



BETTER SHIPS, BLUE OCEANS



**FReady** —

Fleet ready

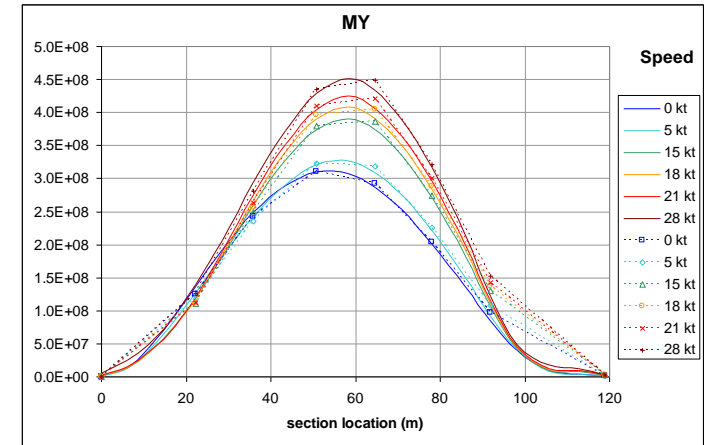
- Valid JIPs achievements
- FReady JIP goals
- FReady JIP scope of work
- FReady JIP benefits
- Schedule and participation fee

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- The Valid JIP has delivered
  - Improved tools for ship design thanks to
    - Advanced model tests
    - Validation of numerical tools
    - Understanding of the uncertainties associated with ship design
  - More rational in structural maintenance decisions thanks to
    - Installation of elaborate hull structure monitoring system
    - Monitoring and subsequent data analysis



- The Valid 2 JIP has delivered
  - Approaches applicable to service life maintenance and sustainment efforts thanks to
    - An optimized cost effective physical hull structure monitoring system design
    - Development and implementation of new ship as a wave buoy approach
    - Continued monitoring and evaluate on of measured data in reliability frame work
  - First steps toward virtual HSM system thanks to
    - Investigation of usefulness of satellite wave data bases



- The Valid 3 JIP has delivered and will deliver
  - Physical approaches applicable to service life maintenance and sustainment efforts thanks to
    - Continued data analysis and condensing this to essentials
    - Improved the ship as a wave buoy approach
    - Risk assessment of ship under different maintenance and operating scenarios
  - Virtual approach for service life maintenance and sustainment efforts thanks to
    - Investigation of accuracy of hindcast wave data in the light of VHSM
    - Investigation into the accuracy of VHSM itself

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## Main goal

- Fleet deployment optimization and structural integrity management through an efficient, low cost combination of virtual and physical monitoring\*

## Supporting goals

- Continued hull structural data analysis for quantifying uncertainties in ship design and operation
- Maturing of the low cost, low intrusive virtual monitoring approach
- Improvement of the strength and resistance side of the equation for sharper designs and maintenance decisions

\* The developed approach will be applied to the National Security Cutters but can be applied to any fleet of sister ships



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OPTIMIZED MAINTENANCE AND DESIGN

F-VHSM

FATIGUE  
RESISTANCE

HSM

WAVES

FORECAST

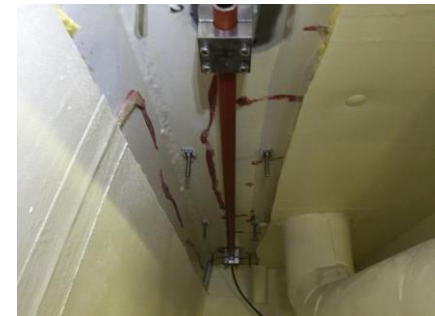


# Hull structure monitoring (HSM)

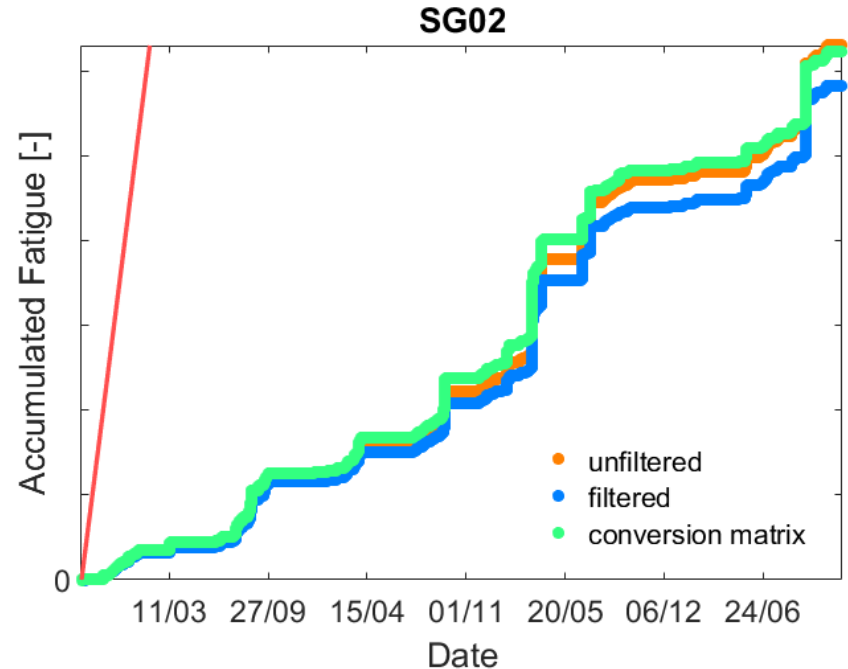
- Continued hull structure monitoring of USCGC BERTHOLF and STRATTON and subsequent data analysis for increased knowledge and quantifying uncertainties in ship design and operation



