Propulsion plant requirements for naval applications have seen during the last years on one side a change to mainly commercial requirements in today's procurement programs. Nevertheless on the other side vessel operators are setting up more stringent requirements for noise, vibrations and shock both to improve combat behaviour as well as to improve the comfort for the crew on their new vessels.

In parallel also the mission profiles for naval vessels have changed due to new tasks to be performed like international peacekeeping missions, fight against terrorism/asymmetrical threads, etc. These new missions and threads also influence the selection of propulsion systems.

Main driving factors for vessel and propulsion system design are tightened defence budgets, forcing the procurement agencies to scrutinize their requirements closely. They are specifying more versatile, but less sophisticated ships, looking for components-of-the-shelf (COTS) featuring reduced Life Cycle Costs (LCCs), long overhaul intervals, require low manning and allow for easy maintenance.

Selection of propulsion plant components is one of the most important factors to fulfil the above customer requirements. Individual design, specifications and test instructions of the various components do not guarantee the optimum overall performance of the whole propulsion system. Solutions for the respective technical and commercial demands with respect to the whole propulsion system and the responsibility for the complete propulsion plant in one hand will result in reduced interface problems and furthermore ensure for the operator one hand contractual responsibility for the complete propulsion system from installation throughout the lifetime of the ship.

Propulsion System Integration

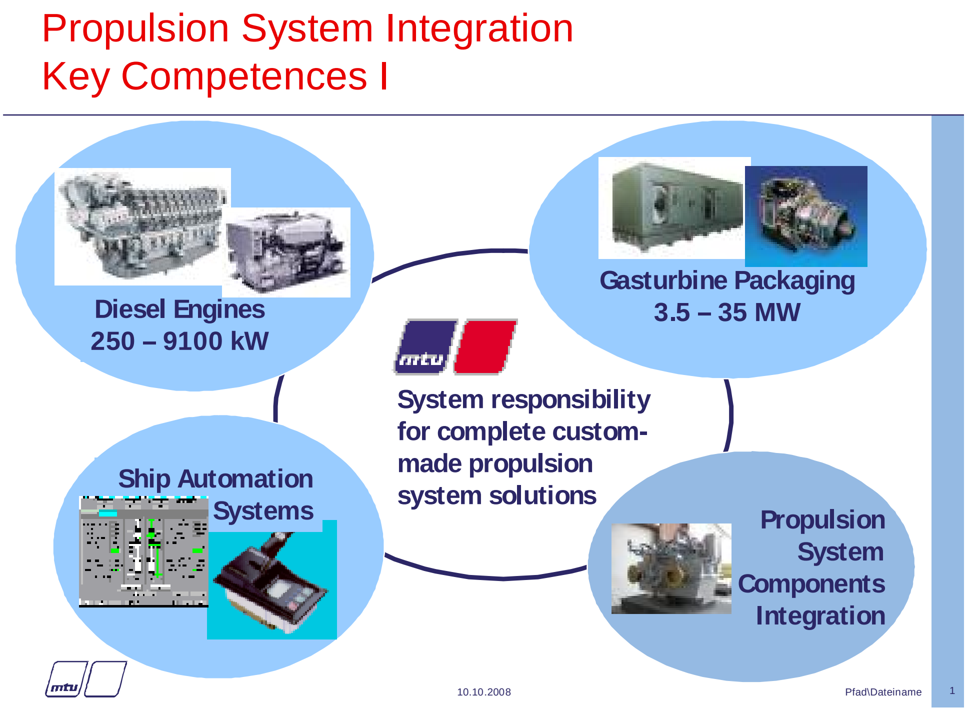
Expectations to the system integrator as well as requirements from customers are:

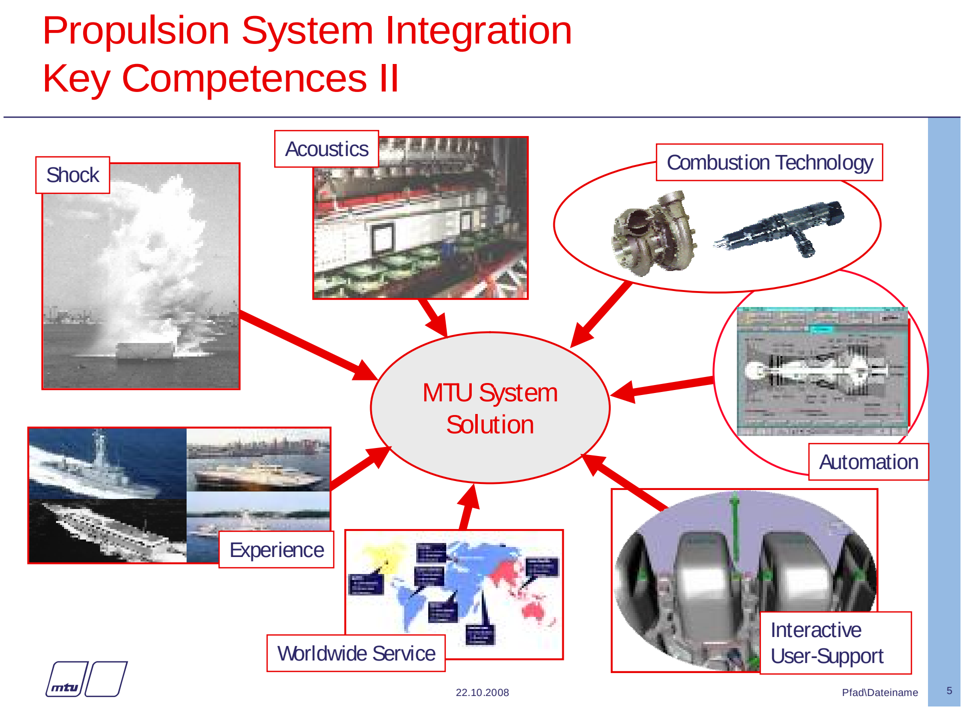
- Design and integration of ship propulsion systems into a ship system
- Solutions for respective technical and commercial demands with respect to the whole system and responsibility in one hand
- Co-ordination of system interfaces for the propulsion and machinery components
- Assistance during installation and setting to work
- Service and management of fault rectification during operation of the ship from one source independent of the individual component supplier

In the presentation the above will be detailed and various propulsion options for medium sized OPV's with comparison of performance values will be shown based on the example of the future demand of OPV's for Indian Navy and Coast Guard and also based on MTU long lasting experiences from various system integration projects.

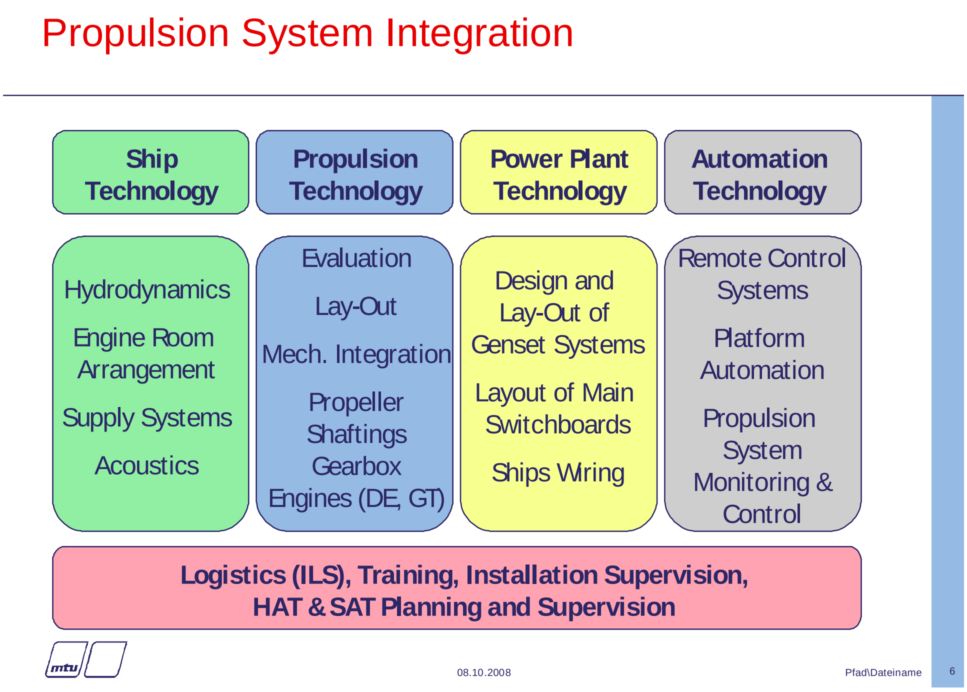
Required Key competences of Propulsion System Integrator

