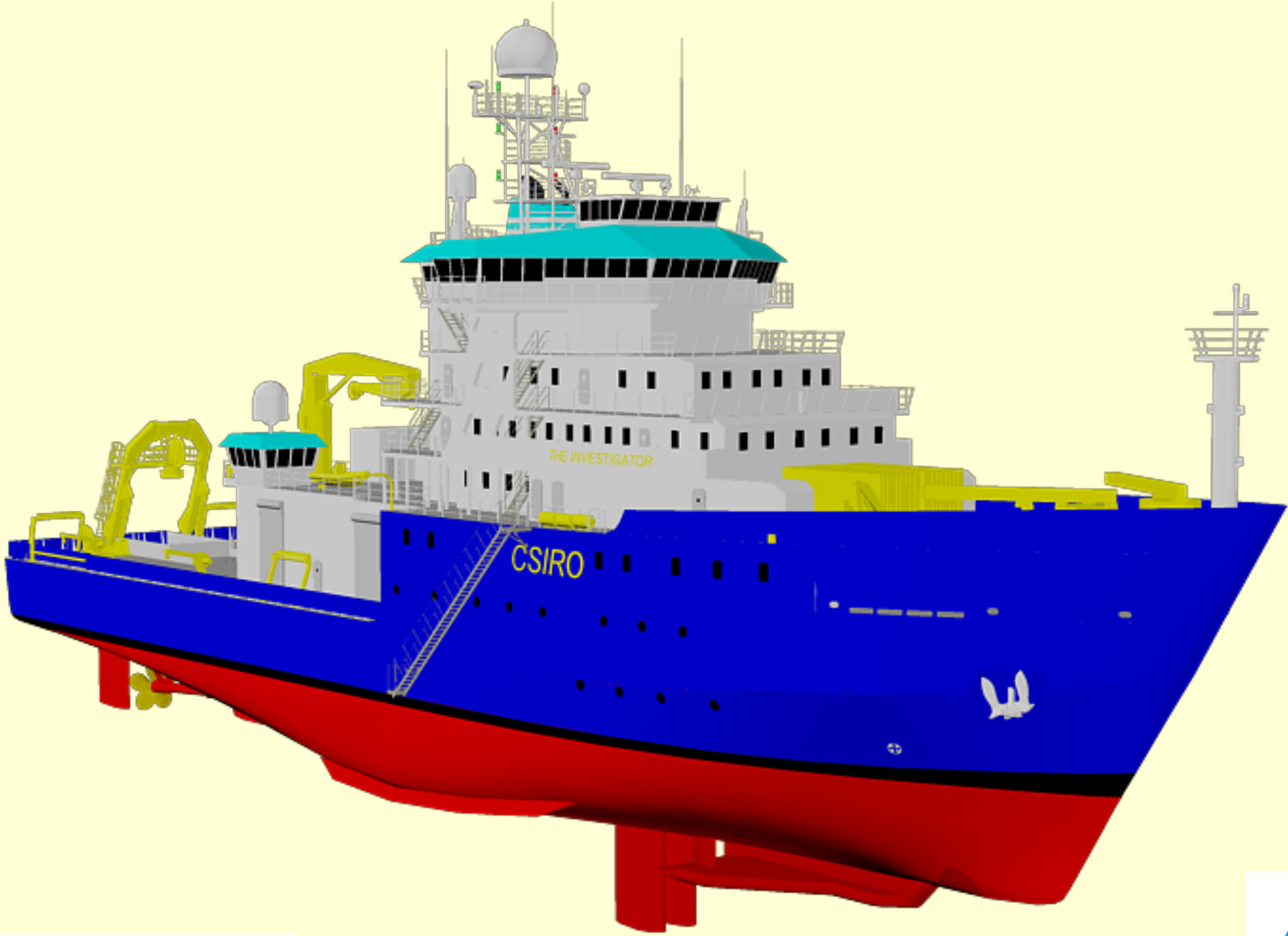
CSIRO R/V INVESTIGATOR



RALion

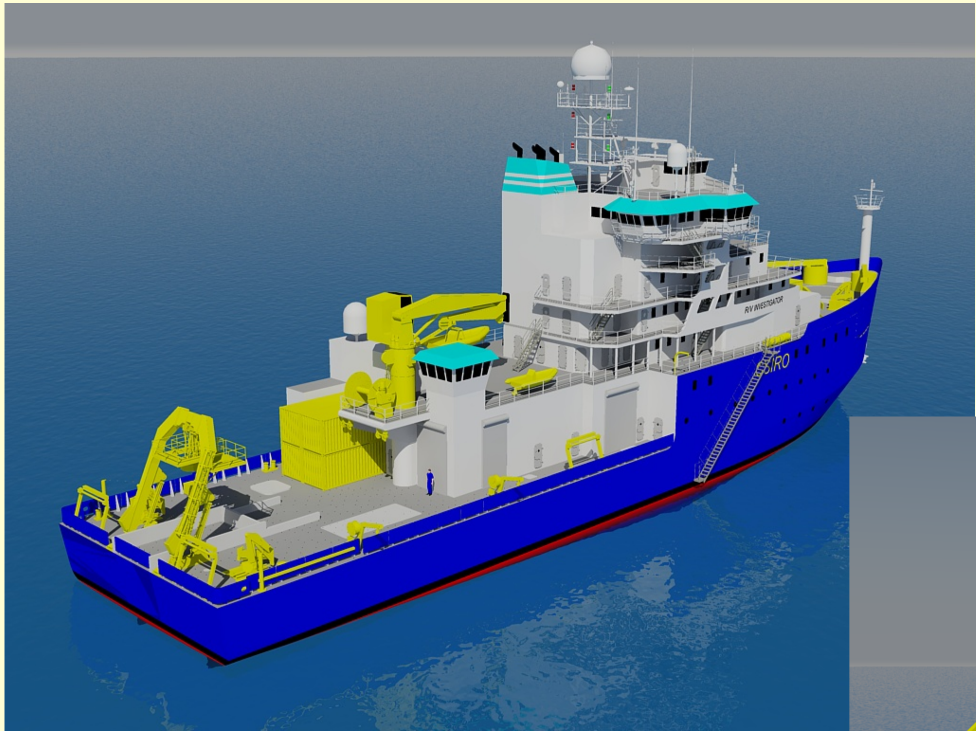
A Robert Allan Ltd. / Alion Science and Technology Joint Venture