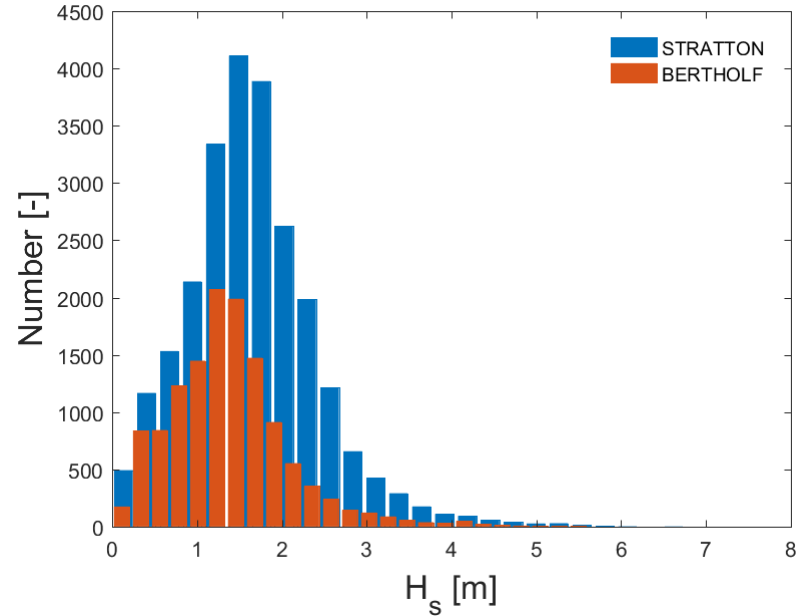
- Continued monitoring of USCGC BERTHOLF and STRATTON
  - Measurements of
    - motions
    - vertical bending moments
    - local strains
  - Derivation of critical stresses from global measurements
  - Estimation of wave conditions
    - SAWB and hindcast
  - Determination of fatigue life
  - Assessment of extreme loads



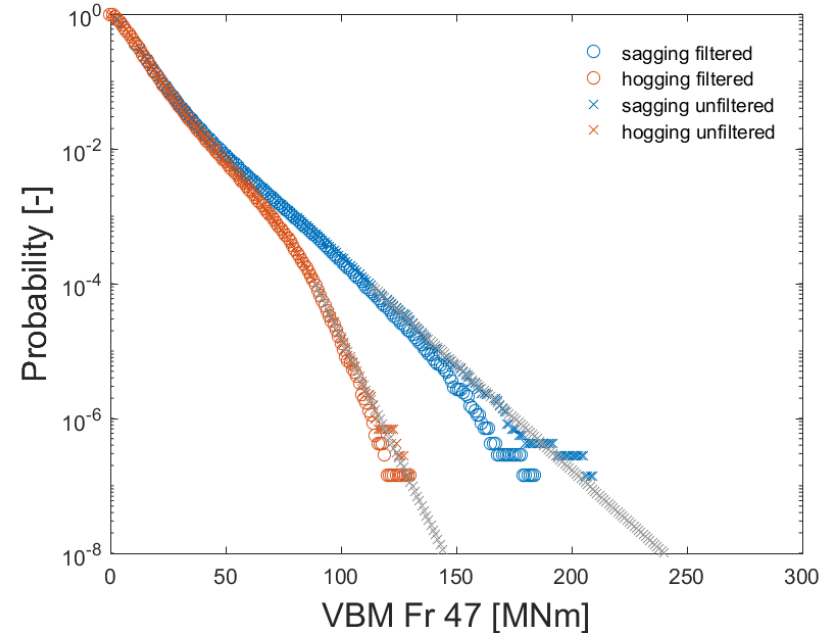
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OPTIMIZED MAINTENANCE AND DESIGN

F-VHSM

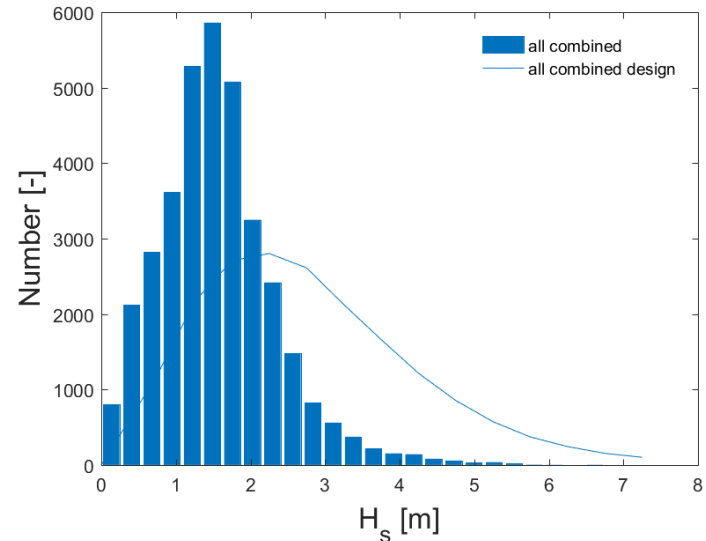
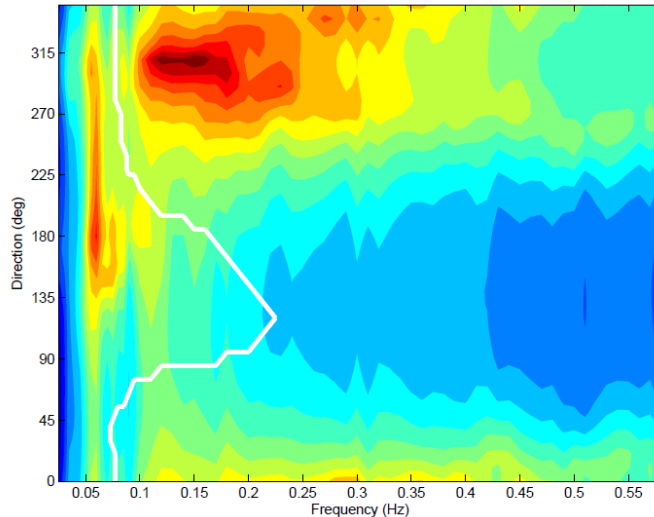
STRENGTH  
AND  
RESISTANCE