For carrying out propulsion system integration certain competence is required. MTU Friedrichshafen is a supplier with this key-competences:





Overview of the technical aspects and fields for propulsion system integration

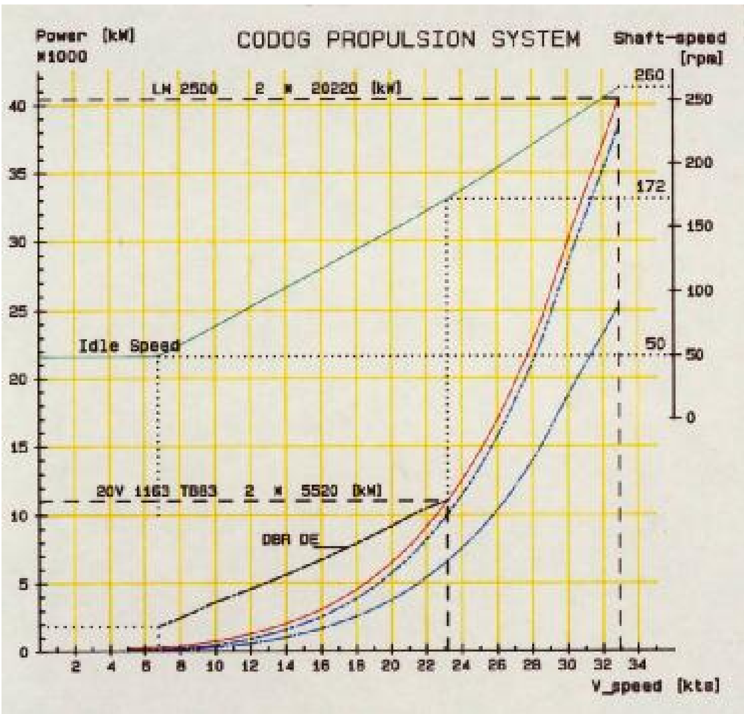


In above table the various fields for propulsion system integration is shown. In particular the following tasks must be performed:

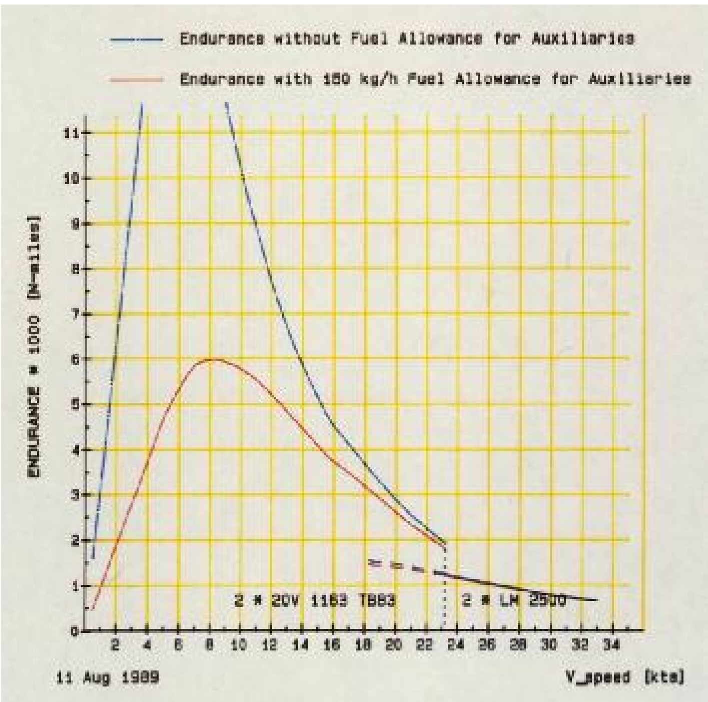
- Power demand, ship speed and endurance predictions
- Evaluation of suitable system components and recommendations for selection
- Manoeuvre simulations incl. crash stop calculations
- Mechanical and Electronical Integration
- Propulsion Train Vibration Analysis
- Acoustic analysis and optimisation of the propulsion system
- Consultancy for supply system layout
- Compete Integrated Platform Management System (IPMS)
- Integrated Logistic Services incl. Training

Examples of System Integration tasks are show below:

Determination of required power and ship speed prediction:



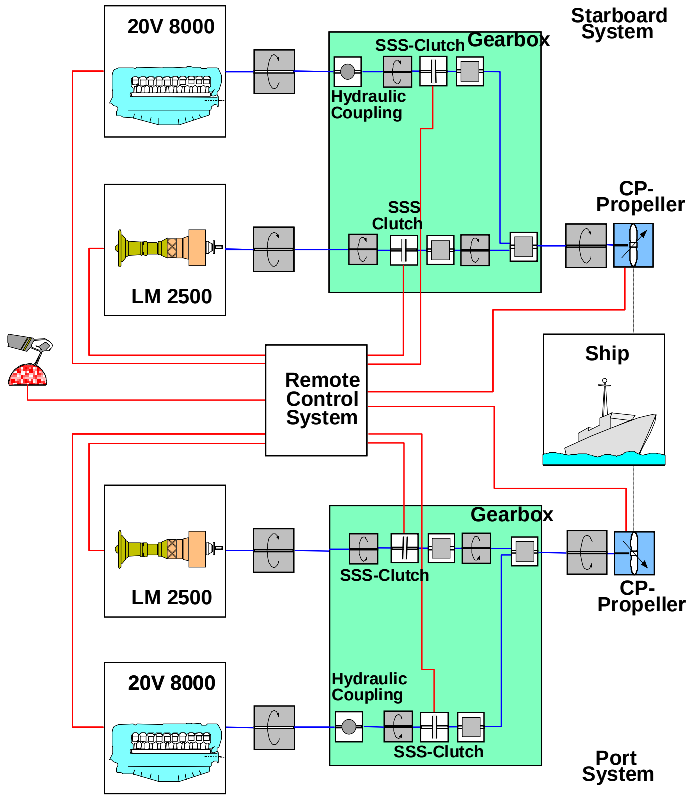
Endurance Calculation:



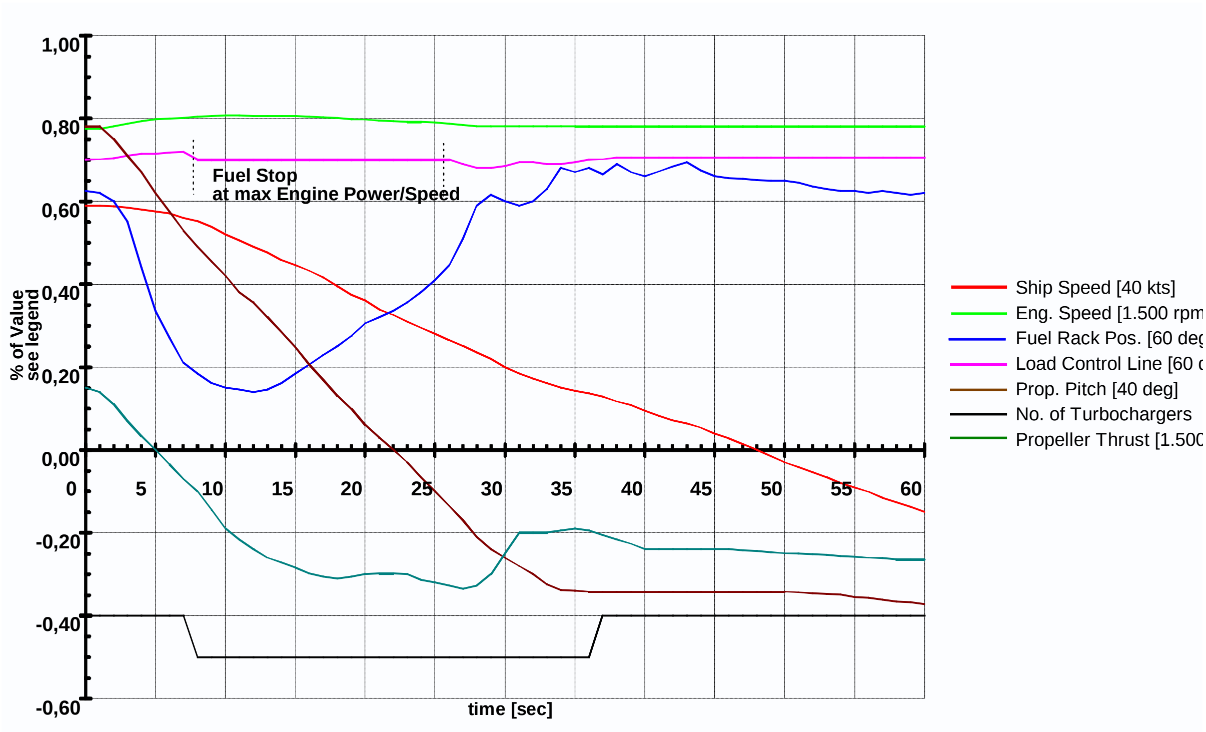
Ship Manoeuvre Simulation:

