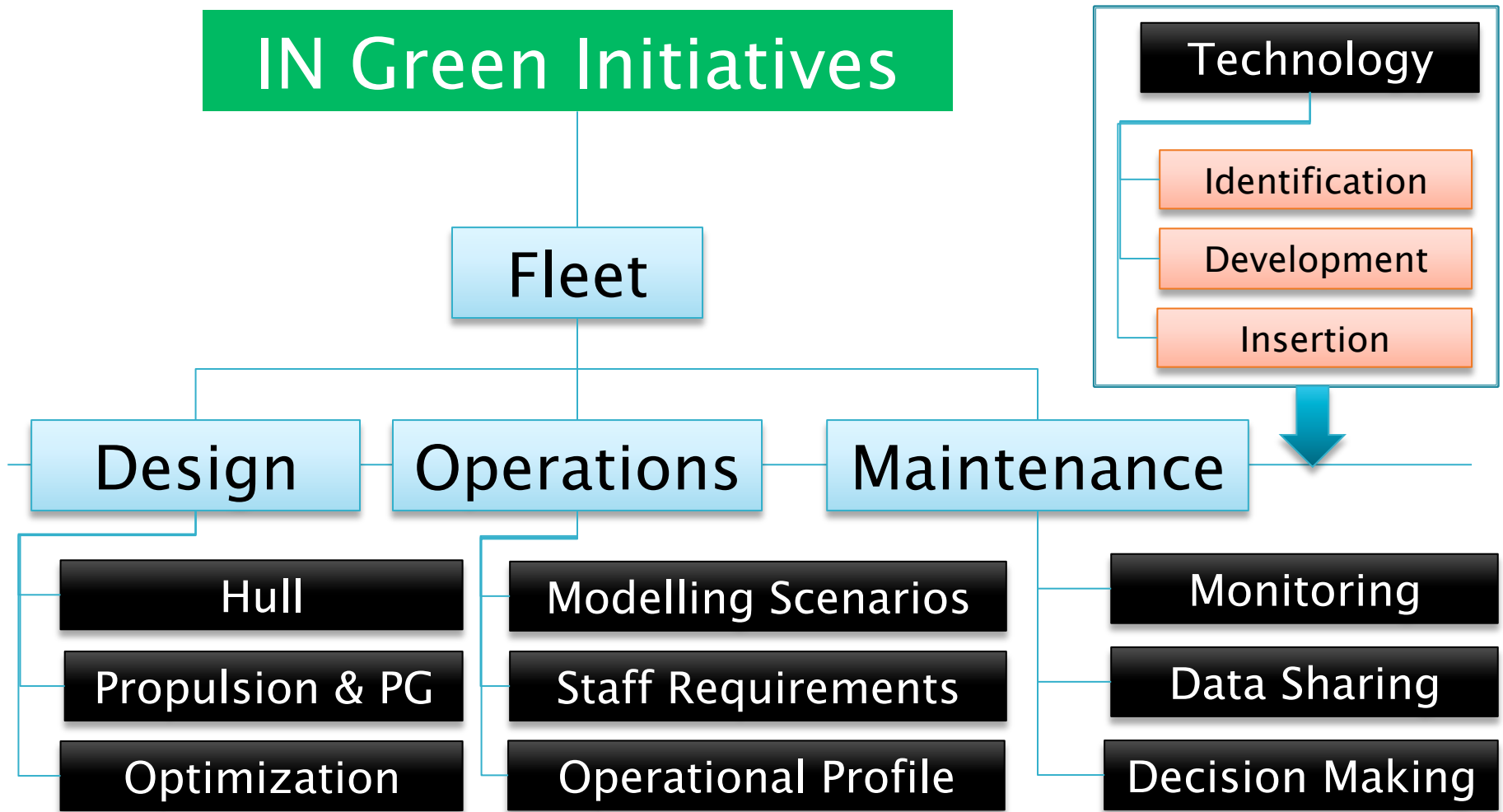
- ▶ Operations Monitoring
  - EEF–running hours based (indirect approach)
- ▶ Condition Monitoring
  - Fuel consumption trials – comparison to CST figures
  - Engine health monitoring
- ▶ Monitoring Mechanism
  - Maintenance of Logs: manual logs, returns, post analysis by INSMA
    - Advantages
      - Simplicity – low crew training
      - Low cost
    - Limitations
      - No hull health monitoring
      - Data collation and analysis: manual