HSM

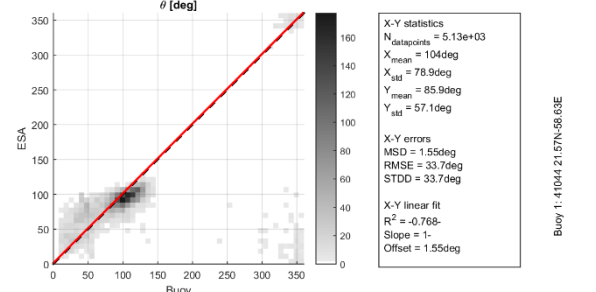
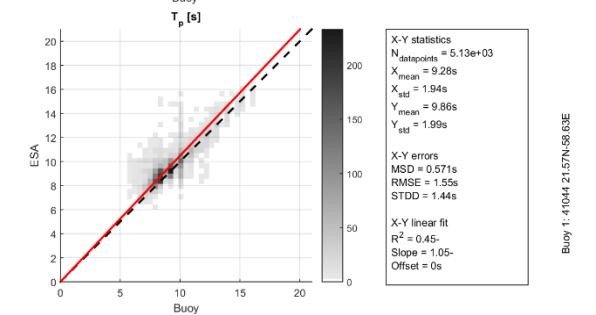
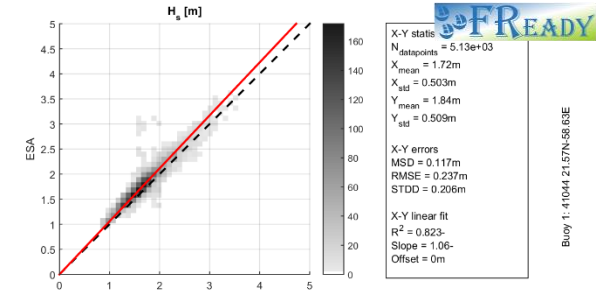
WAVES

FORECAST

- Improve the accuracy of the sea state inference in absence of direct measurements
  - Wave hindcast data
  - Ship as a wave buoy (SAWB) approaches

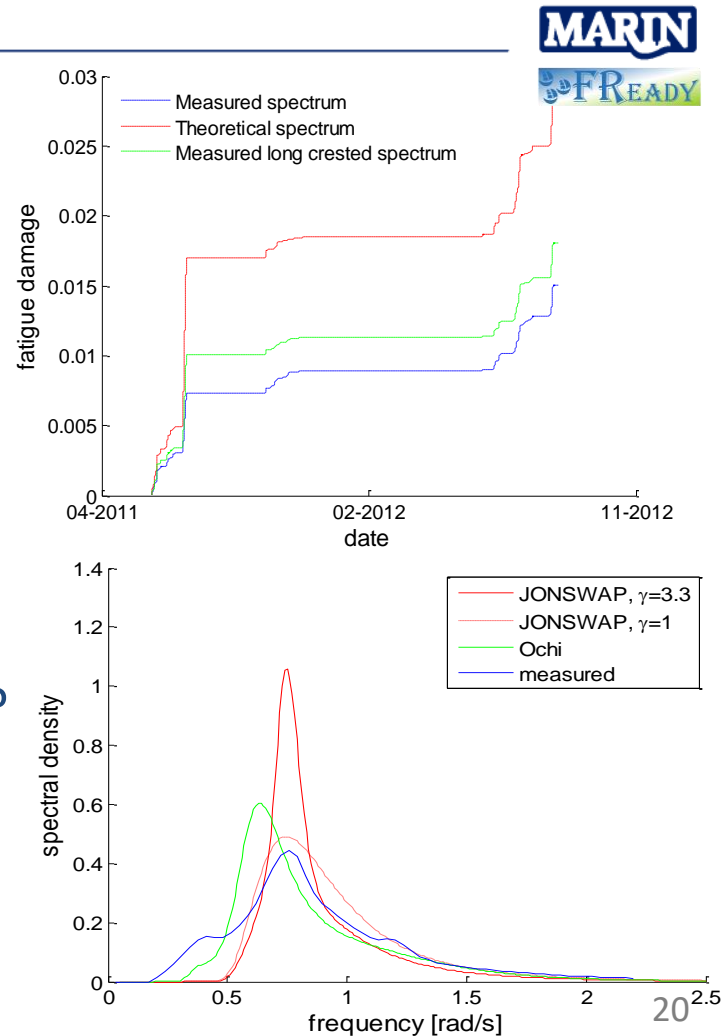


- Accuracy of wave hindcast data
  - For determining fatigue and extreme loads effects
  - Which accuracy is needed for both?
  - What is the accuracy of
    - Copernicus?
    - WaveWatch3?
    - ERA5?
  - How does the accuracy depend on location?
  - Work done already, but no complete overview yet for fatigue and extreme load effects