Simulation model comprising:

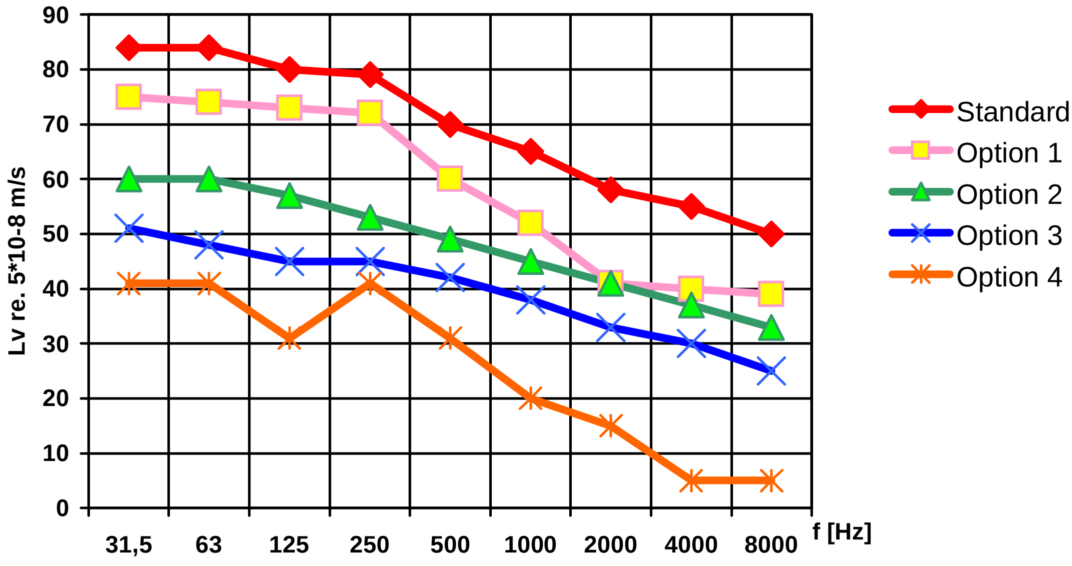
- Diesel Engine
- Gas turbine
- Gearbox
- Propeller
- Ship characteristics



Example Crash Stop simulation

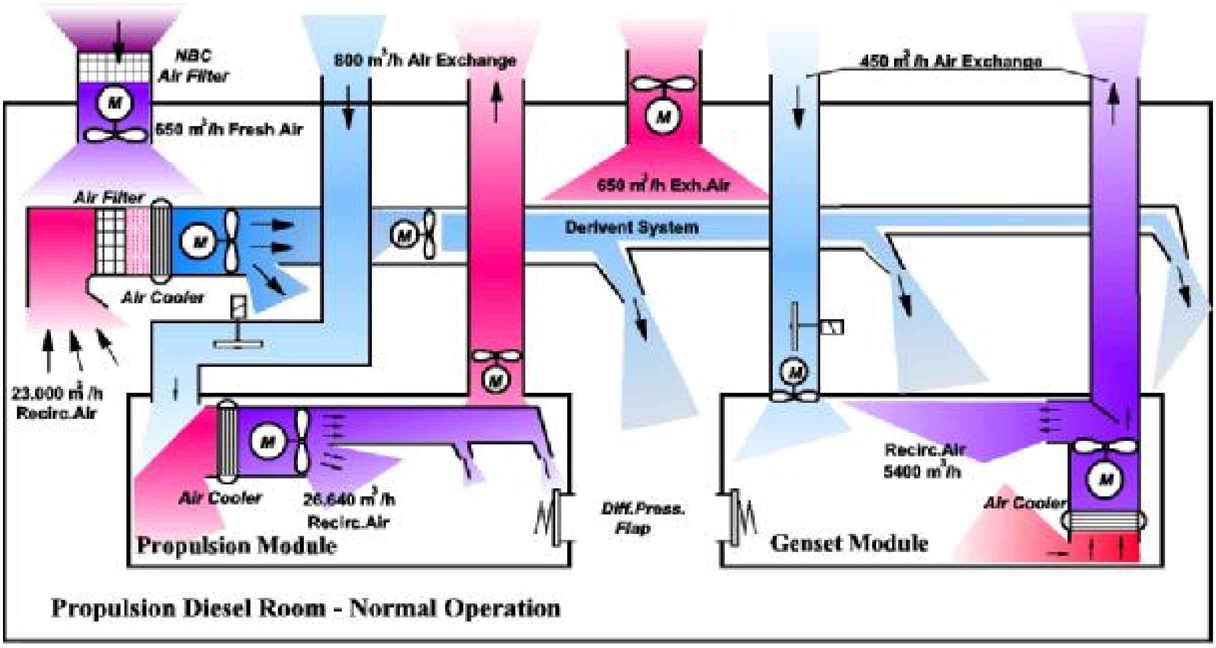


Mounting System Design:
(Selection and design of resilient mounting system)

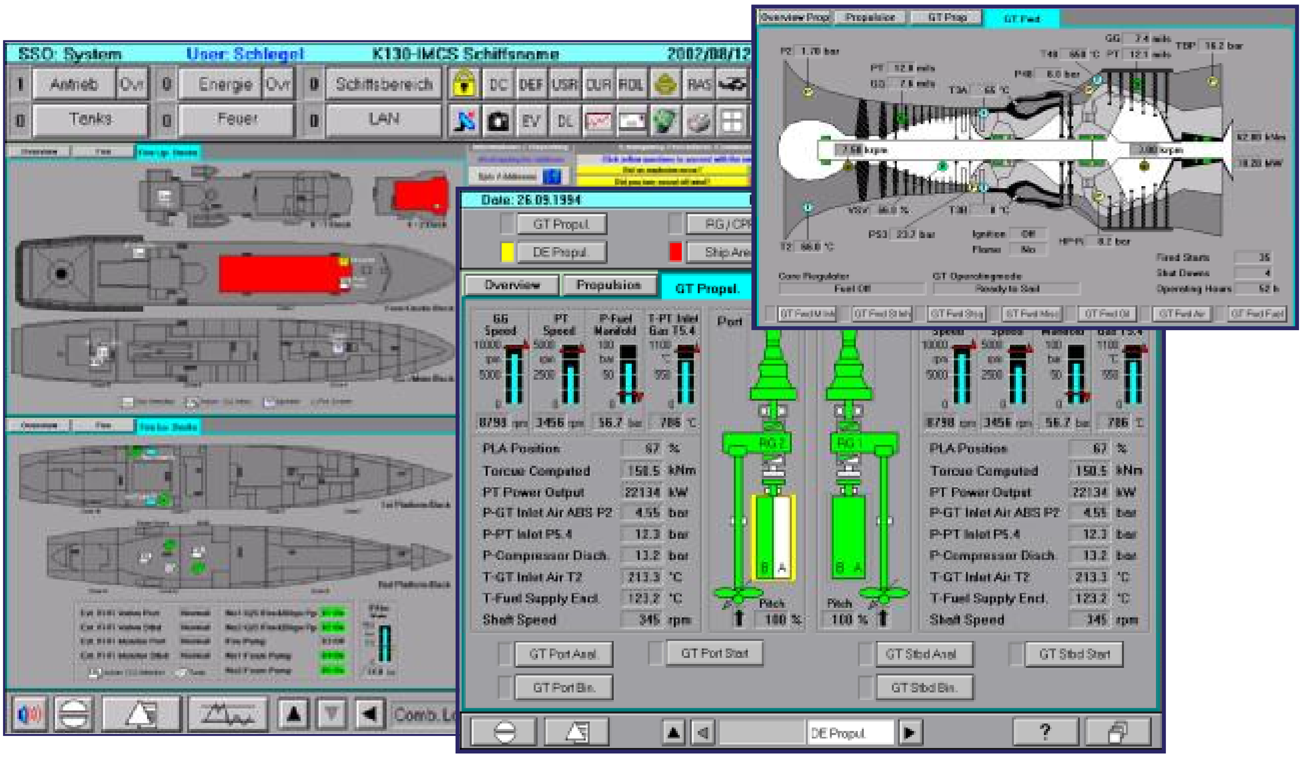


The diagram is showing possible structure borne noise levels depending on mounting system design. Shown is a comparison of from standard single resilient to special double resilient mounting system including sound enclosure.