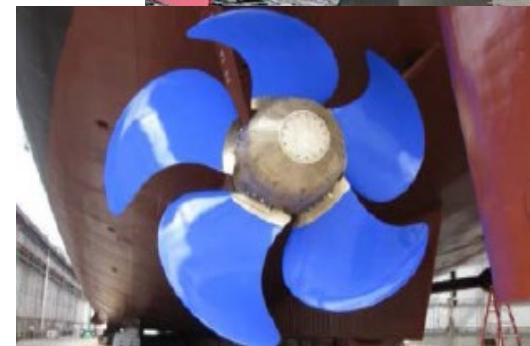
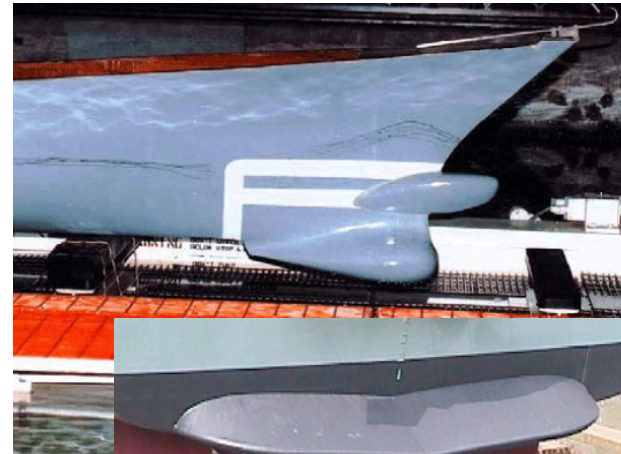
# IN 'Go Green' Enablers

## IN Green Initiatives



# Ship, Hull and Propulsor Design

- ▶ Increase hull efficiency
  - Bow, Stern End Bulb
  - Stern flap
  - Propeller Boss Cap Fins
  - Against bio-fouling
    - Hull paint schemes
    - Propeller coatings
- ▶ Trim Optimization
- ▶ Fleet & Ship Operations Management
  - Voyage Planning
  - Weather Routing
- ▶ Technology insertion applicability for retrofit
  - Applicable



Images courtesy of NAVSEA, USA



# Propulsion and PG Design

- ▶ Enhance Overall Plant Efficiency
  - Over complete range of Operating Profile
  - Target
    - Engine Efficiency
    - Plant Efficiency
      - Recuperation
      - Integrated plants
        - All Electric
        - Hybrid