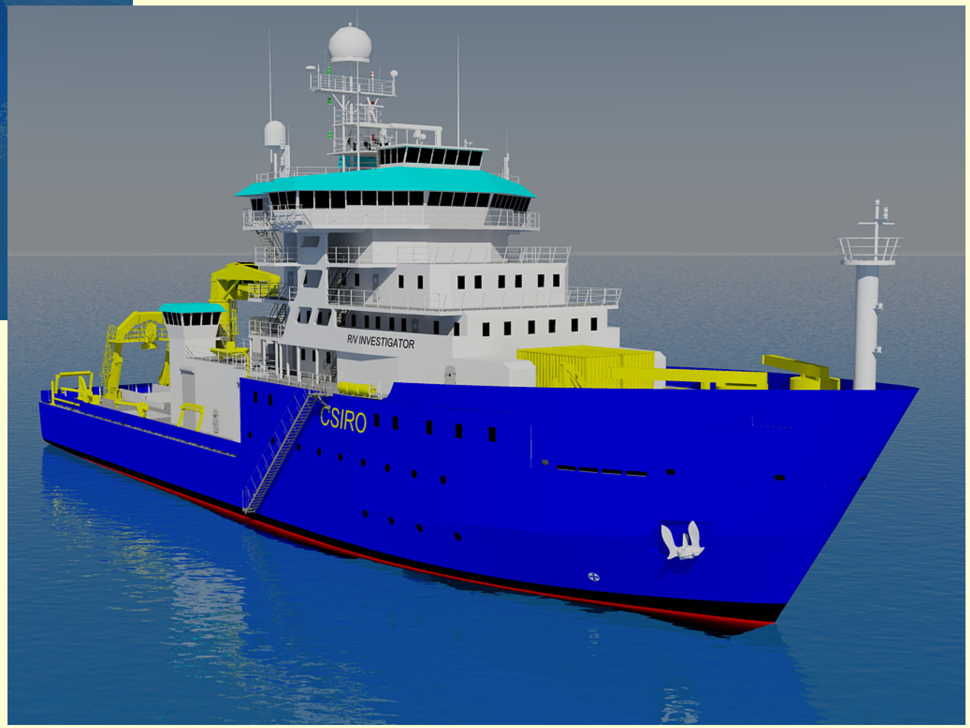
ERVO May 2011

CSIRO

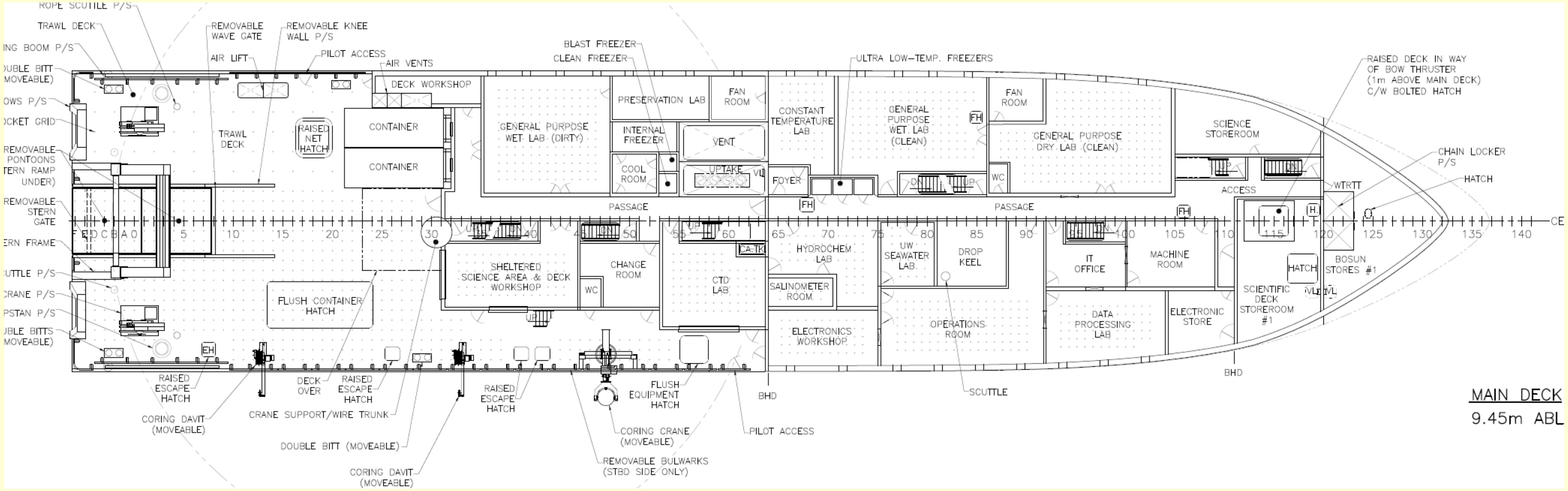
Ship Particulars

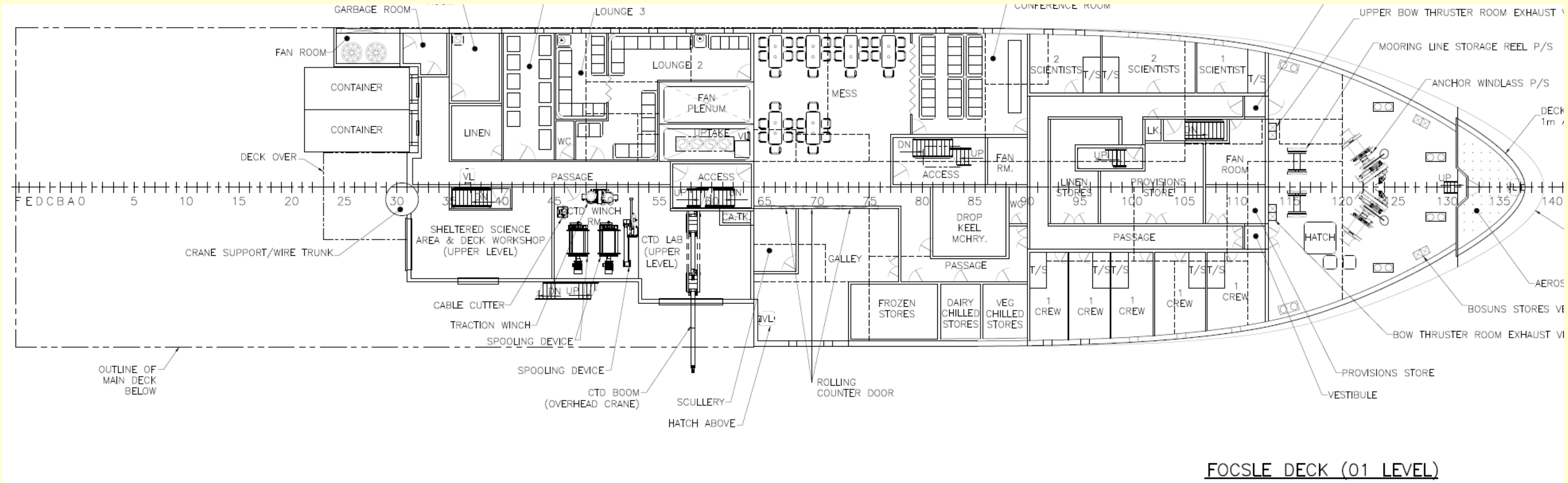
Owner:	**Commonwealth Scientific and Industrial Research Organization (CSIRO)**
Length:	**90 Meters**
Displacement	**4,575 Tonnes**
Accommodations:	**40 Scientists, 20 Crew**
Range:	**10,800 NM at normal cruising speed (12 Kt)**
Speed:	**Maintain 12 Knots in SS6; 15 Knots in SS2**
Missions:	**General purpose oceanographic; fisheries**
Science load:	**250 Tons**
Acoustics:	**Deep, mid, and shallow multibeams; other systems**