Supply System Design:
(Example Engine Room Ventilation System with NBC Condition)



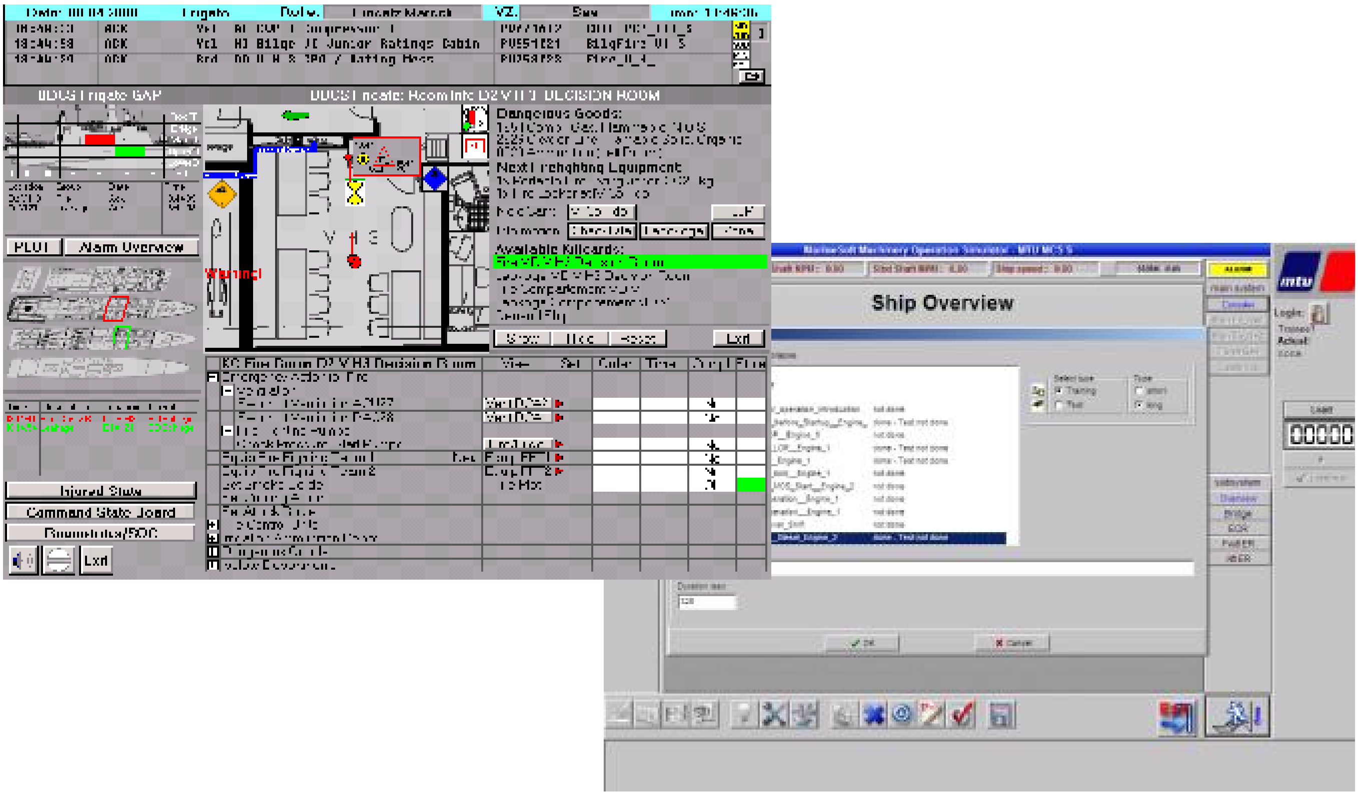
Propulsion Plant Automation:
(Example pages: Ship area-, Propulsion plant- and GT- monitoring)



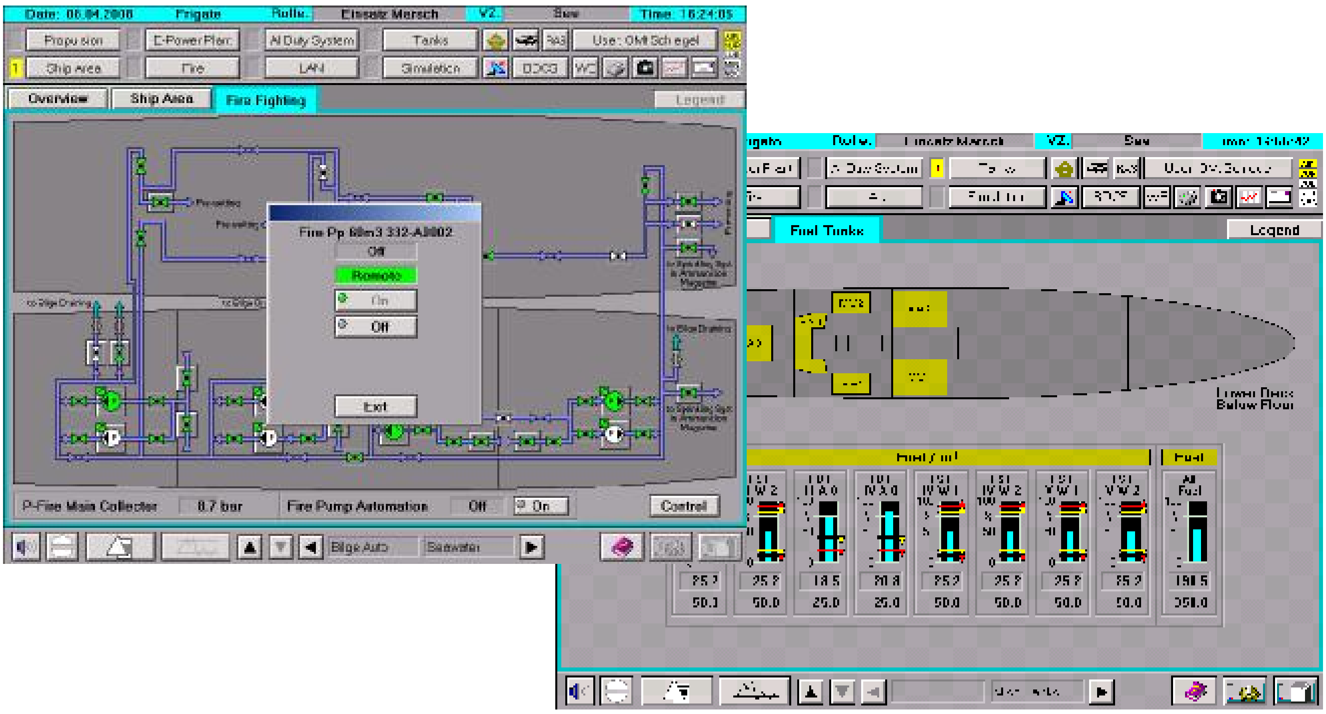
Extensions and Options in the responsibility of System Integrator with respect to Propulsion Plant Automation:

- ***Consoles***
  Tailored to application and customer specific requirements.
- ***Machinery Telegraph System - MTS***
  Emergency back-up system.
- ***Electrical Power Management - EPMS***
  Electric Power Management System with data link to the Ship Automation
- ***Fire Detection System - FDS***
  Fire Alarm and Detection System with data link to the Ship Automation
- ***Battle Damage Control System (BDCS)***
  Tailored to application and customer specific requirements.
- ***On Board Training System (OBTS)***
  Tailored to application and customer specific requirements.
- ***Accessories***
  Approved and tested cables, sensors, solenoids, actuators, etc. to optimize interfacing and sourcing.
- ***Further extensions***
  Navigation systems, radar, ECDIS, communication systems, voyage data recorder, CCTV systems, with data link to the Ship Automation

Example “Killcard” BDCS and Overview OBTS:



Example FIFI system and and Tank Monitoring system:



Examples / MTU references of Propulsion System Integration

MTU has successfully performed PSI for various propulsion systems

MTU accumulated PSI analysis know-how for both mechanical and electronical interfaces

MTU delivers and takes over the responsibility for hardware and services for complete propulsion systems

MTU is fully capable of dealing with GE LM2500/+/G4 engines as a certified marine gas turbine packager

References of Propulsion System Integration by MTU:

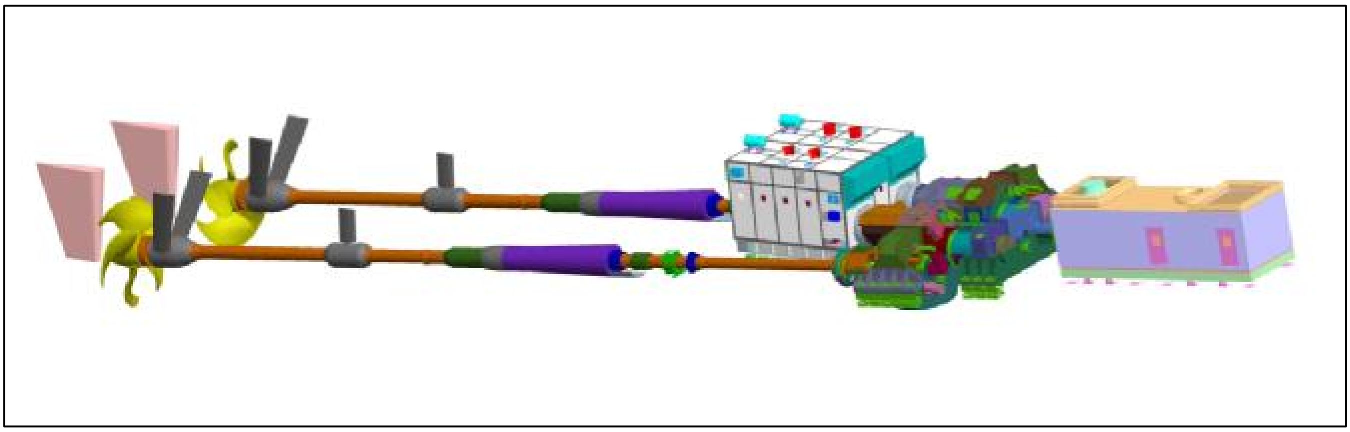
- KDX I, Republic of Korea Navy
- Milgem Corvette, Turkish Navy
- Corvettes „Baynunah“, UAE Navy
- National Security Cutter, US Coastguard
- X-Craft „Sea Fighter“, US Navy
- various Patrol Vessels

New Corvette Program Milgem (Turkish Navy):

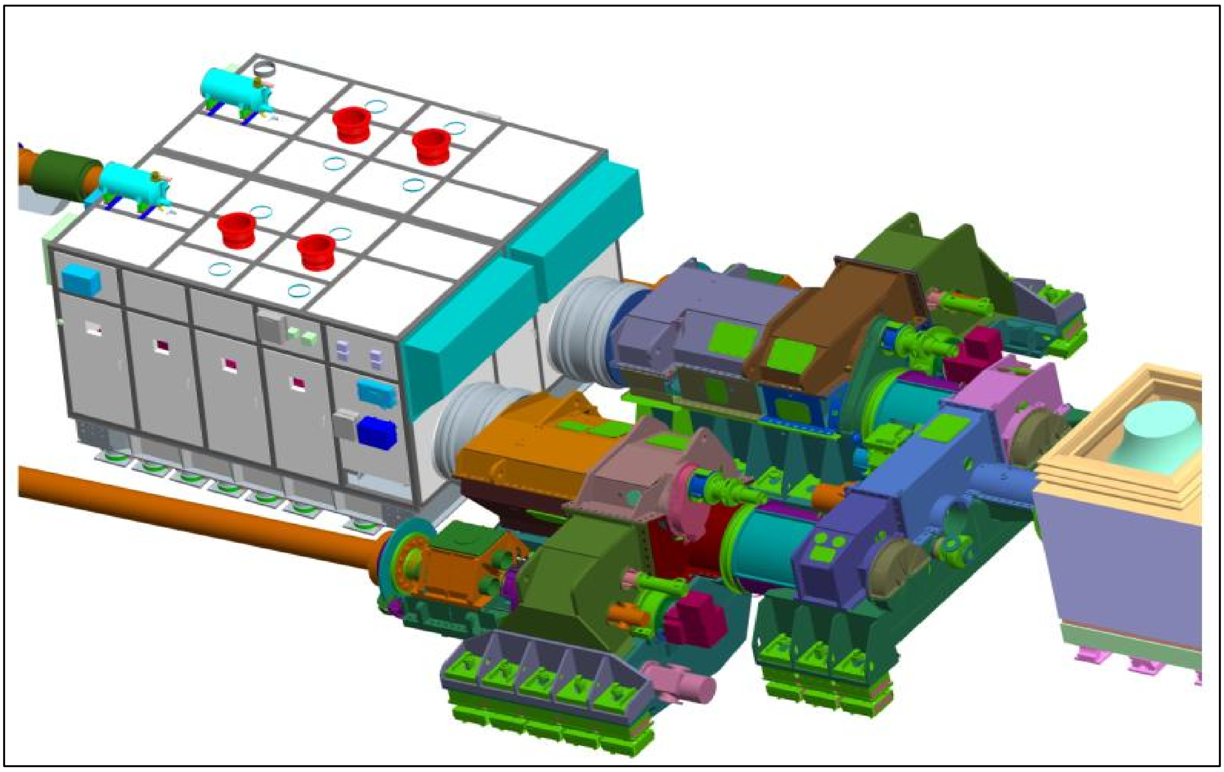
Length: 99 m,
Beam: 14.4 m,
Draft: 3.75 m
Displacement: 2000 t ,
Max. Speed: > 29 kn

MTU Scope of Supply MILGEM:

- 2 x MTU16V 595 TE90 DE in sound enclosures
- 1 x MTU LM2500 GT in MTU module
- RENK CODAG gearboxes
- VA Tech Escher Wyss Shafting and Propellers
- Machinery Control System MCS-5 and RCS-5



Propulsion Plant overview

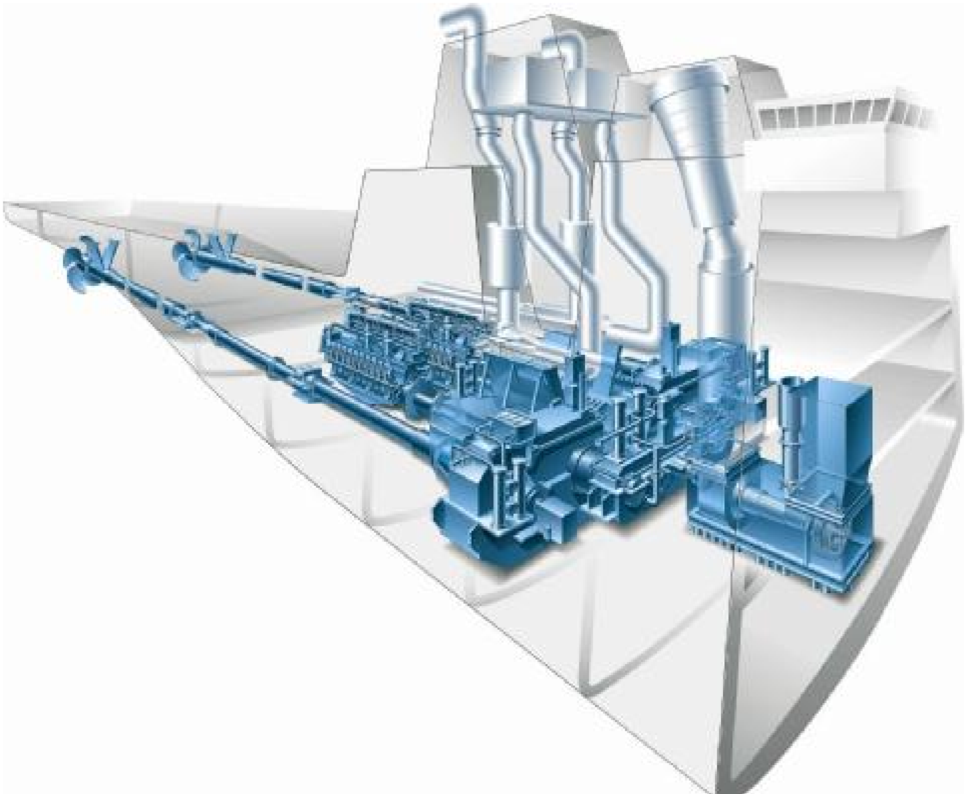


Detail of Propulsion Module “MILGEM”