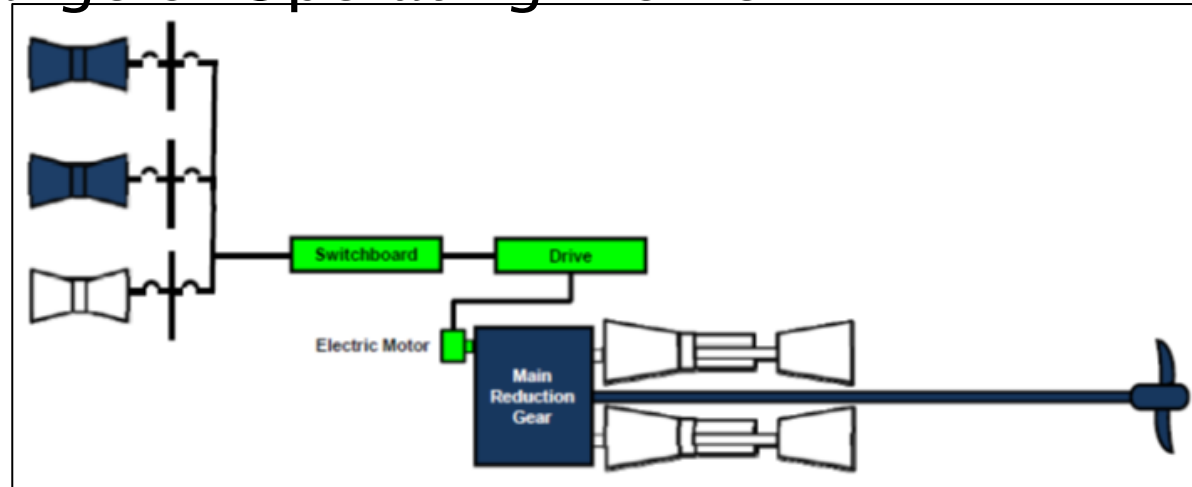


Image courtesy of NAVSEA, USA

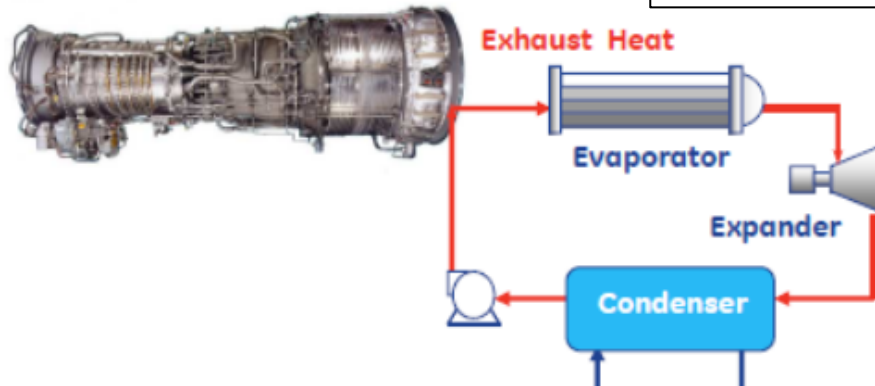
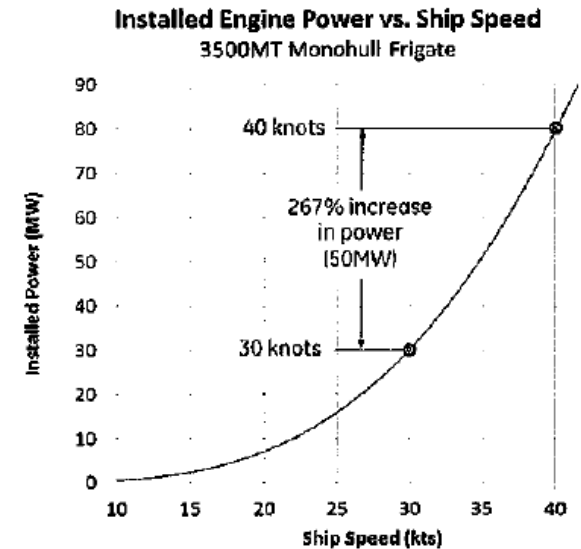
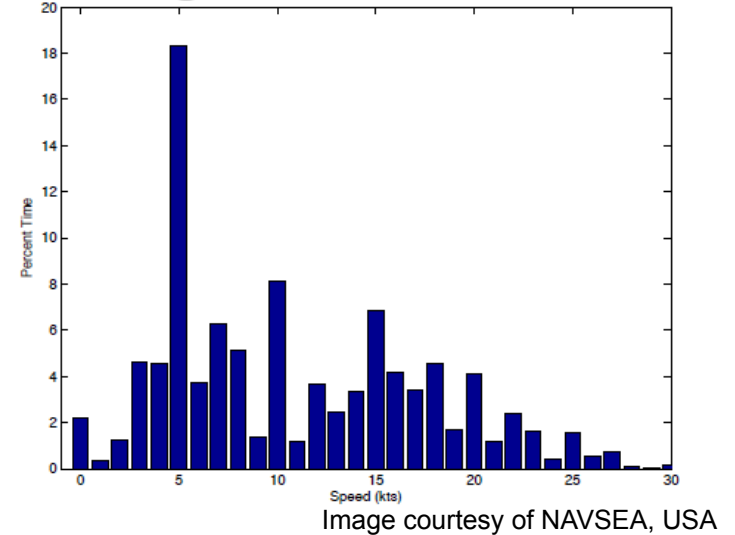