Handling Systems	**Full suite of winches, cranes, and overboard gear**
Design:	**DNV Classed, DP1, Ice Class 1C, AMSA inspected**
Laboratories:	**600 Sq M**
Containers:	**12 standard 20 Ft ISO containers on deck and in hold.**
Delivery:	**Late Summer 2013**




R/V INVESTIGATOR
CSIRO

Deck Arrangements





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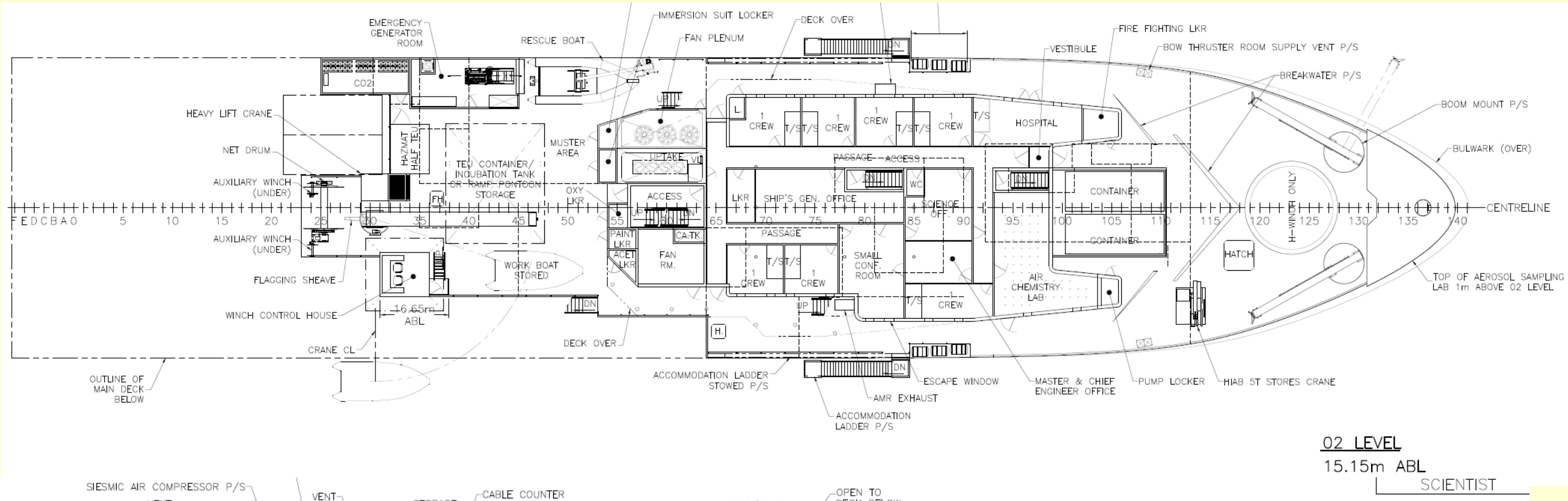
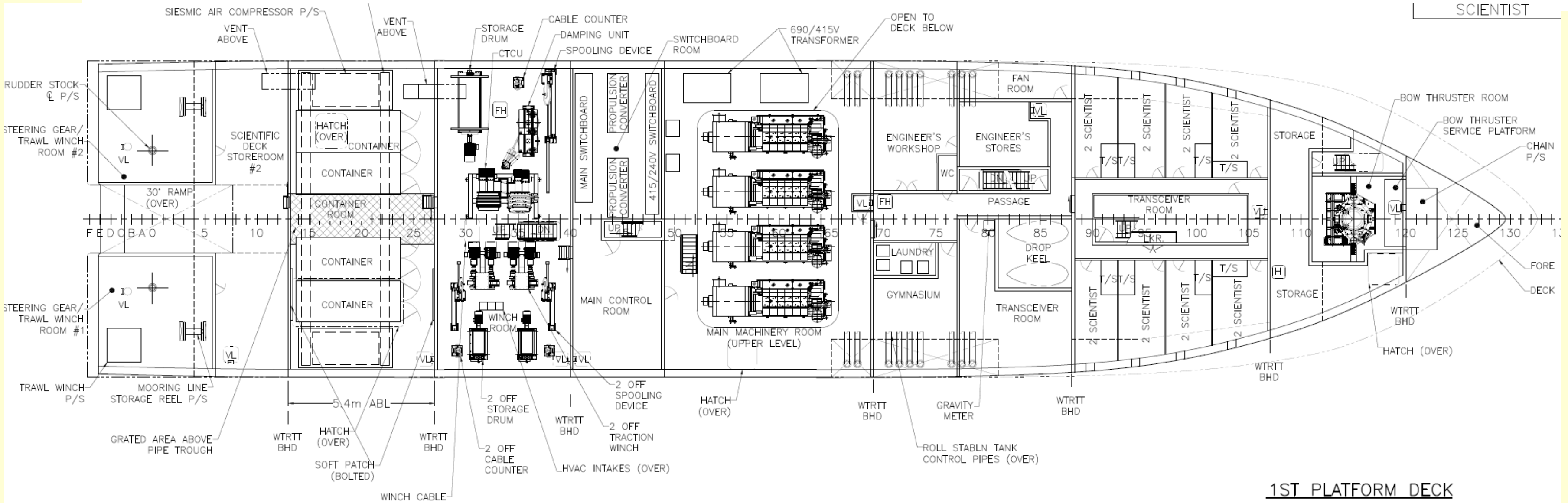
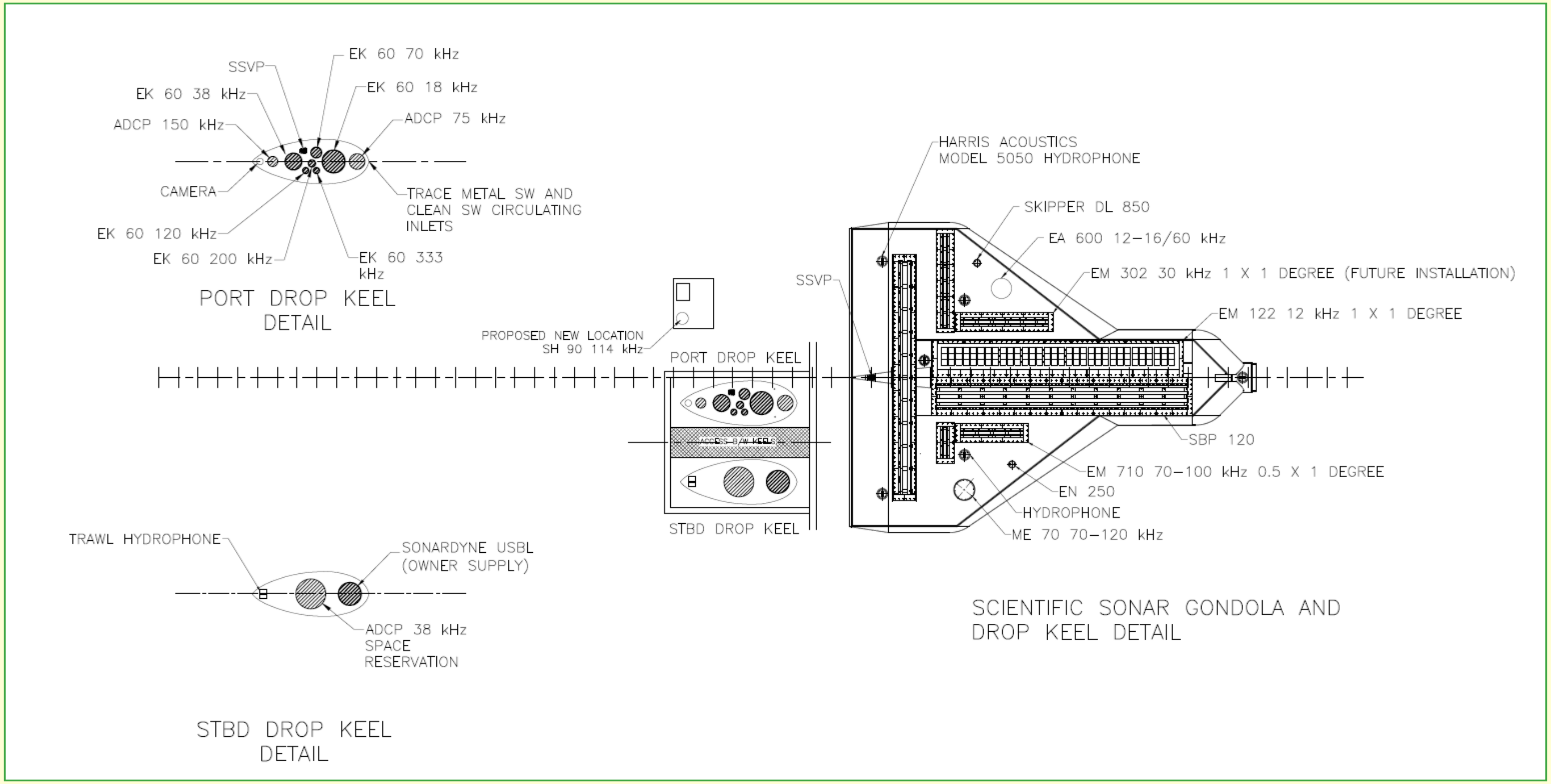
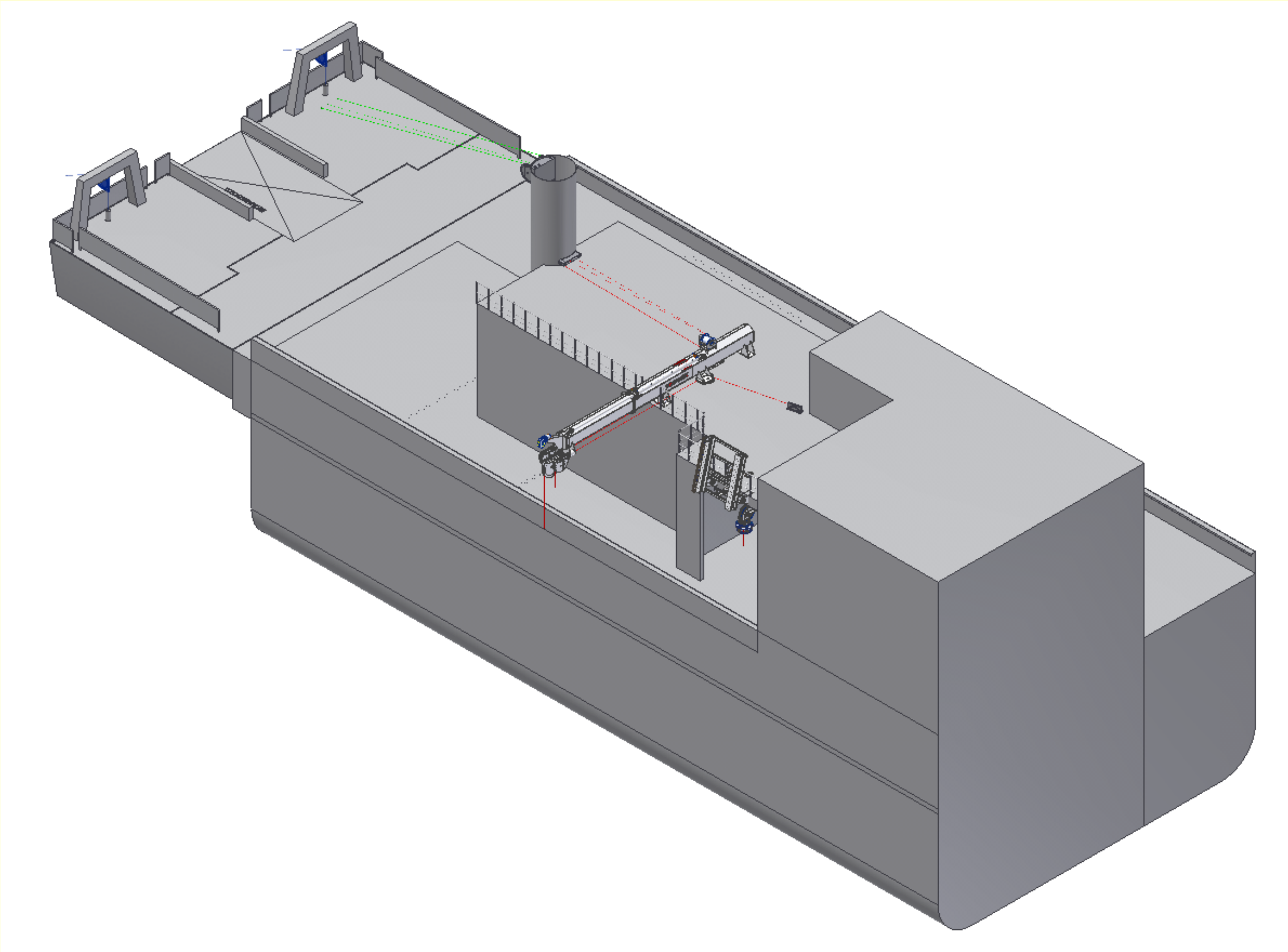