National Security Cutter (USCG):

MTU Scope of Supply:

- 2 x 20V 1163 TB93 Diesel Engine
- 1 x GE LM2500 Gas Turbine
- Renk CoDAG gearboxes with Cross Connect
- 2 x RR Shaftlines and Propellers
- Propulsion Monitoring Control System and Remote Control System



Propulsion Plant Arrangement NSC

Propulsion plant selection

Criteria for propulsion plant selection:

- Required Vessel Speed / Power Requirement
- Through Live Costs (Invest costs, Fuel costs, Maintenance costs..)
- Manning considerations
- Space / Weight Restrictions
- Vessel Operating Profile
- Redundancy / Safety considerations
- Shock / Noise Requirements

A propulsion plant selection study using the new OPV planned by the Indian Coast Guard as an example was performed considering the following vessel data:

Length:	90 m
Beam:	12 m
Draft:	6 m
Displacement	1800 to

Calculation of power requirement based on vessel data:

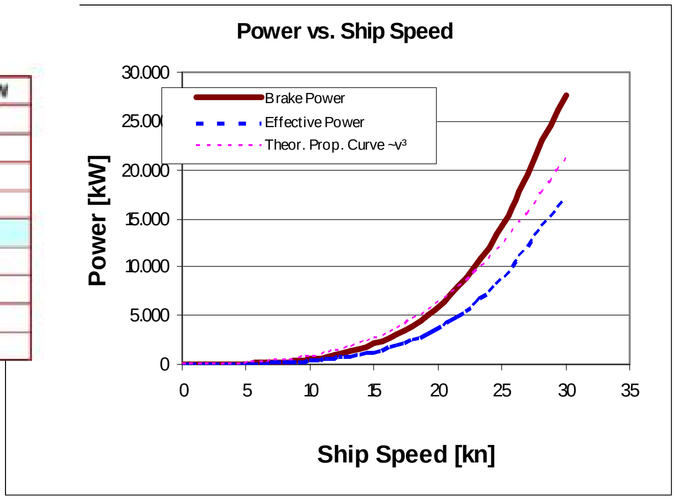
Length:	90,0 m		
Beam:	12,0 m		
Draft:	6,0 m	Finess Coefficient =	7,48
Displacement:	1.800 t	Block Coefficient =	0,27
Type of Hull:	R Round Frame	B/D =	2,00

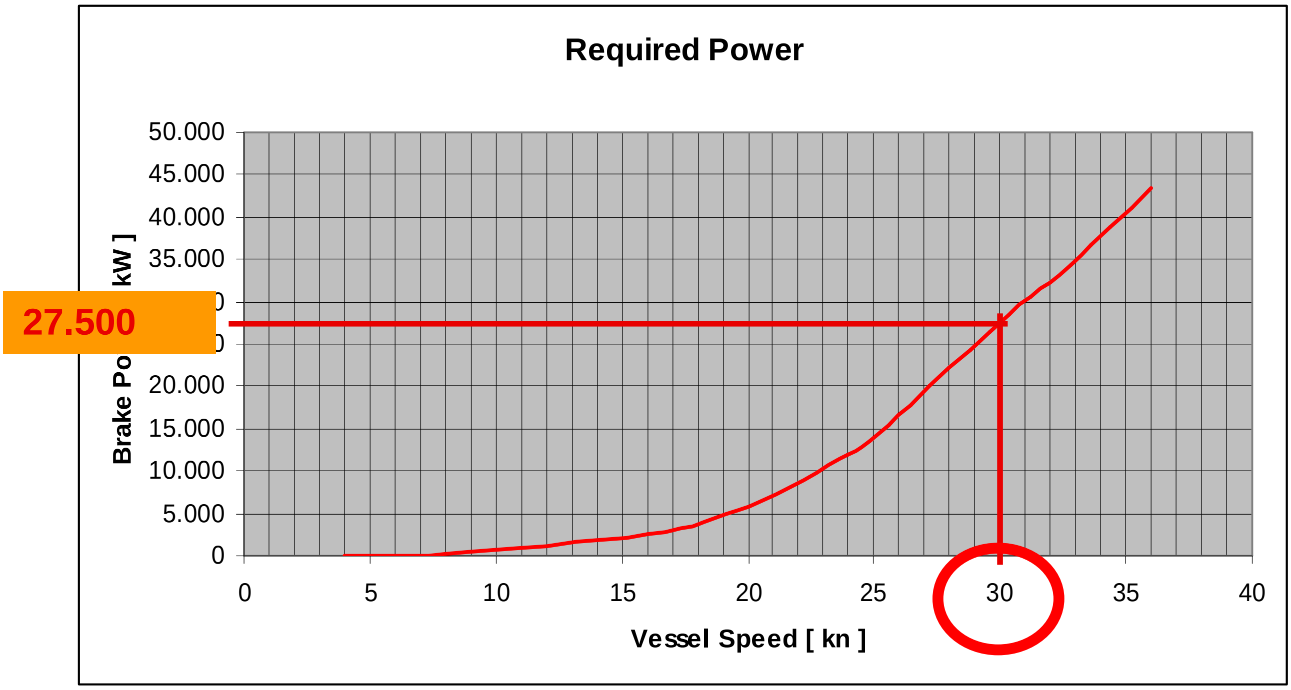
Desired Speed:	29,0 kn	
Max. Avail. Engine Power:	27.300 kW	
		Defaults:
Additional Fouling Resistance:	0,0%	*0% clean hull, 17% after 6 months*
Estimated Propulsor Efficiency:	66,0%	65,0%
Estimated Gear Efficiency:	96,5%	97,5%
Estimated Shaft Efficiency:	98,0%	98,0%
Gear and Shaft Efficiency:	94,6%	

	desired:	achieved at: 27.300 kW
Speed:	**29,0 kn**	**29,83 kn**
Thrust:	106.318 kp	111.411 kp
Propulsion Power:	15.403 kW	16.758 kW
Shaft Power:	23.697 kW	25.782 kW
Engine Power:	**25.057 kW**	**27.262 kW**
Wave Resistance:	56.884 kp	60.270 kp
Friction Resistance:	32.636 kp	34.429 kp
Total Resistance:	89.520 kp	94.699 kp
Froude Number:	0,502 p.u.	0,516 p.u.