# Wave inference

- Improvements SAWB
  - SAWB for a fleet
  - 2D spectra
  - Direct assessment of structural response from motions
  - Combined SAWB and hindcast
- Theoretical spectra
  - Are existing spectral formulations sufficient?





OPTIMIZED MAINTENANCE AND DESIGN

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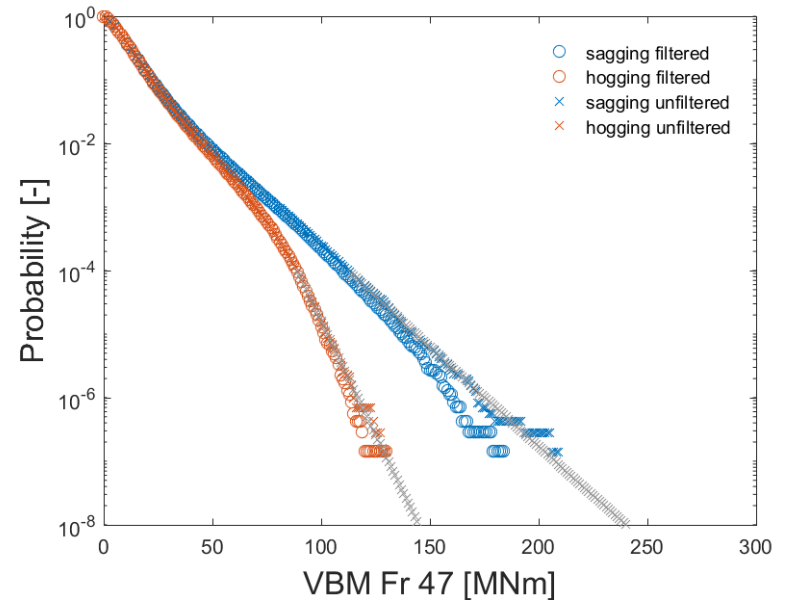
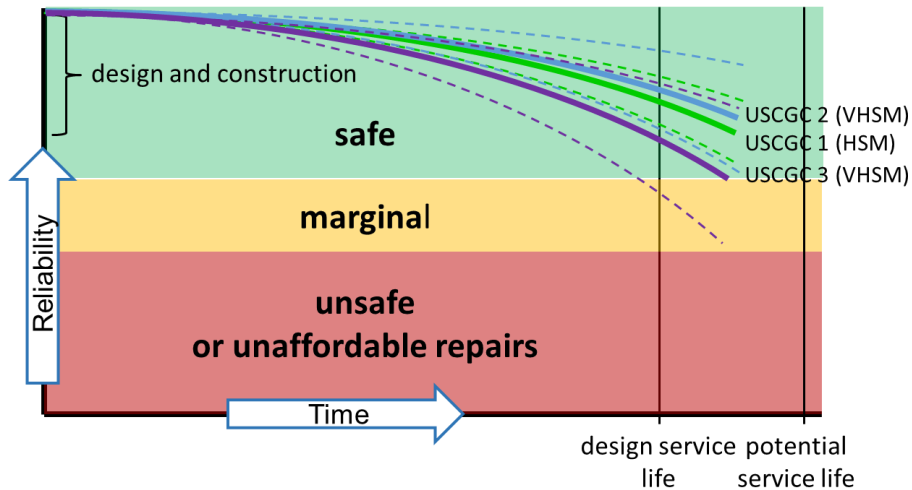
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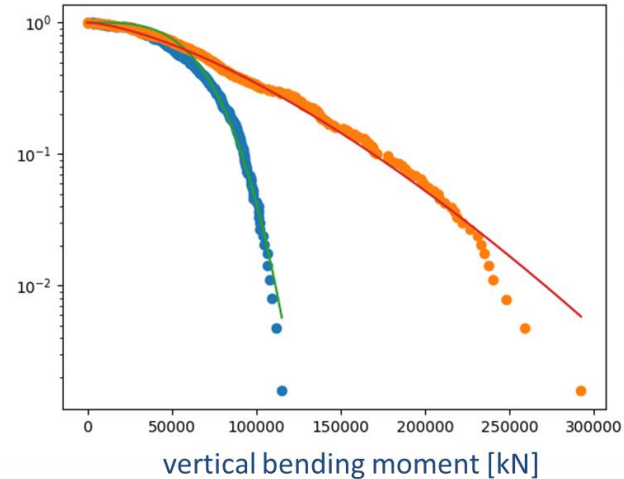
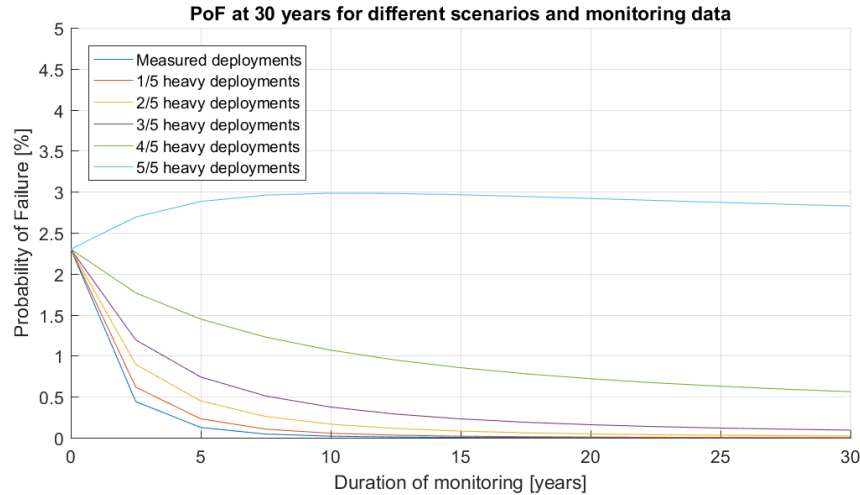
WAVES