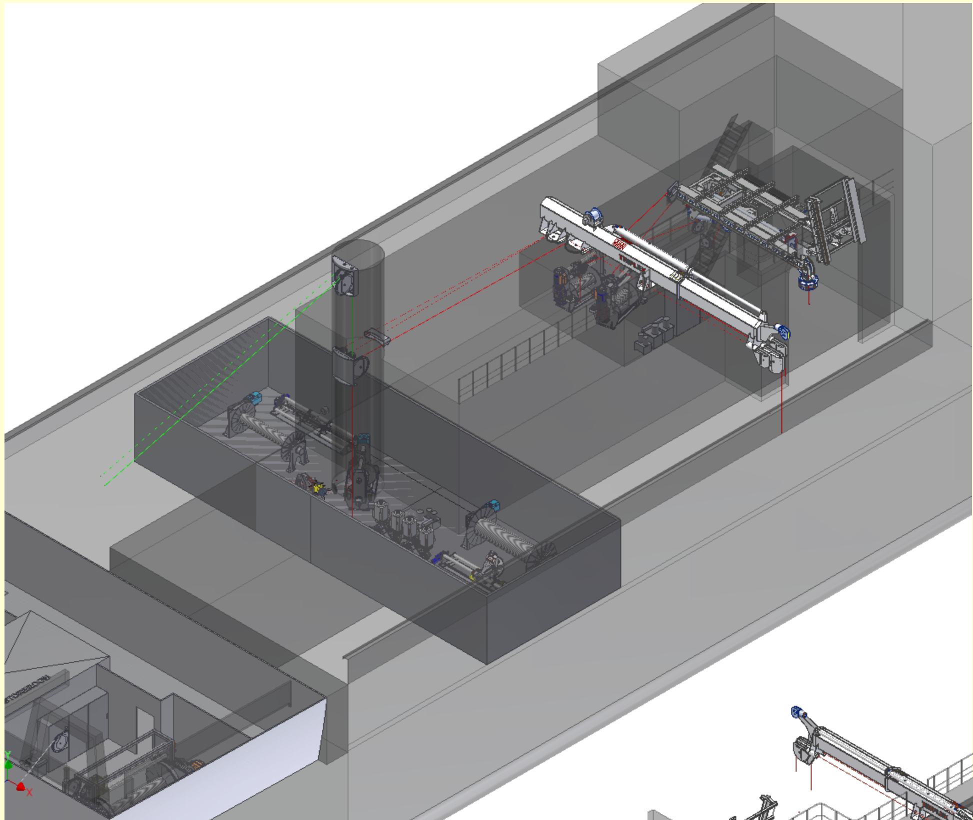
Sonar Arrangements

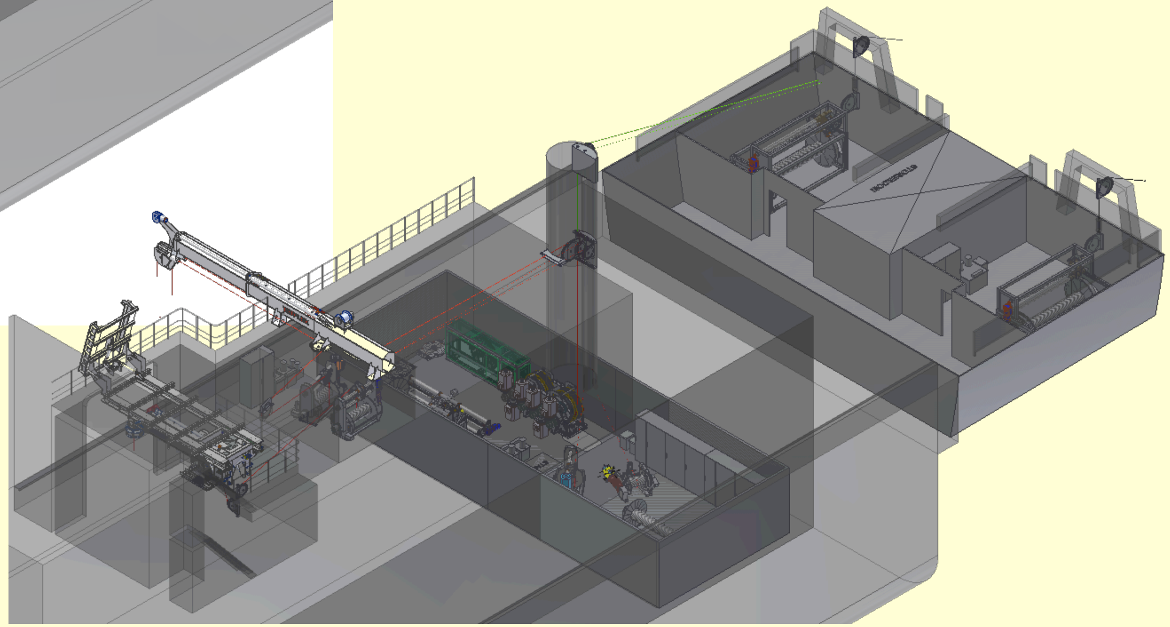


Overboard Handling Systems

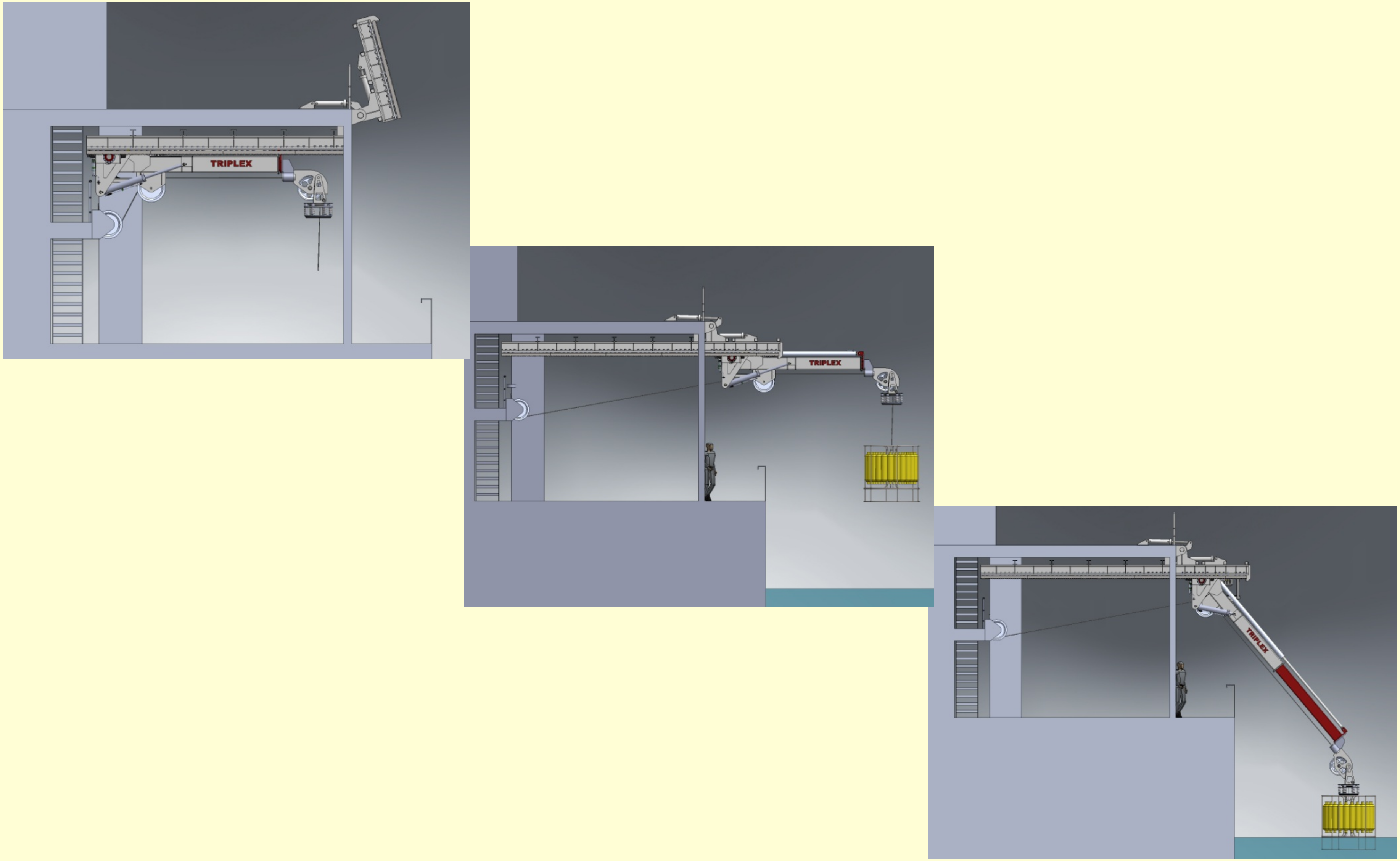


Overboard Handling Systems



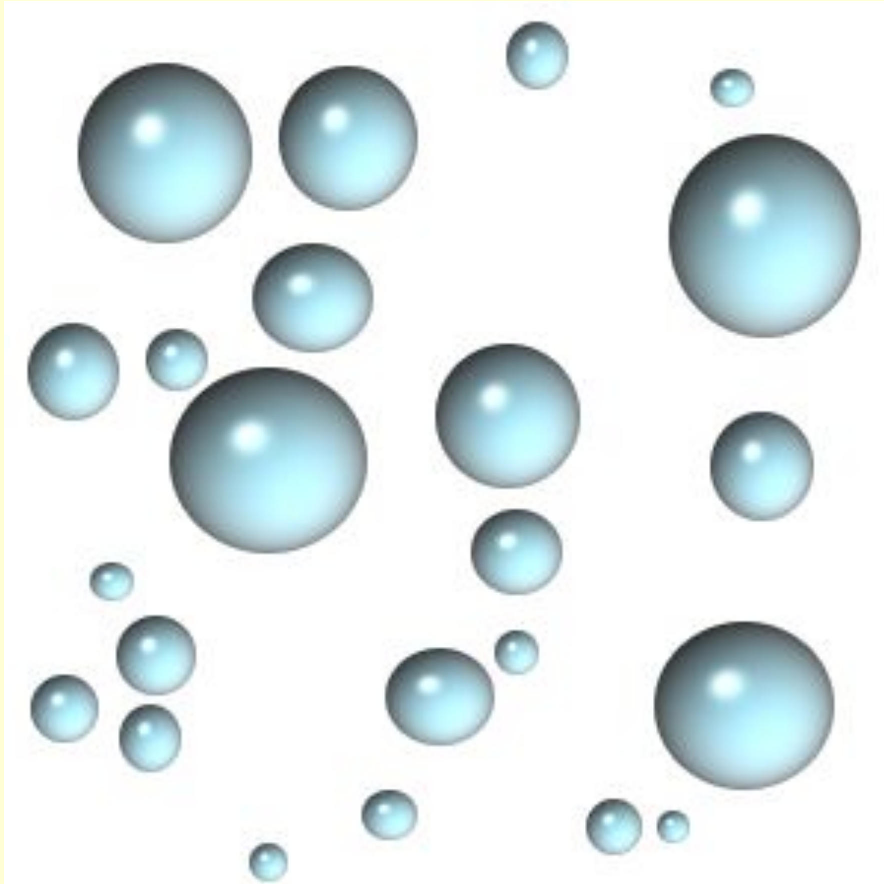


CTD Handling System



What is Bubble Sweepdown?

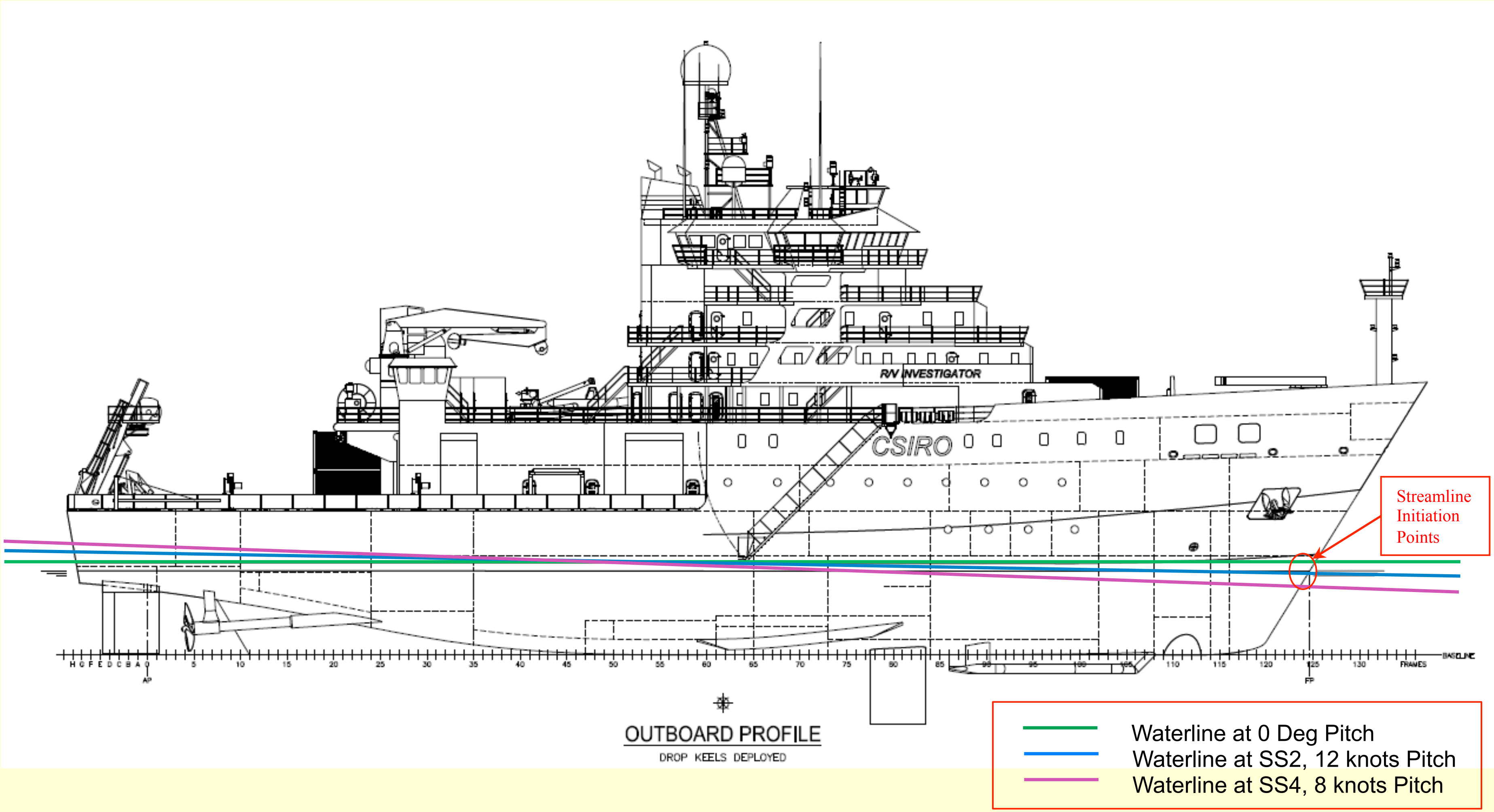
- Air bubbles originating at the surface caught in the vessel flow stream lines and swept along and under the hull
- Primary source is the ship's bow wake but also natural wind/wave interactions (in higher sea states)
- Can cause significant sonar performance degradations
- Increases ambient noise as well as creating a barrier that can attenuate both outgoing and returning sonar signals
- Effects generally worse at higher sea states and higher speeds