3x 20V8000 (3x 9100 kW)

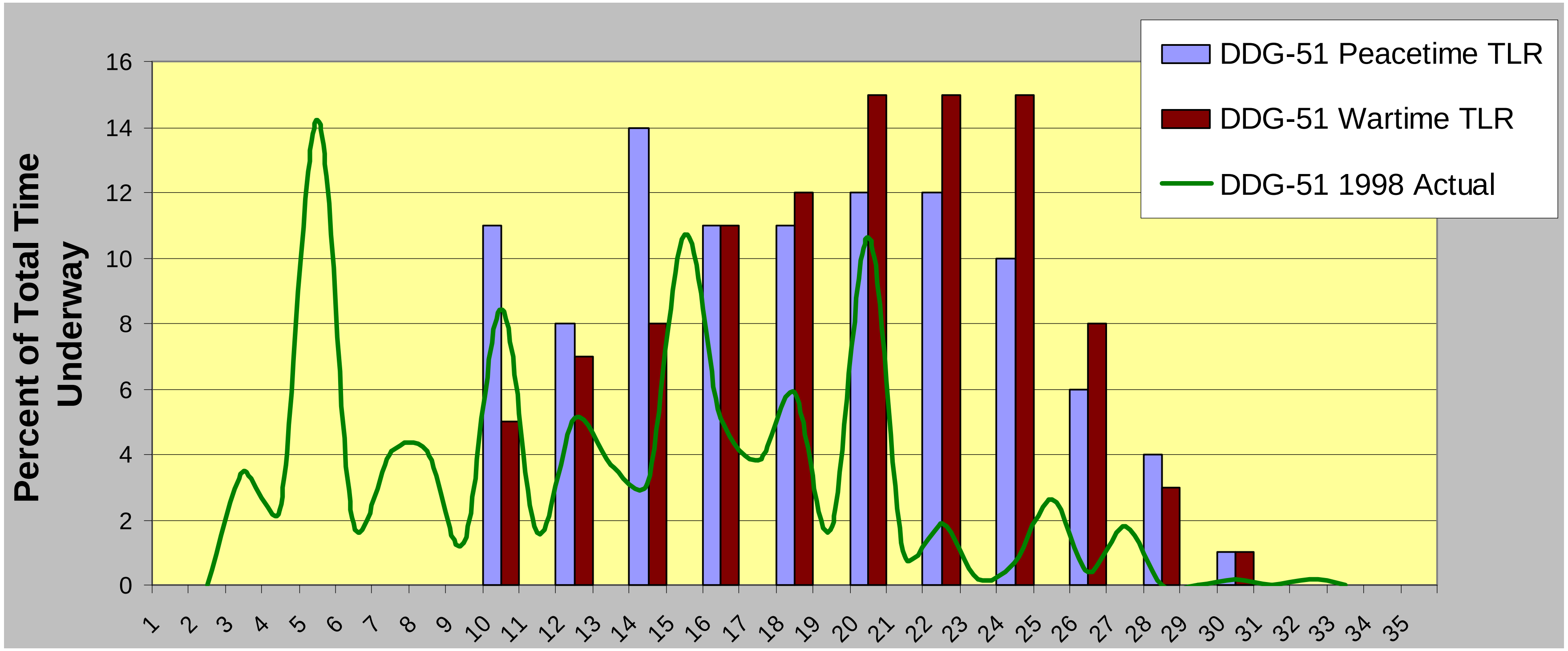
29,8 kn





Resistance curve

Vessel Operating Profile (only example)



Design Requirements vs. Actual Profile

As power requirement increases with vessel speed on cubic law, vessel speed requirement should be questioned in detail during design phase.

Comparison of possible propulsion plant options

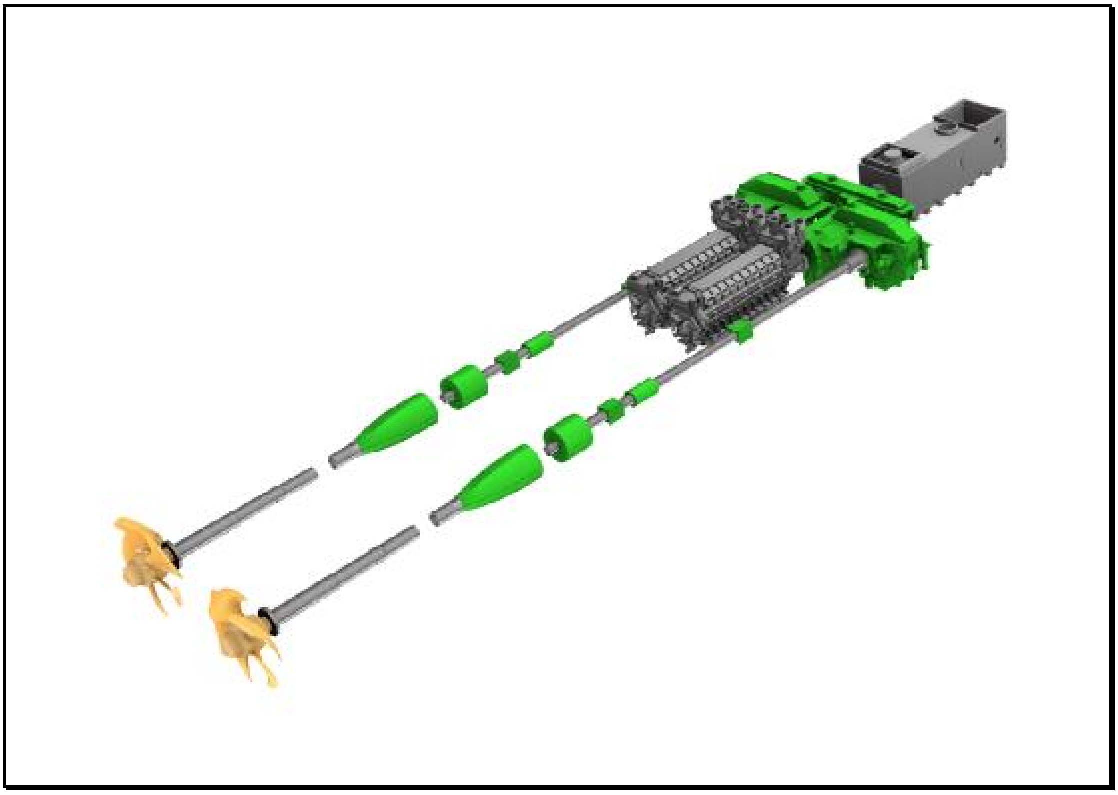
(Vessel speed versus budgetary costs and propulsion plant weight - only engines and gearboxes - without shafting and propeller)

Configuration	Engine-type	Power engine [kW]	Power total [kW]	Estimated Vessel speed [kn]	Estimated Budgetary cost (engines+gearboxes) [%]	Estimated weight (engines+gearboxes) [tons]
2-shaft Direct Drive	2 x 20V 8000	9100	18200	26,5	100	140
3-shaft Direct Drive	3 x 20V 8000	9100	27300	29,8	148	210
2-shaft CODAD with Cross-connect GB	3 x 20V 8000	9100	27300	29,8	166	230
2-shaft CODAD (U-Arrangement GB)	4 x 20V 8000	7200	28800	30,3	159	255
2-shaft CODAD (U-Arrangement GB)	4 x 20V 8000	8200	32800	32,0	177	262
2-shaft CODAD (U-Arrangement GB)	4 x 20V 8000	9100	36400	33,3	193	268
2-shaft CODAG with Cross-connect GB	2 x 16V4000 1 x LM 2500	2880 20000	25760	29,3	190	130
3-shaft 2-shaft Diesel plus 1 Booster WJ	2 x 16V4000 1 x LM 2500	2880 20000	25760	29,3	155	67
3-shaft 2-shaft Diesel plus 1 Booster WJ	2 x 20V 8000 1 x LM 2500	7200 20000	34400	32,6	223	143