**FORECAST**

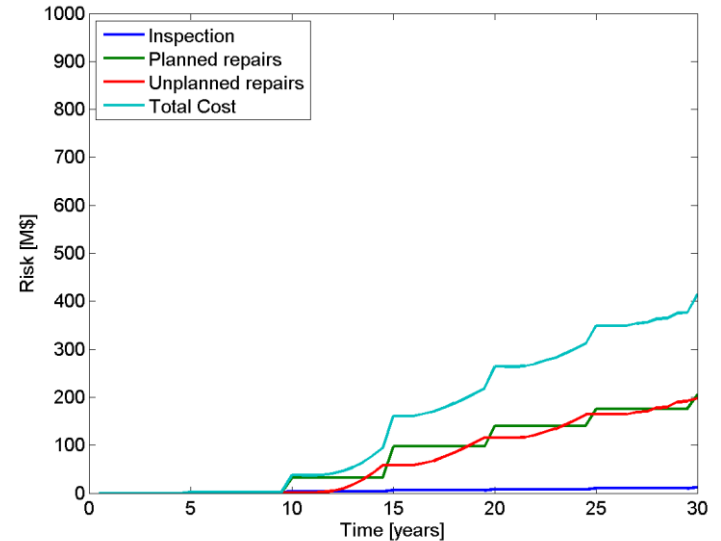
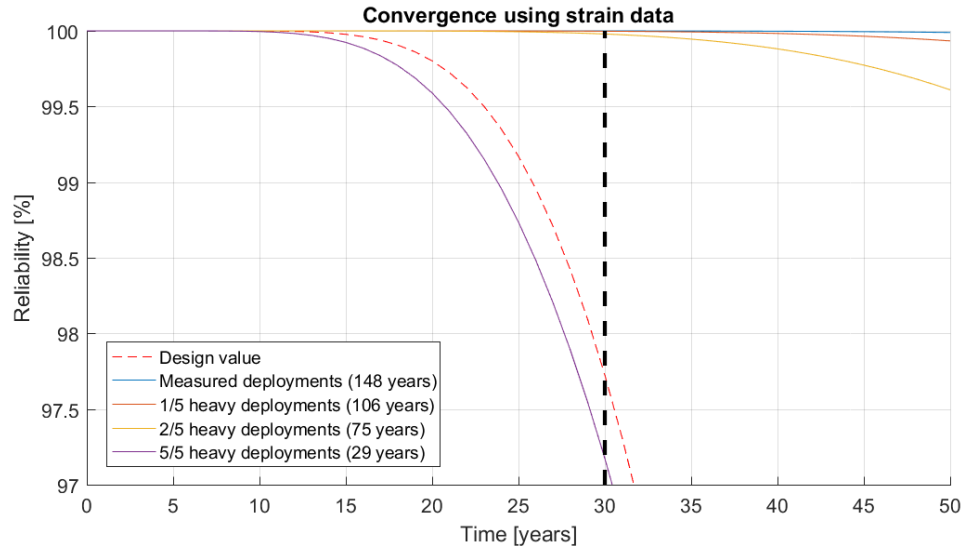
- Develop forecasting techniques able to support fleet deployment optimization and structural integrity management



- Forecasting fatigue and extremes
- How long and what should we monitor?



- Fleet level reliability
  - Mixed HSM and VHSM monitoring of fleet
  - Update reliability following deployments
  - Assess reliability after maintenance and lifetime extension