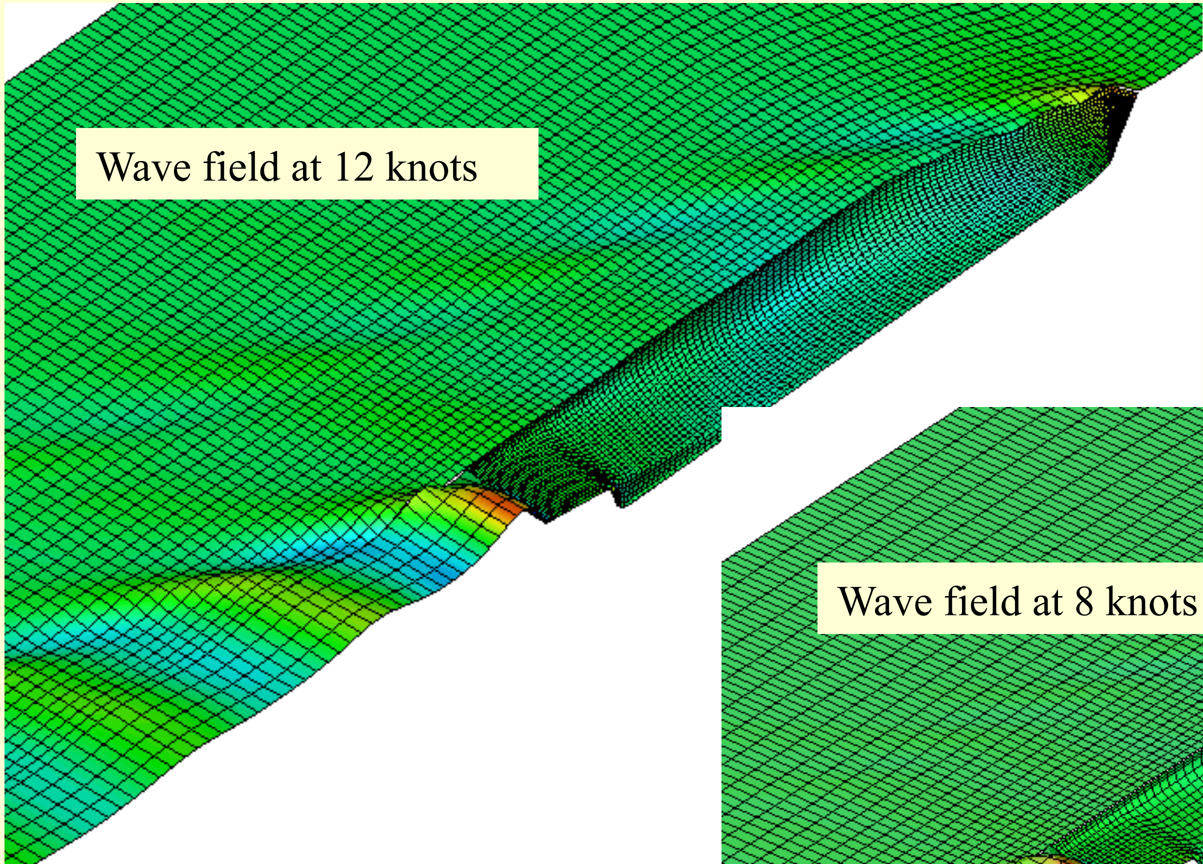
Tools to Be Employed At Each Design Stage

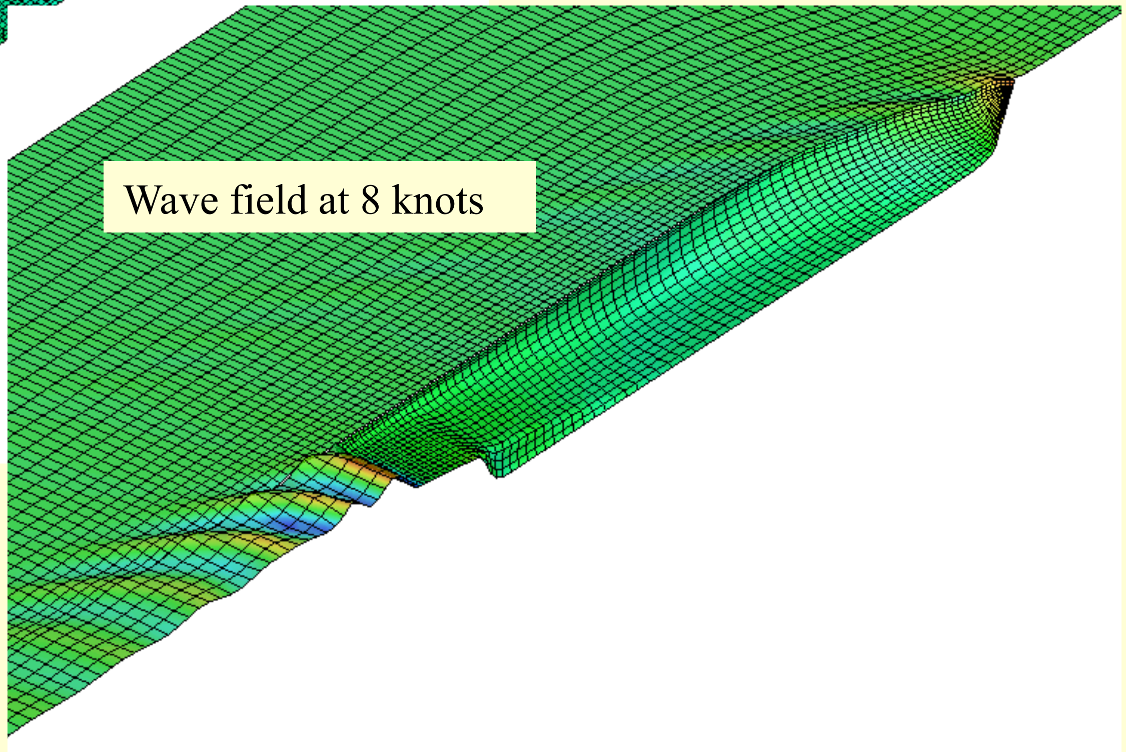
- *<u>Concept Design</u>*
  - Hull Features to Avoid Known Causes of Bubbles
    - No Bulbous Bow; No Tunnel Thrusters
  - Transducers Located in Gondola and Drop Keel
    - The Most Effective Technique to Avoid Bubbles
- *<u>Preliminary Design</u>*
  - CFD Analysis of Flow lines Around Hull and Sonar Appendages to Confirm That Flow Lines Originating at Stem Do Not Cross Transducer Faces
  - Flow Origination Points Varied Below Even Keel DWL to Simulate Pitching
- *<u>Contract Design</u>*
  - Physical Model Testing for Flow Visualization
    - Yarn Tuft and Wet Paint "Smear" Tests
    - Flow Testing Using Dye Injected at Ship Bow
    - Flow Origination Points Varied Below Even Keel DWL to Simulate Pitching