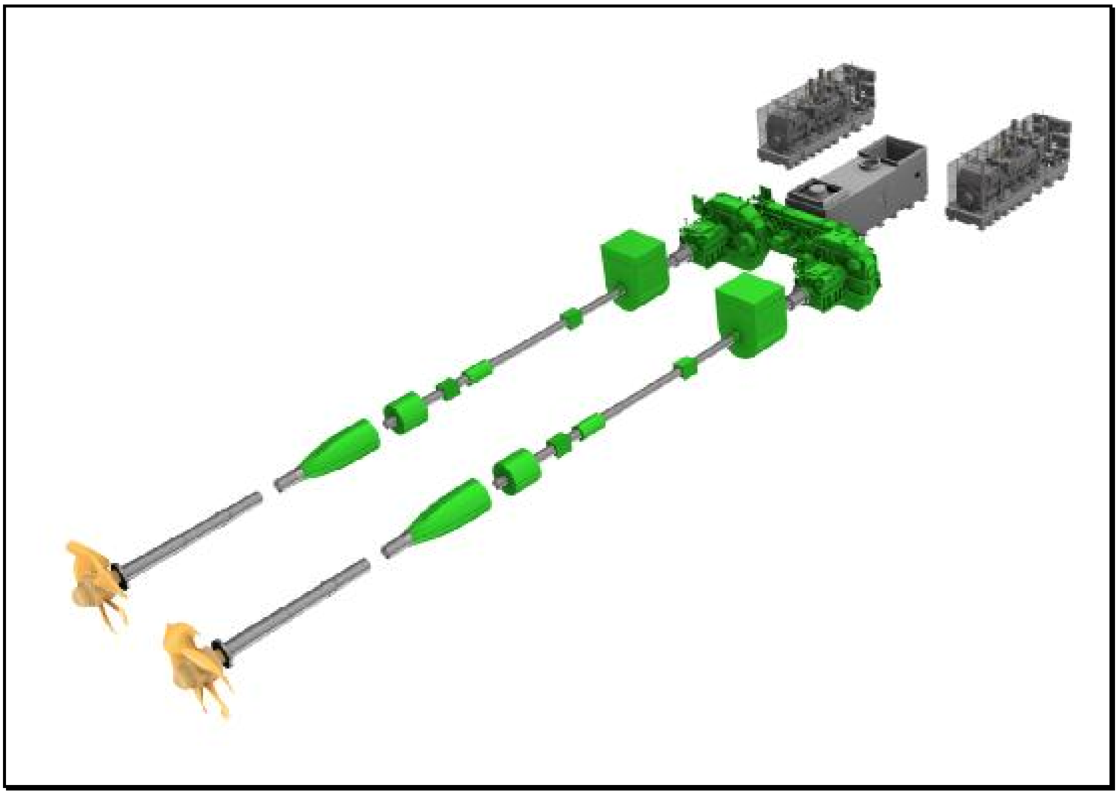
In the following table some Pros and Cons are shown for various propulsion plant configurations:

	"Pros"	"Cons"
Diesel medium speed	efficiency, endurance	power density
Diesel high speed	power density, efficiency	---
Gas turbine	power density, high power output	efficiency, invest. cost
(Nuclear)	*high output, AIP, endurance*	*investment cost, LCC*
(Fuel cell)	*noise signatures, AIP*	*invest. cost, low power output*
Combined Propulsion Systems		
CODAD	cruise + sprint, efficiency	power density
COGAG	cruise + sprint, power density	Investment cost, efficiency
CODOG	cruise + sprint, efficiency	investment cost
CODAG	cruise + sprint, power density	investment cost
All-electric with D/ E	LCC, efficiency	Investment cost, power density
All-electric with GT	power density + high output	Investment cost, LCC

CODAG propulsion plant on CPP:



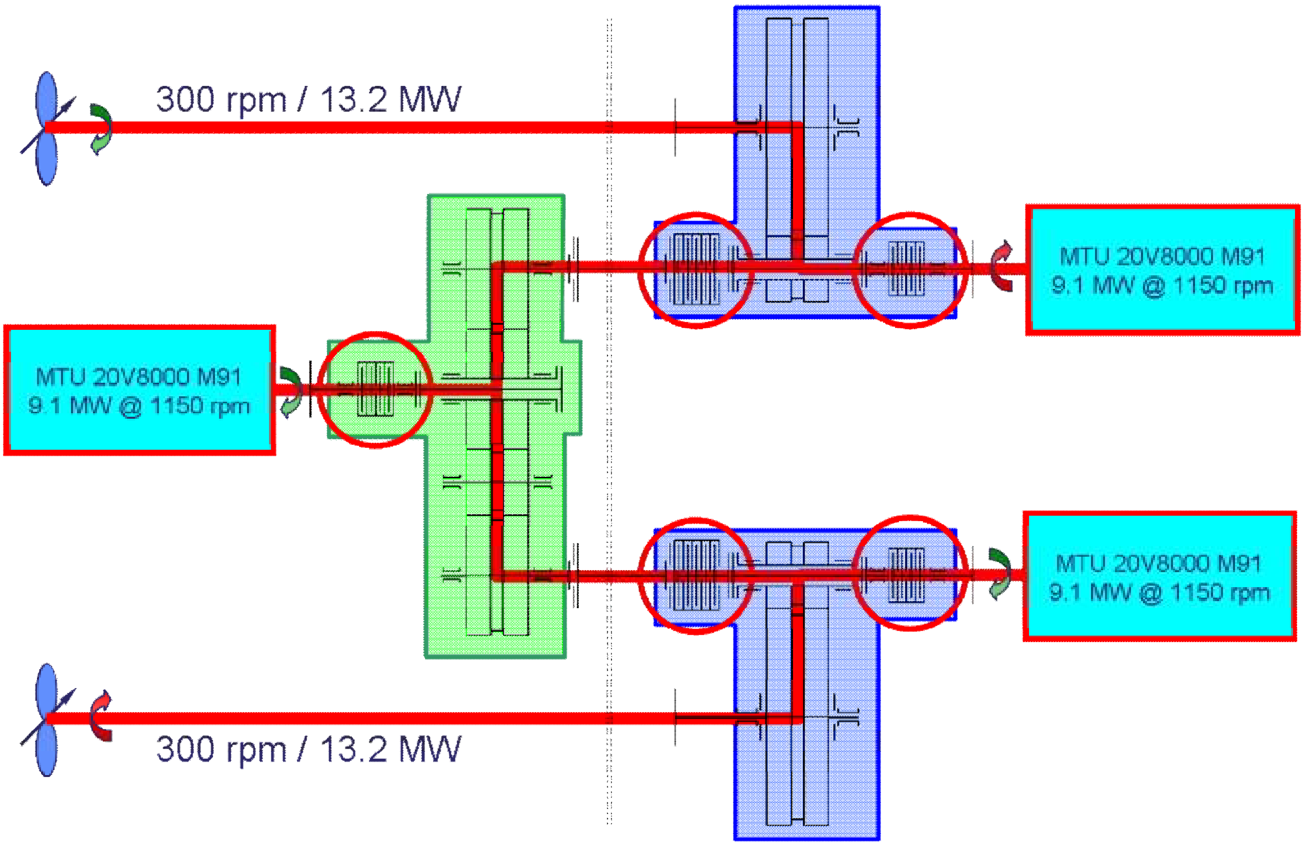
CODELAG propulsion plant on CPP:



Redundancy and survivability considerations:

Combined propulsion plants offer some advantages with respect to redundancy and survivability which also must be considered when finally selecting the propulsion plant configuration.

As an example this is shown for the 3-engine / 2-shaft CODAD propulsion plant:.



Type of Damage	Remaining Operating Modes
One diesel inoperable	Other diesel engines (one or two) operating on both propellers
Two diesels inoperable	Third DE driving one or two propeller shafts
Cross connect gear inoperable	Each front diesel drives its own propeller shaft
One main gear and cross connect gear inoperable	Diesel on other main gear drives referring shaft
Aft DE compartment flooded	Front DE can operate without restrictions
Front DE compartment flooded	Aft DE driving one or two propeller shafts

Summary of Customer requirements and key selection criteria for propulsion plant:

These are:

- Invest cost (Value for money)
- Life Cycle Costs, dominated by fuel consumption
- Reliability / Availability / Maintainability
- Low-load operation capability
- Capability to run in single engine operation efficiently
- Good manouevring characteristics
- Compact design, saving space for mission payload and/or crew
- Logistic support (parts, documentation, training, service)
- Logistic commonality with other vessels in the fleet
- Redundancy
- References

Conclusion

- The propulsion system is elemental for the vessel's operational economy and flexibility.
- Careful system analysis, careful selection of the propulsion plant components and respective integration into the system „ship" is a vital requirement for the customer.
- Propulsion system integration requires competent and experienced propulsion system integrator with know-how for both mechanical and electronical/automation components integration.

Customer Advantages and why Propulsion System Integration by MTU

- One hand contractual responsibility for the complete propulsion system, both for the mechanical systems and components as well as for electrical/automation system and components
- Proven system integration know-how and experience
- Full assistance from design phase to commissioning of the vessel and throughout the further vessel lifetime
- Single source logistics for the Navy
- Holistic problem solving during commissioning, trials and the in-service period
- Reduction of technical and commercial risk, necessary manpower and administration complexity on the shipyards side

MTU takes over the system integrator role when also being selected as propulsion system supplier

MTU can be Your Partner for:

Propulsion System Integration

Contact:

marine@mtu-online.com