OPTIMIZED MAINTENANCE AND DESIGN

F-VHSM

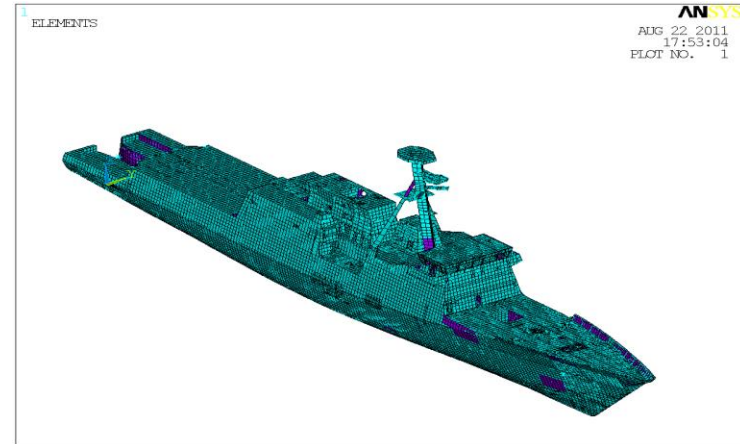
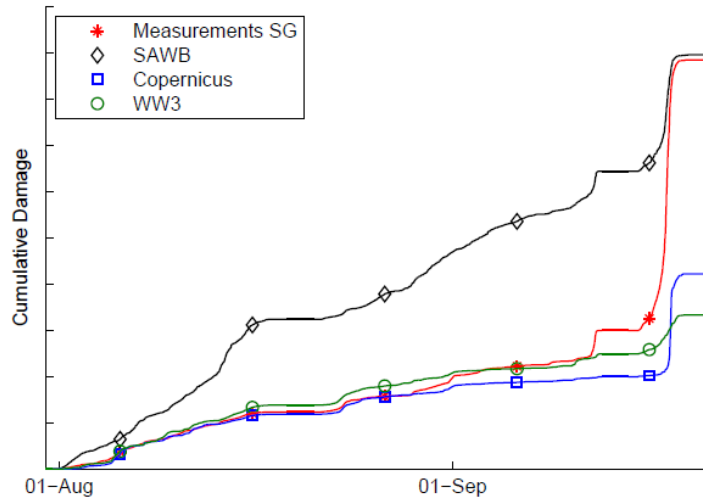
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FORECAST

- Develop the fleet virtual hull monitoring as a low cost, low intrusive monitoring approach to the current physical monitoring