Streamline Initiation Points

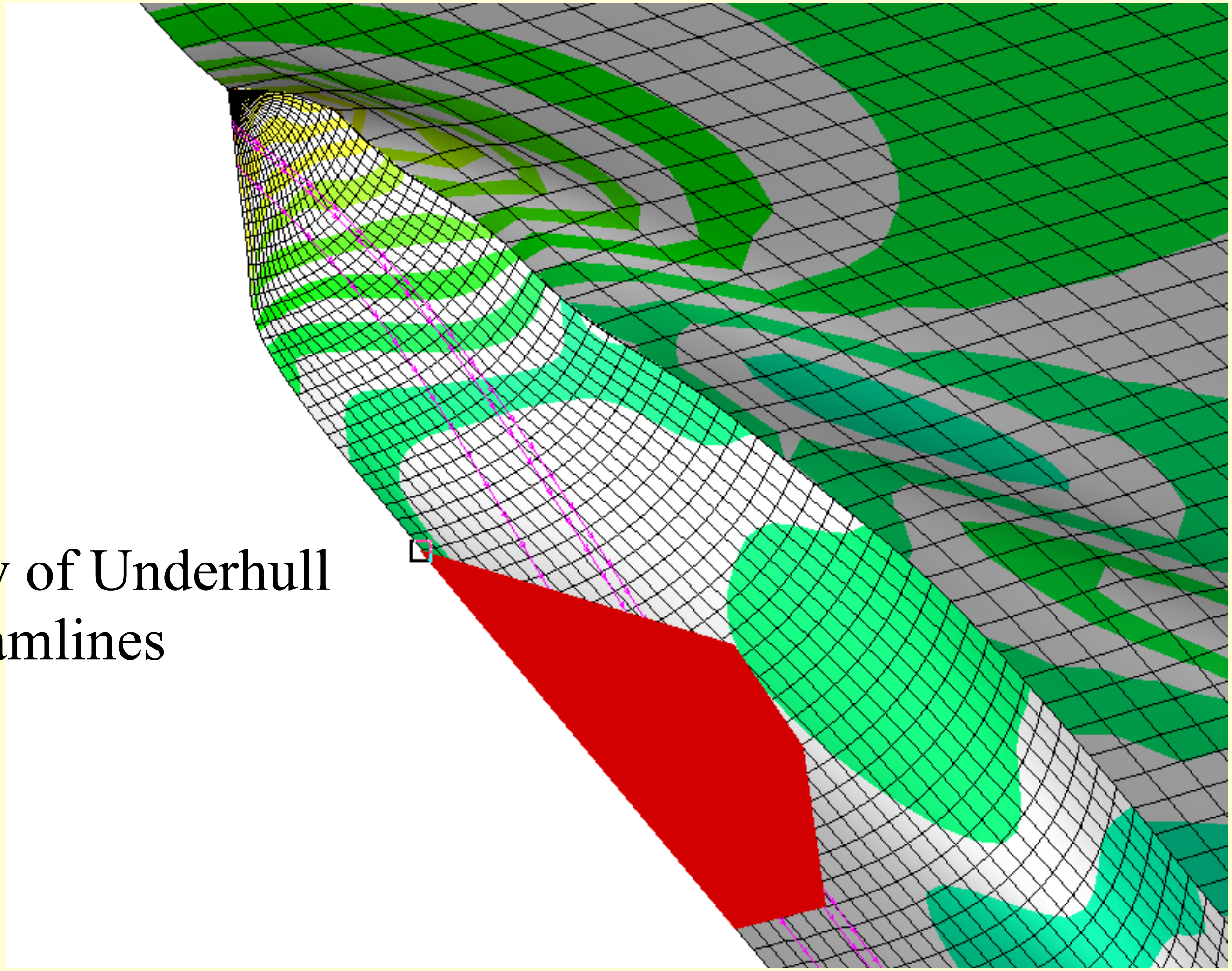


Bubble Sweepdown CFD



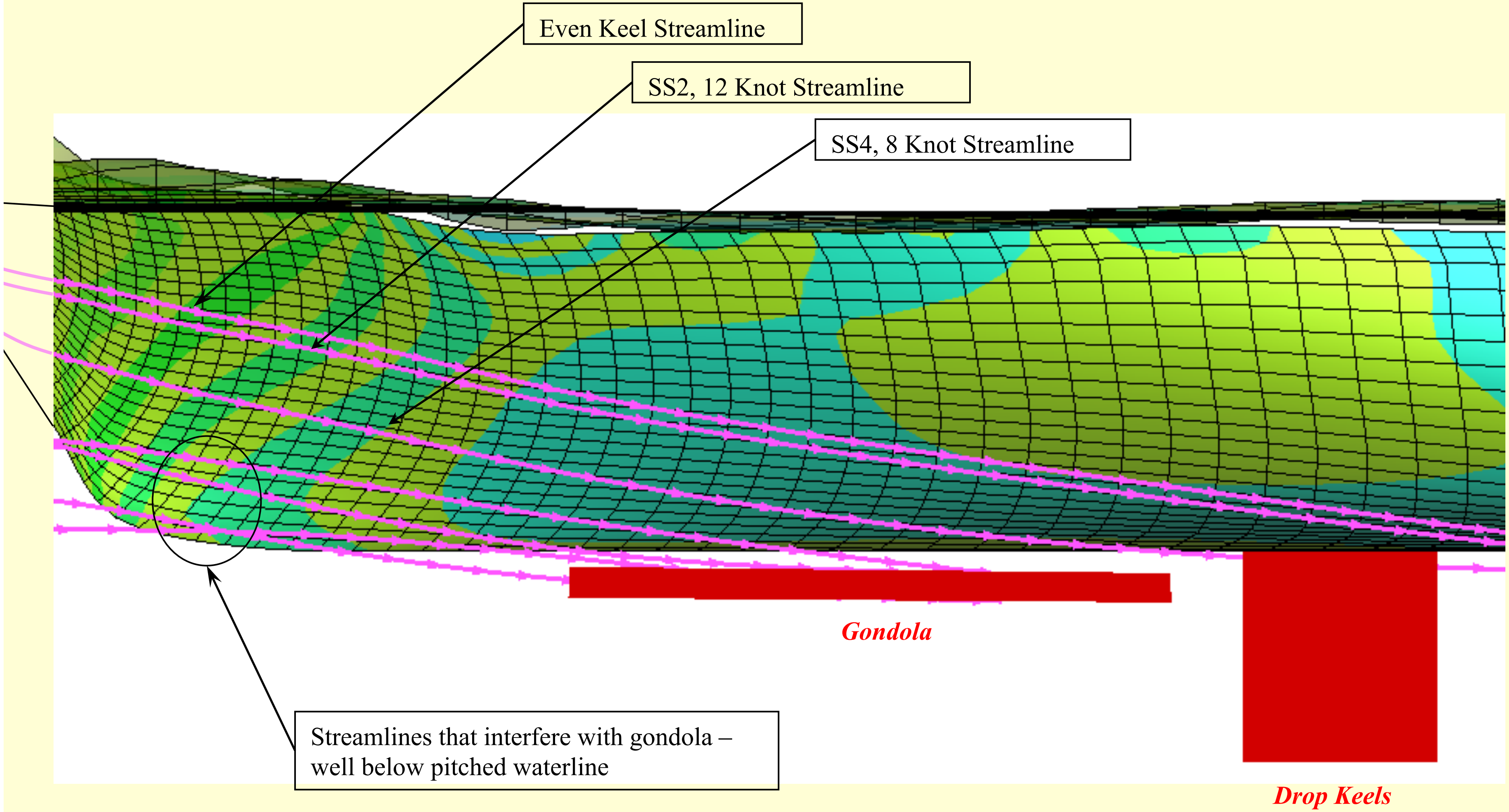


Bubble Sweepdown CFD



View of Underhull Streamlines

Profile View of Underhull Streamlines



Model Dye Testing Arrangement

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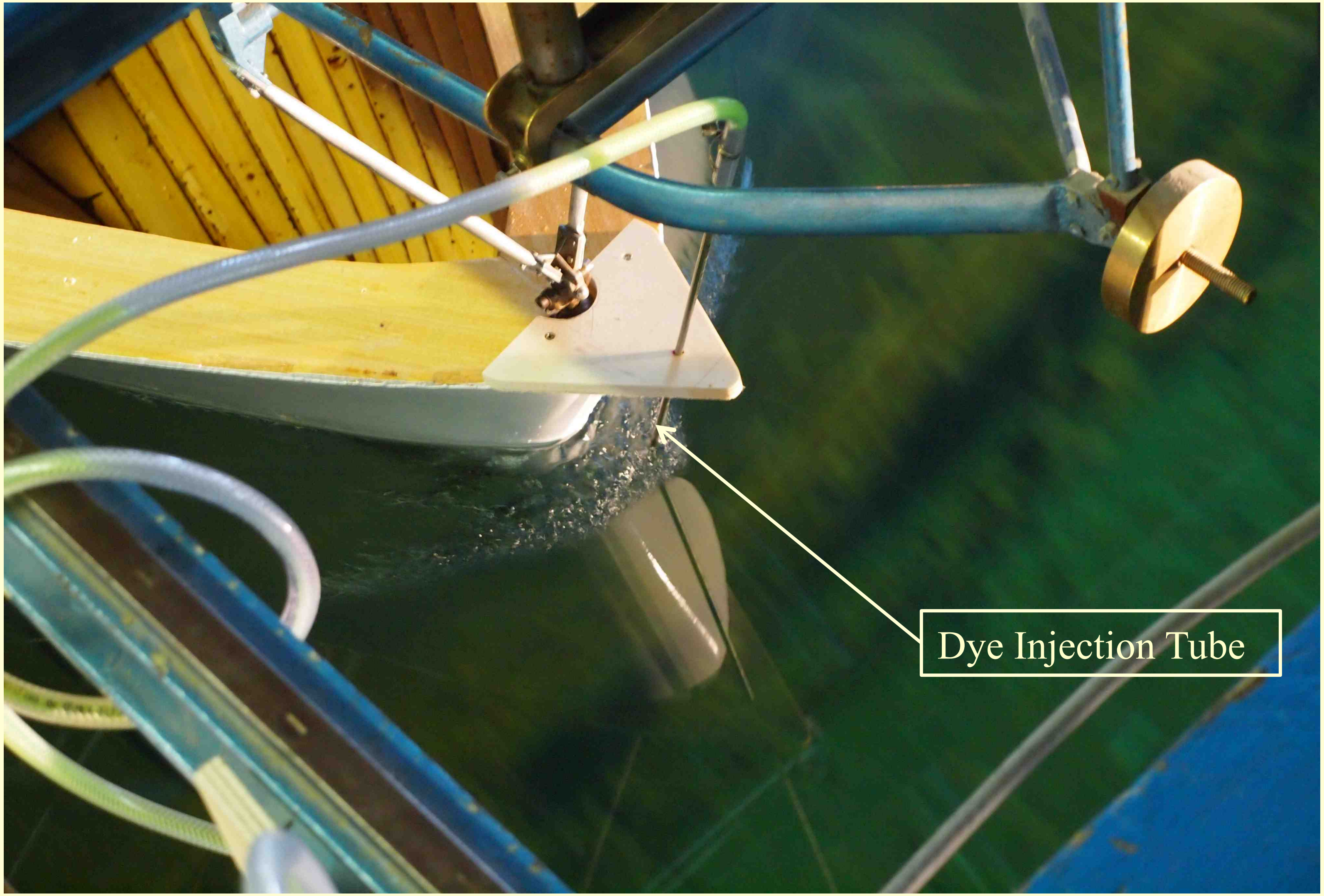