Image courtesy of GE Aviation

- ▶ Technology insertion applicability for retrofit
  - Applicable for Hybrid Plant in limited cases

# Design Requirements & Optimization

- ▶ Design stage optimization
  - Ship efficiency: inherent design objective
    - High endurance
    - Low running cost
- ▶ Choice of propulsion and electric power plants
  - Conventional, Hybrid or All Electric
  - Optimized Staff Requirements
    - Conditioned for modern role
    - Consider top speed requirement carefully
    - Realistic operational profile
  - Through Life Cost: Acquisition vs Running Cost



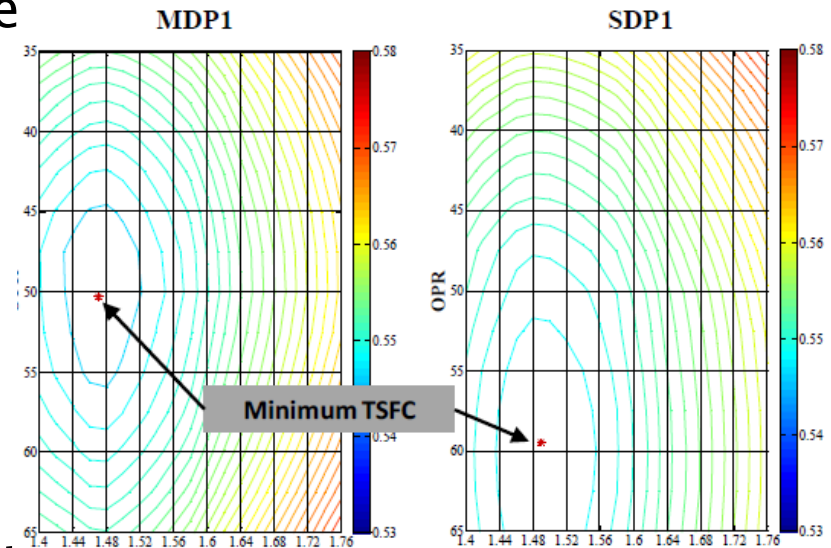
# Design Optimization

## ▶ Multipoint Design Point vs Single Design Point Optimization

- Design variables: independent cycle parameters
- Multiple combinations of design variables gives: CDS
  - Comprises of numerous candidate cycles
- Constraints
  - Technology limits
  - Performance limits

## ▶ MDP allows many design points to be included in the analysis

- Ensures that all performance requirements met at all design points





# Monitoring Operations

- ▶ Energy Efficient Operations
  - Baselining of Energy Requirements
    - Capture data–class of ship wise
    - Analyze and establish ‘Baseline Levels’
      - Existing ships
      - Future acquisitions
  - Monitor Energy Consumption
    - Intelligent dashboard: Real time monitoring and management tool
      - Ship Level
      - Fleet Level



# Monitoring Indices

Energy Efficiency Design Index

$$\text{EEDI} = \frac{\text{FOC} \times C}{\text{Capacity} \times V_s}$$

(g/ton-mile)

Energy Efficiency Operational Indicator

$$\text{EEOI} = \frac{\text{Fuel (ave.)} \times C}{\text{Cargo} \times \text{Distance}}$$

(g/ton-mile)

Combatant  
Type, Class

Operation  
Theatre

Operational  
Mode

# Conclusion

- ▶ IN developing a strong 'Green Program' for its fleets
- ▶ Many indirect benefits of the program
  - Lower running costs
  - Higher endurance
  - Better engine and plant health
- ▶ Synergy: need of the hour
  - IN: Open to partnerships in developing
    - Design optimization tools
    - Ship and Fleet Energy Dashboards
    - Trim optimization tool
    - Hull fouling measurement system



# Questions



# Thank You