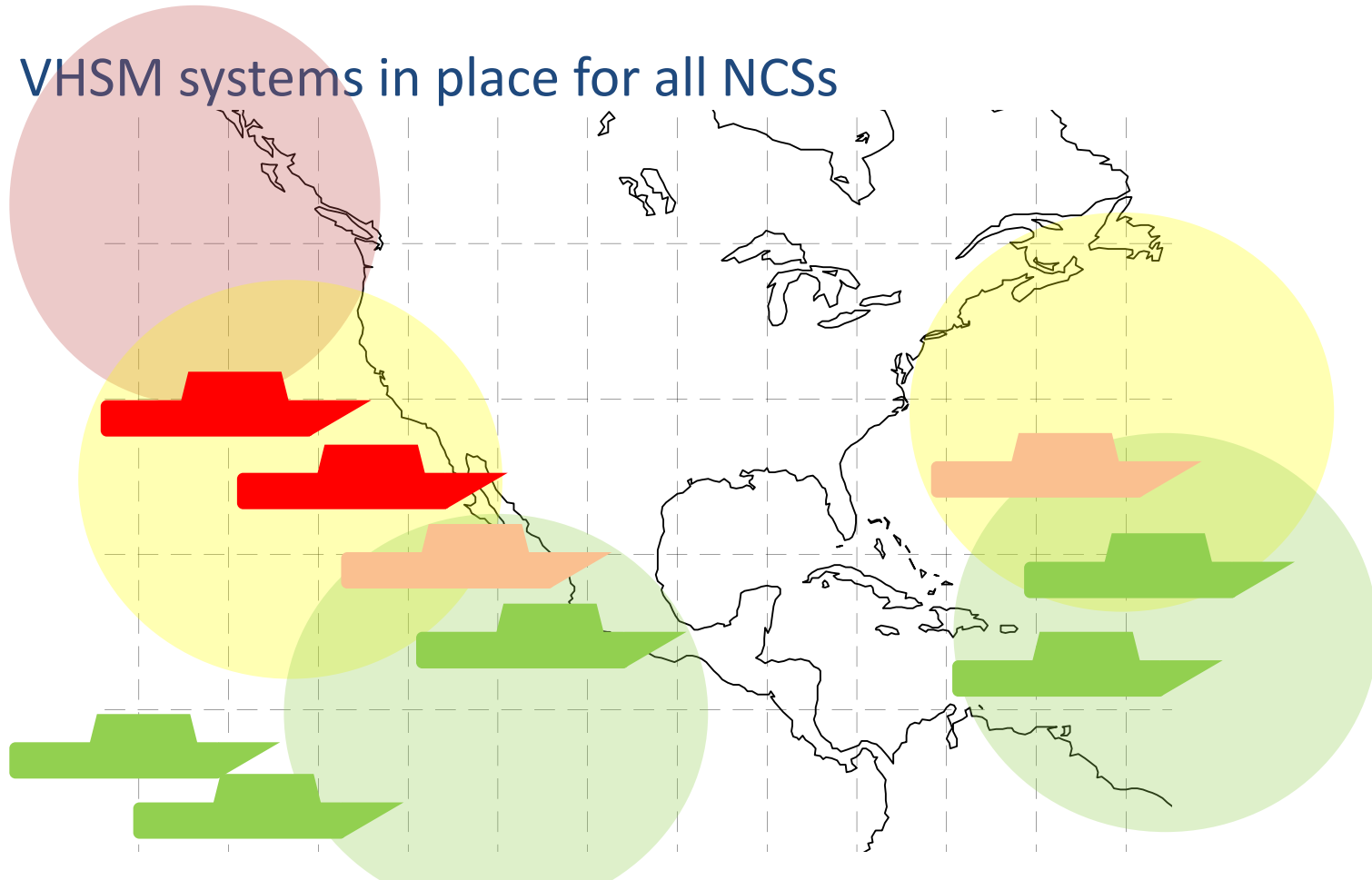


# Fleet virtual hull structure monitoring (F-VHSM)

- VHSM systems in place for all NCSs

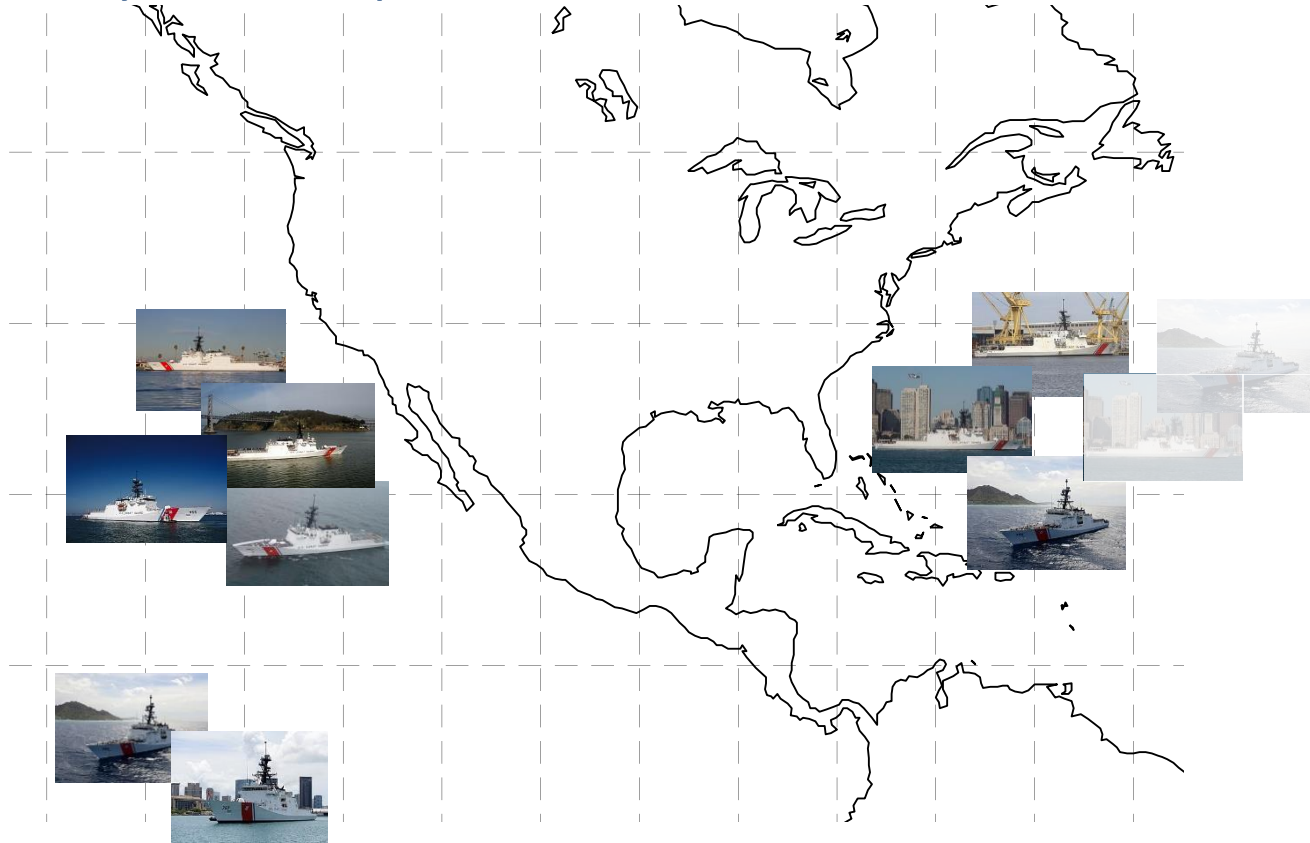


- VHSM systems in place for all NCSs



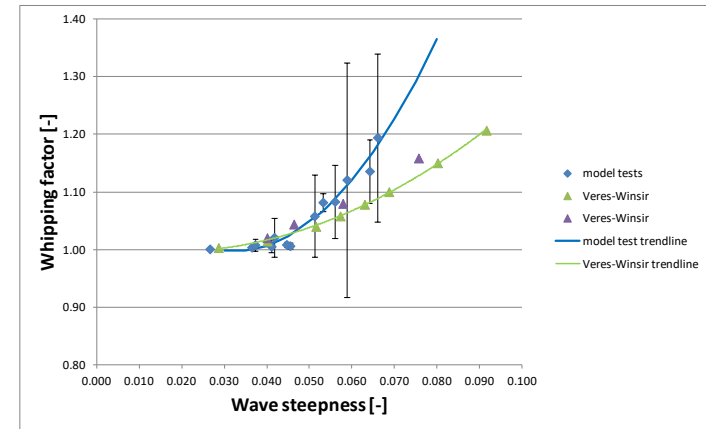
# Fleet virtual hull structure monitoring (F-VHSM)

- VHSM systems in place for all NCSs



- What can we achieve with VHSM?
  - Realistic operating conditions
  - Vessel ranking
  
- What needs to be incorporated?
  - Tool accuracy factors
  - Strong/weak nonlinear loads
  - Dealing with (incomplete) AIS data