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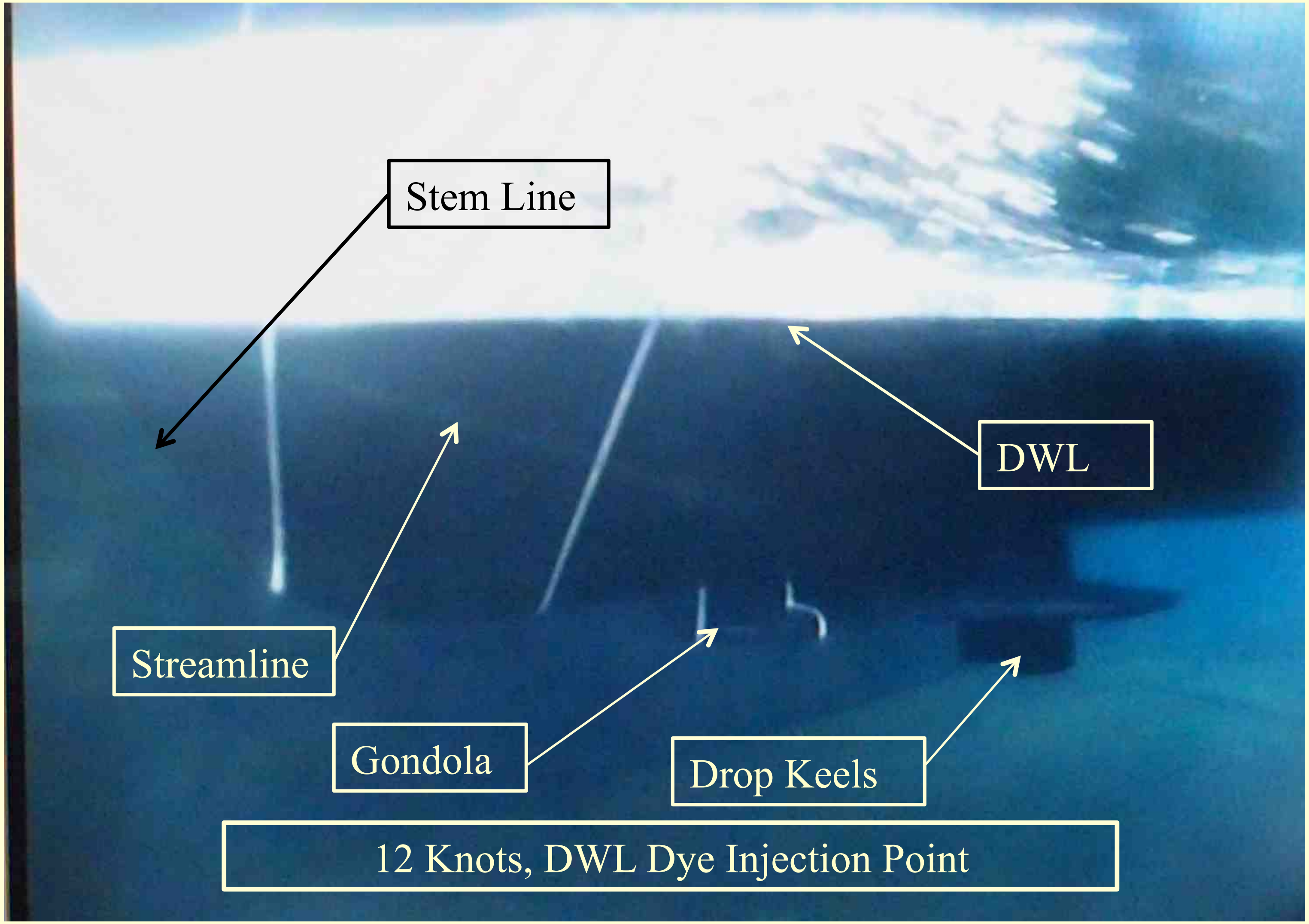
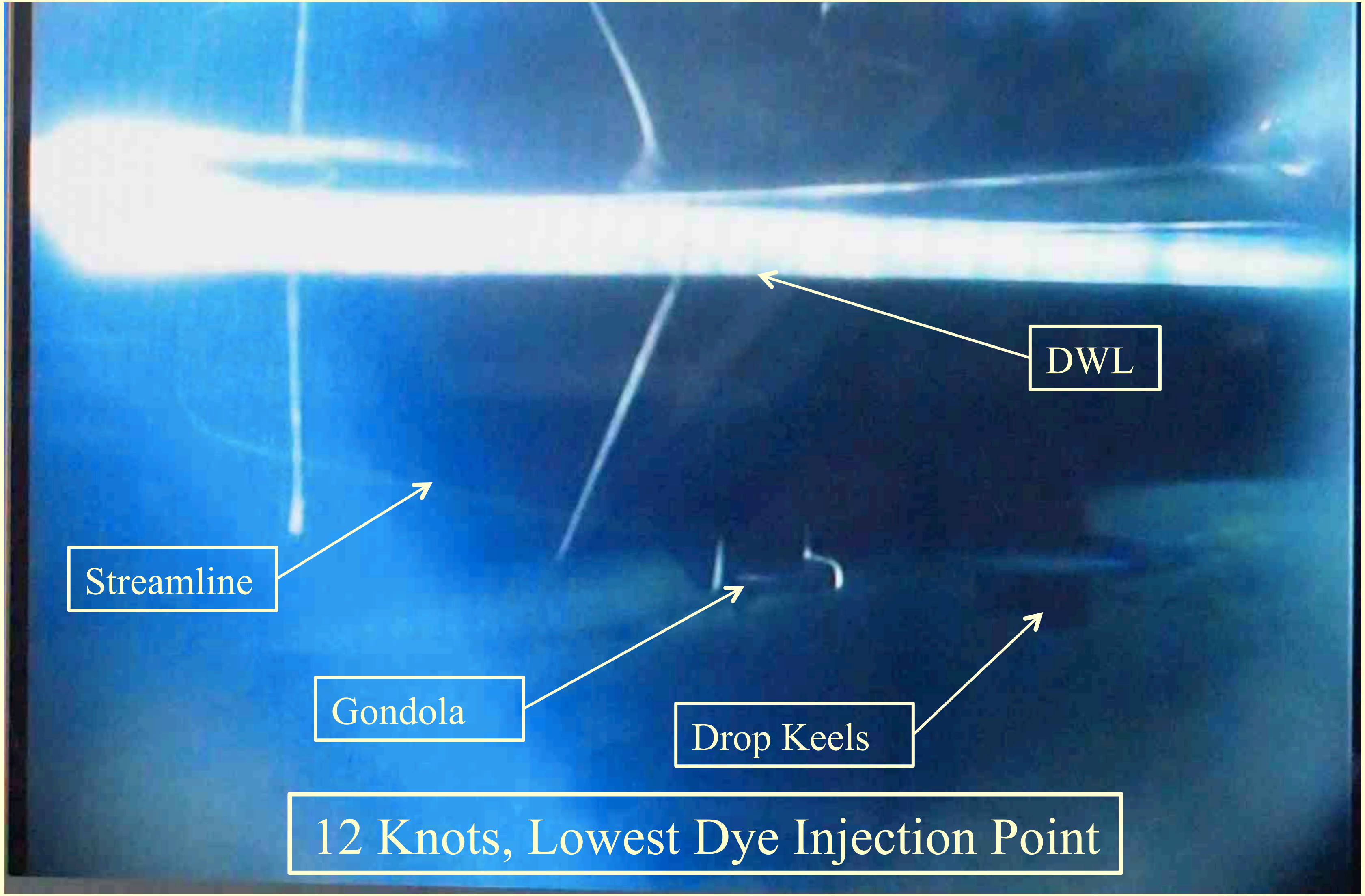
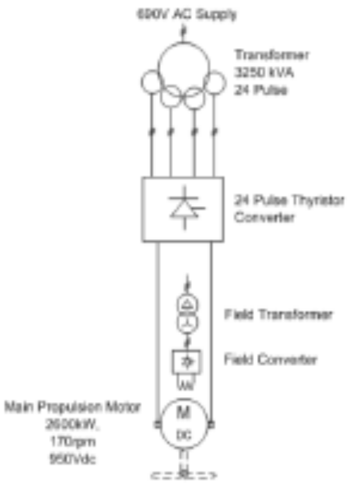


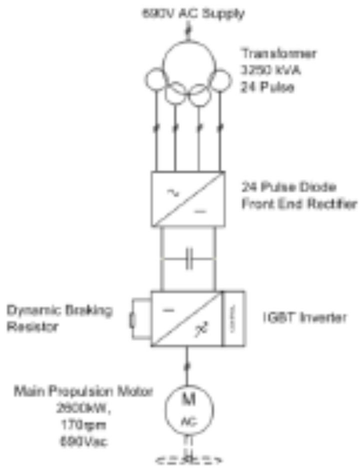
Model Dye Testing Arrangement



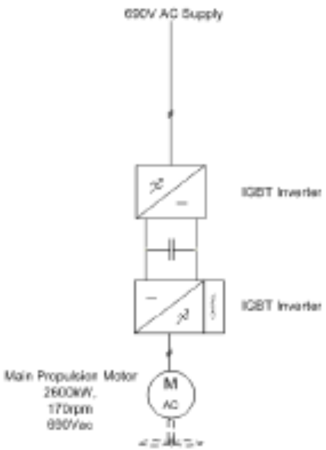
AC-DC Propulsion Study



DC Option

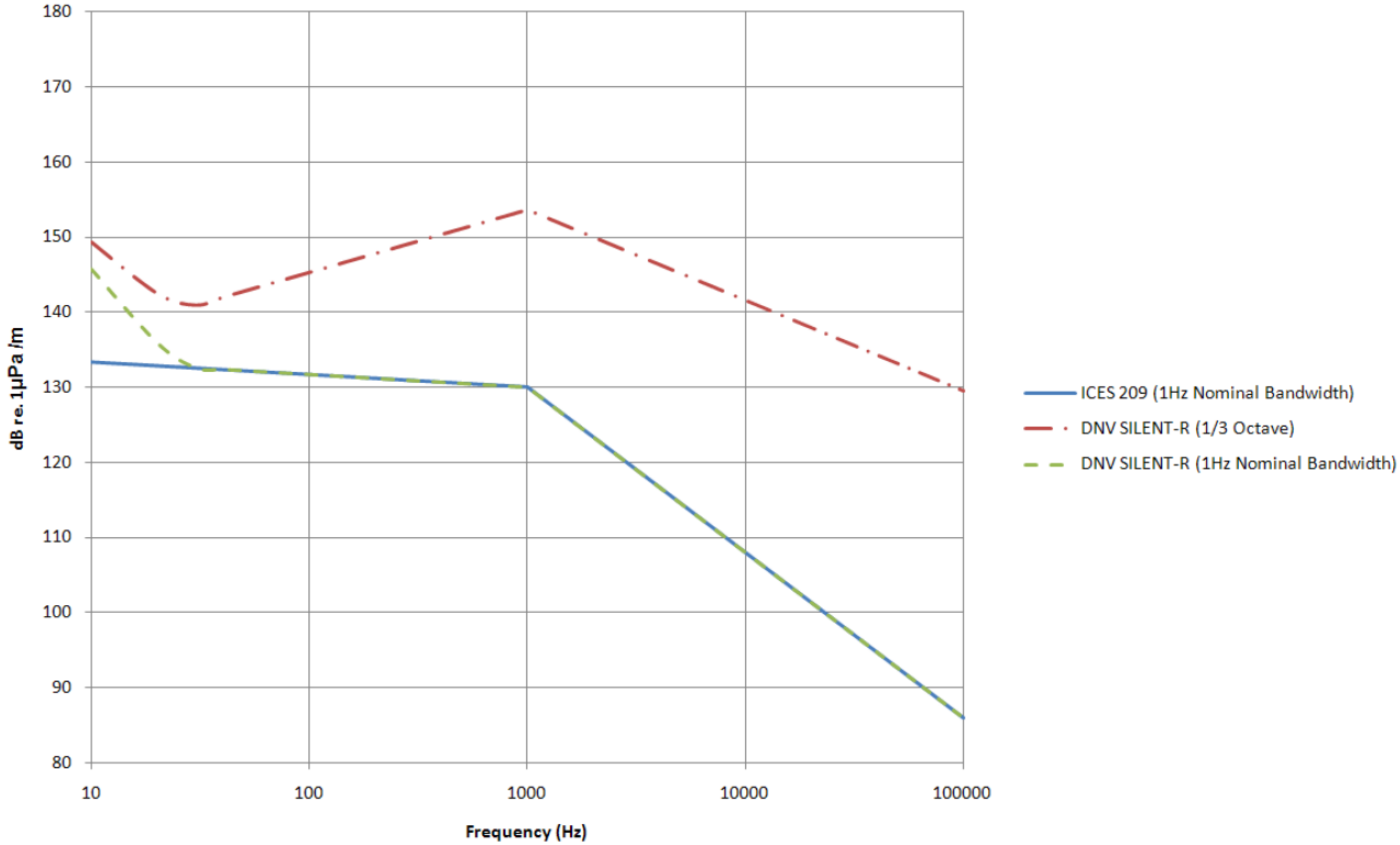


AC Option with Diode Front End



AC Option with Active Front End

Radiated Noise Requirements



Why Have DC Motors Been Used?

- Only available choice for electric propulsion until ~ 15 years ago
  - AC low speed control difficult
  - AC development of high torque at low speed difficult
- DC technology was mature and modified to meet low structureborne noise requirements
  - Skewed slots
  - Increased number of poles
  - Special stacking of laminations
  - Low flux
  - Specially designed brushes and rigging
  - Resilient mounting of cooler fans
  - Other measures

Why Shift to AC Motors?

- DC motors have some disadvantages
  - Brushes require maintenance and replacement
  - Thyristor power converters introduce undesired electrical harmonics into the electrical system (require harmonic filters unless a 24 or more pulse system is used)
  - Large phase shifting transformers are required
- AC motor technology has matured significantly and is now the main choice for electric propulsion
  - Motors are smaller and lighter
  - Power conversion equipment is heavier than DC
  - Overall an AC system is lighter and usually less expensive
  - Saves space in the ship
  - Less maintenance overall

Why Have AC Motors Not Been Used in Quiet Ships?

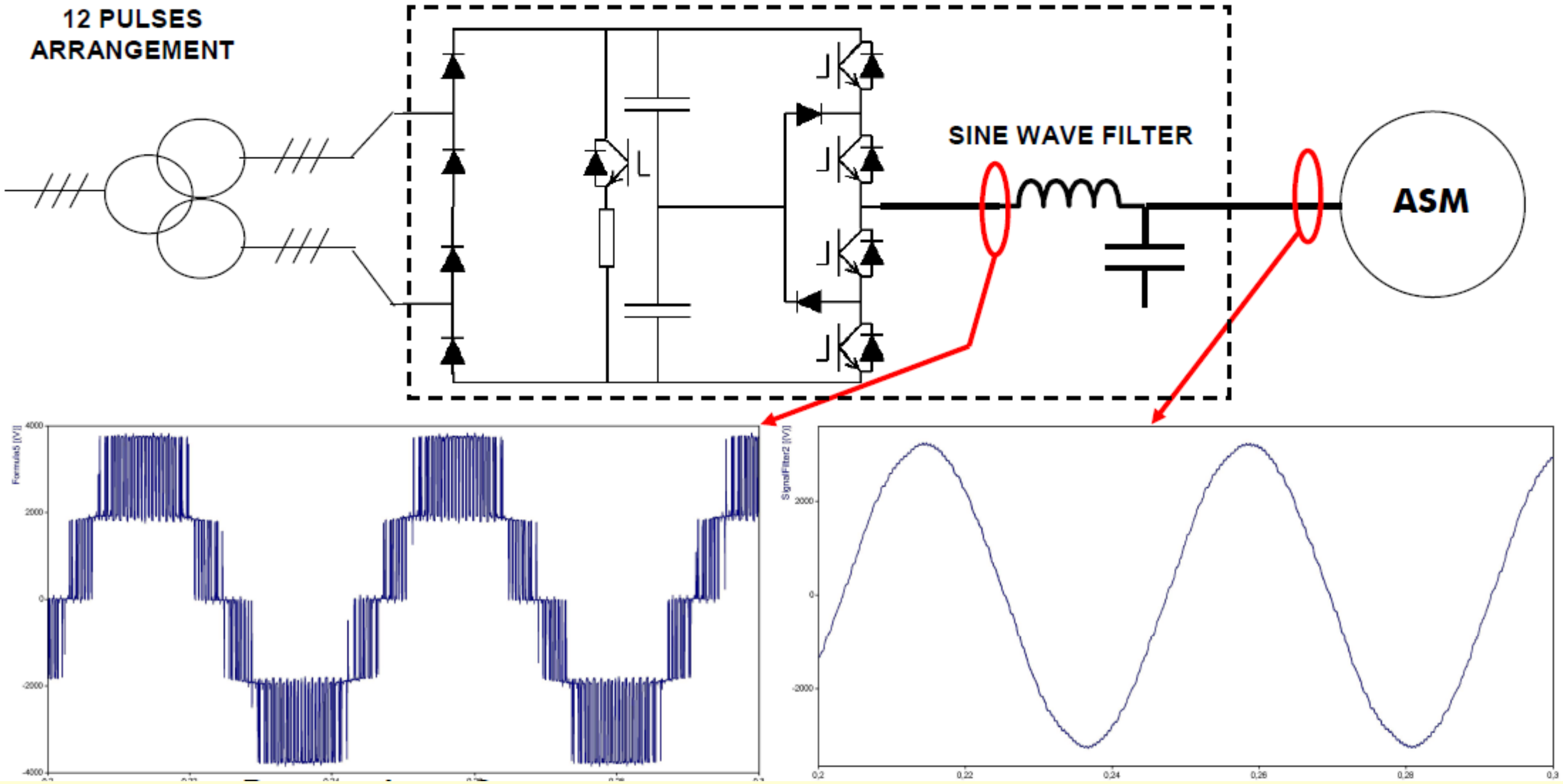
- AC drives require two power conversions
  - AC to DC and DC back to AC which creates torque pulses in the motor
    - Creates structureborne vibration
    - Creates unsteady forces on the propeller
  - Introduction of pulse width modulation (PWM) and indirect power conversion reduces noise (active front end)
  - Use of simpler induction motors with an active front end and a sine wave filter at the input to the motor show promise for quiet ships

Is ICES 209 or DNV Silent R Achievable with AC Propulsion?

- Based on existing vessel data and manufacturer predictions it appears possible that AC propulsion can support ICES 209 or Silent R
- Drive system must use an active front end and sine wave filter
- Motors must meet a structureborne noise requirement
- Motors must incorporate quieting technology:
  - Electromagnetic Design (stator arrangement, slot ratio)
  - Shaft Design (balance, stiffness, fundamental frequencies)
  - Bearing Design (high quality sleeve bearings, concentricity)
  - Frame Design (interface to stator, stiffness, and fundamental frequencies). Occasionally this can require resilient mounting of stator within the motor frame although this is more normal when there are shock requirements on the motor.
  - Cooler Box Design (Use of anti-vibration mounts between the cooler box and motor frame)
  - Coupling Design and Motor Mounting (selection of resilient mounts)

Quiet AC Drive System

Frequency converter design / PWM harmonics mitigation :



AC-DC Comparison of System Sizes

Comparison of System Volumes

DC Drive System	$64 m^3$
DFE AC Drive System	$54 m^3$
AFE AC Drive System	$43 m^3$

Comparison of System Weights

DC Drive System	80 tonnes
DFE AC Drive System	57.7 tonnes
AFE AC Drive System	51.5 tonnes

AC-DC Comparison of Efficiency and Fuel Consumption

Table 1: Electrical System Efficiency

	Service Load	Shaft Output Power (Num. of Gens Online) 25% 2 x 650kW	50% 2 x 1300kW	75% 2 x 1950kW	100% 2 x 2600kW
DC Drive System	0	82.21% (2)	86.35% (3)	86.95% (3)	86.40% (4)
	750kW	86.54% (3)	86.56% (3)	88.37% (3)	87.56% (4)
	1000kW	87.72% (3)	89.12% (3)	88.67% (4)	87.89% (4)
DFE Drive System	0	79.97% (2)	84.98% (2)	85.94% (3)	85.81% (4)
	750kW	85.82% (2)	87.16% (3)	87.49% (3)	87.03% (4)
	1000kW	86.94% (2)	87.80% (3)	87.83% (4)	87.37% (4)
AFE Drive System	0	80.62% (2)	85.57% (2)	86.48% (3)	86.29% (4)
	750kW	86.31% (2)	87.64% (3)	87.96% (3)	87.46% (4)
	1000kW	87.38% (2)	88.26% (3)	88.27% (4)	87.79% (4)

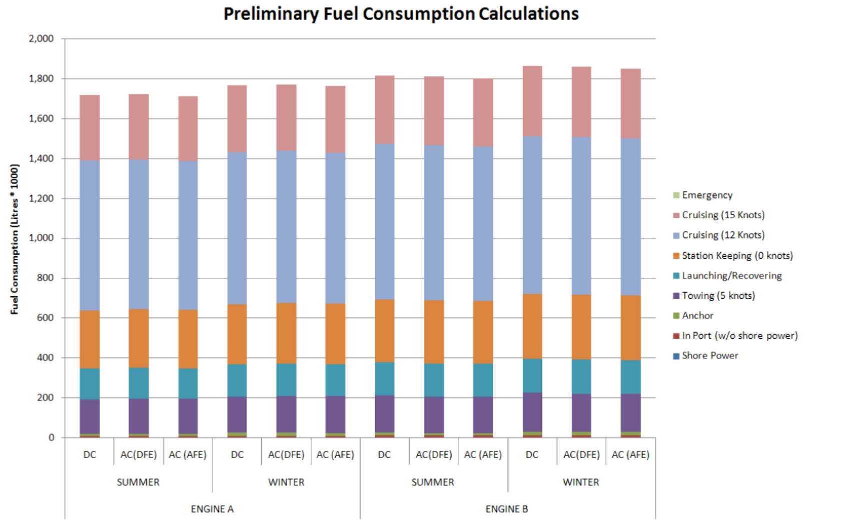


Table 5: Potential Fuel Cost Savings (USD$*1000s)

	Engine A DC	Engine A AC(DFE)	Engine A AC (AFE)	Engine B DC	Engine B AC(DFE)	Engine B AC (AFE)
Engine A (DC)		$783	$714	$15,121	$14,492	$13,075
Engine A (DFE)	$783		$1,498	$14,337	$13,708	$12,292
Engine A (AFE)	$714	$1,498		$15,835	$15,206	$13,790
Engine B (DC)	$15,121	$14,337	$15,835		$629	$2,045
Engine B (DFE)	$14,492	$13,708	$15,206	$629		$1,416
Engine B (AFE)	$13,075	$12,292	$13,790	$2,045	$1,416	

AC-DC Comparison

Item	Description	DC Benefit			AC Benefit		
		H	M	L	L	M	H
Resilient Mounting	No difference			◄	►		
Rigid Mounting	Slight benefit to DC			◄			
Electrical System Efficiency	Slight benefit to DC as losses in drive lower			◄			
Power Factor	Near unity power factor at low speeds mean better generator utilisation by the AC solution				►		
Generator Rating	Possibility to have improved generator rating with AC solution				►		
Harmonics	Different methods used by each solution. Slight benefit to AC				►		
Dimensions	AC benefits due to lack of transformer requirement				►	►	
Weights	AC benefits due to lack of transformer requirement				►	►	
Fuel Consumption	AC due to better generator utilisation				►	►	
Maintenance – Drive System	No difference			◄	►		
Maintenance – Motor	Clear AC benefit with reduced maintenance				►	►	►
Maintenance Rigid or Resilient	There is a slight benefit in rigid mounting as the maintenance costs for inspection and replacement would not be present. However, as there will be other significant equipment also requiring resilient mount (e.g. diesel generator sets, pumps, Air conditioning units, etc.), the actual increase in maintenance will be very small.						

End