$H_s$ [m]	Universal RAO	VERES	PRECAL	Hydrostar
<1	0.90	0.67	0.76	0.92
1-1.5	0.89	0.65	0.81	0.85
1.5-2	0.96	0.70	0.75	0.91
2-2.5	1.07	0.77	0.96	1.01





OPTIMIZED MAINTENANCE AND DESIGN

F-VHSM

HSM

WAVES

FORECAST

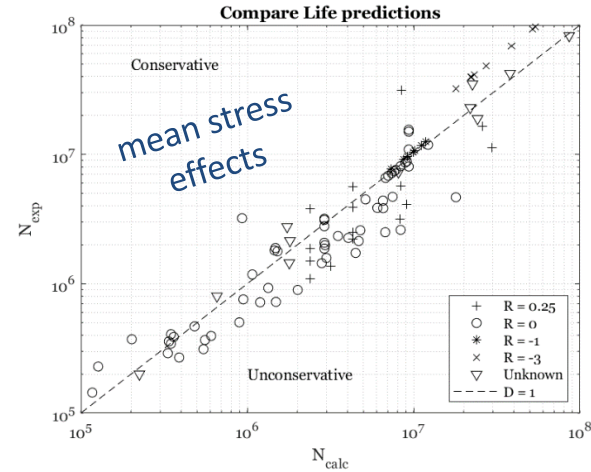
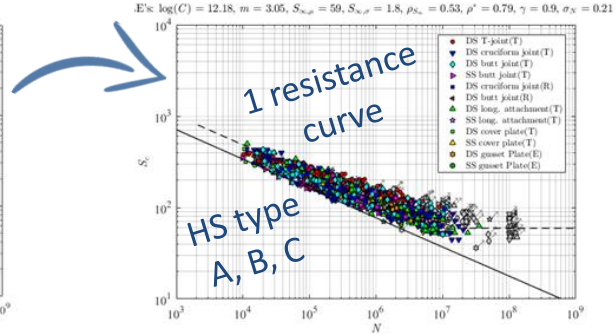
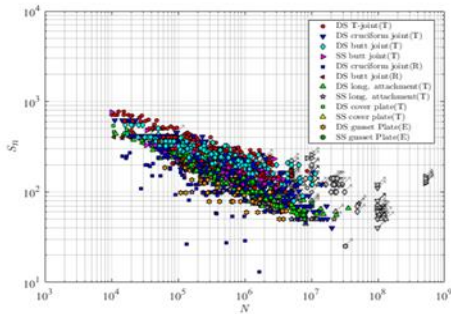
STRENGTH  
AND  
RESISTANCE

- Improved knowledge on the strength side of fatigue. This will allow for putting the measured fatigue loading in a better perspective with respect to the ship's capacity





- Fatigue resistance
  - Naval fatigue standard
  - Steel and aluminium welded joints
  - Effective notch stress- and total stress concept
  - Mid- and high-cycle fatigue
  - Over- and underloads
  - Compressive mean stress effects



courtesy Marije Deul

- Fatigue damage accumulation
  - Constant vs. random variable amplitude characteristics
  - (Non-)linear damage accumulation models
  - HSM based operational profile
  - Time vs frequency domain
  - Load sequencing
- Acoustic emission monitoring



## OPTIMIZED MAINTENANCE AND DESIGN

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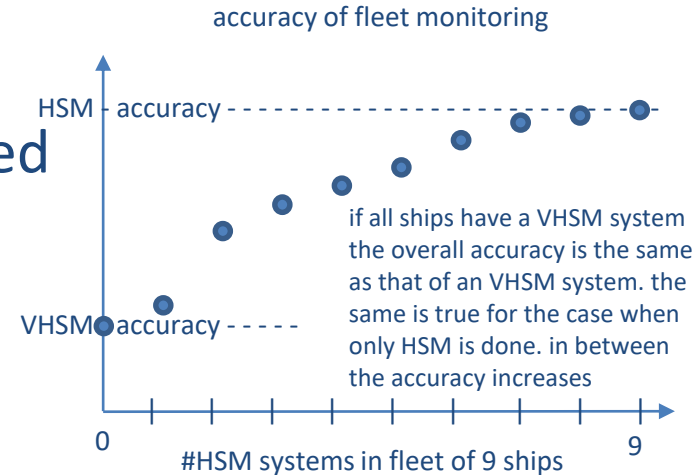
WAVES

FORECAST

- Apply the knowledge developed in this and the previous project for fleet deployment optimization and structural integrity management for potentially under 10keuro per ship per year



- A good trade off between accuracy and costs can be found with only a small number of ships monitored with HSM and the rest virtually
- How does this accuracy change with numbers?
- What is the cost benefit of a combined approach?
- What is the accuracy drop of the combined approach?



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- For operators
  - Structural integrity monitoring for below 10keuro per year per ship
  - Insight in setting up fleet monitoring schemes using combined physical and virtual monitoring
  - Rational for maintenance and life time extension decisions at optimized costs
  - The developed approach will be applied to the NSCs but can be applied to any fleet of ships
- For class societies
  - Input on how monitoring results can improve ship design and decisions on maintenance and life time extension
- For ship builders
  - Input on better future ships designs
  - Better ship maintenance support option

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# Schedule and participation fee

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- The project will run for three years
- The fee per year is envisioned to be 20keuro

# GO F R READY

