C4FF Developing the Future

MariEMS - An Investigation into Making Ships Cleaner and More Energy Efficient

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Summary of the Lecture

Areas for improvement

- Ship operations
- Ship design
- Technology applications
- International response
- Thinking out of the box

SHIP OPERATIONS - AREAS FOR IMPROVEMENT

- Slow steaming
- Weather routing
- Green energy – wind and sun (Flettner rotor & sun panels)
- Use of sea currents
- e-navigation
- Ballast water management
- Hull and trim optimisation
- Ship-port and port-ship system integration
- Port-road-train-airport system integration
- On-board ship management
- AI and VR applications – Virtual arrival, advanced communications, JIT, predictive Analytics

DESIGN

How to reduce resistance to motion – Hull Cleaning, Propeller Retrofit (MAN PrimeServ), etc. vs Sea currents

How to make propulsion more efficient – New vs Retro Cutting a Turbo, or adding an intercooler, etc.

- Propulsion – Gas? Electric? Nuclear? – LNG?
- IMO SEEMP – Energy Efficiency Design Index (EEDI)
- Predictive ship life cycle – IMO vs C4FF

INTERNATIONAL RESPONSE

Cause for concern - continued dependence on fossil fuel

- International Efforts
- Energy sources and security
- The impact of air emissions
- Energy management
- IMO efforts – MARPOL Annex VI Chapter 4
- EU efforts
- Societal responsibilities

TECHNOLOGIES THAT CAN HELP

- Artificial Intelligence (AI) – Parametric Relationships, Predictive Analytics. Etc.
- Virtual Reality – Ship Design, Training, etc.
- Wind Cylinders – Mangus effect (air at right angle)
- JIT - production, ship and/or port operation
- Novel e-navigation

Crazy Ideas?

Innovation is ‘not business as usual’

- Flettner rotor, wind turbines
- Application of AI in ship automation and self-optimisation;
- Application of Quantum Physics
- Water injection

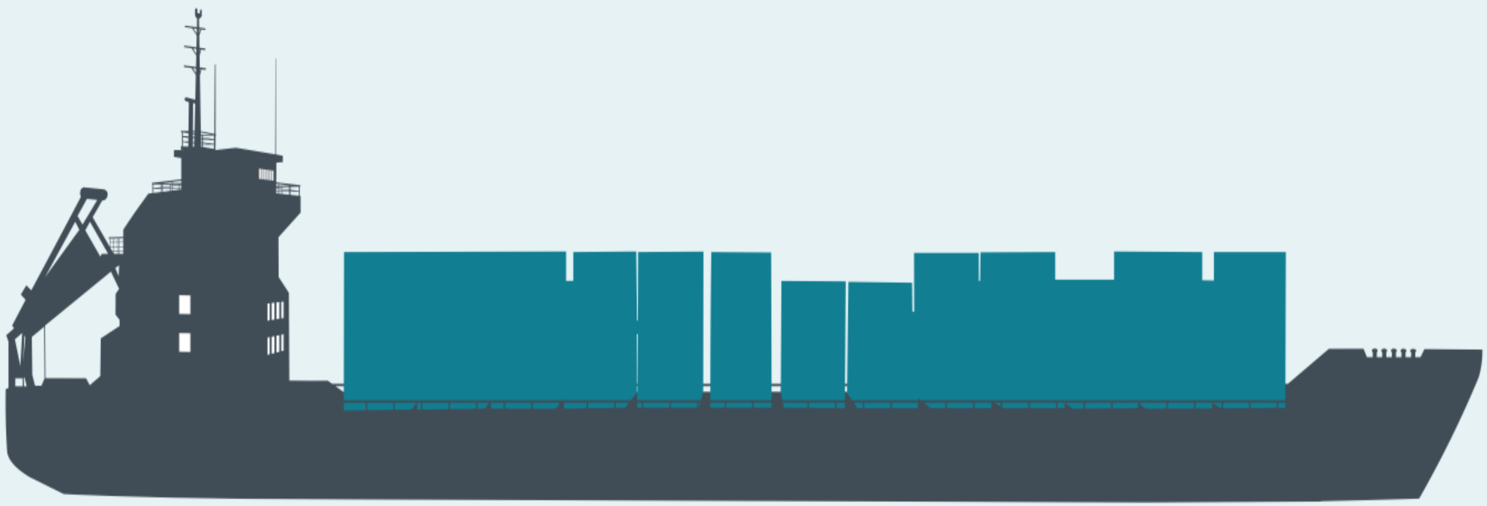
Will come to these crazy ideas which in some case have proven not to be that crazy! But let us go through not so crazy ideas first.

Potential Areas for Energy Efficiency

Operational
Weather routing **1-4%**
Autopilot upgrade **1-3%**
Speed reduction **10-30%**

Auxiliary power
Efficient pumps, fans **0-1%**
High efficiency lighting **0-1%**
Solar panel **0-3%**

Aerodynamics
Air lubrication **5-15%**
Wind engine **3-12%**
Kite **2-10%**



Thrust efficiency
Propeller polishing **3-8%**
Propeller upgrade **1-3%**
Prop/rudder retrofit **2-6%**

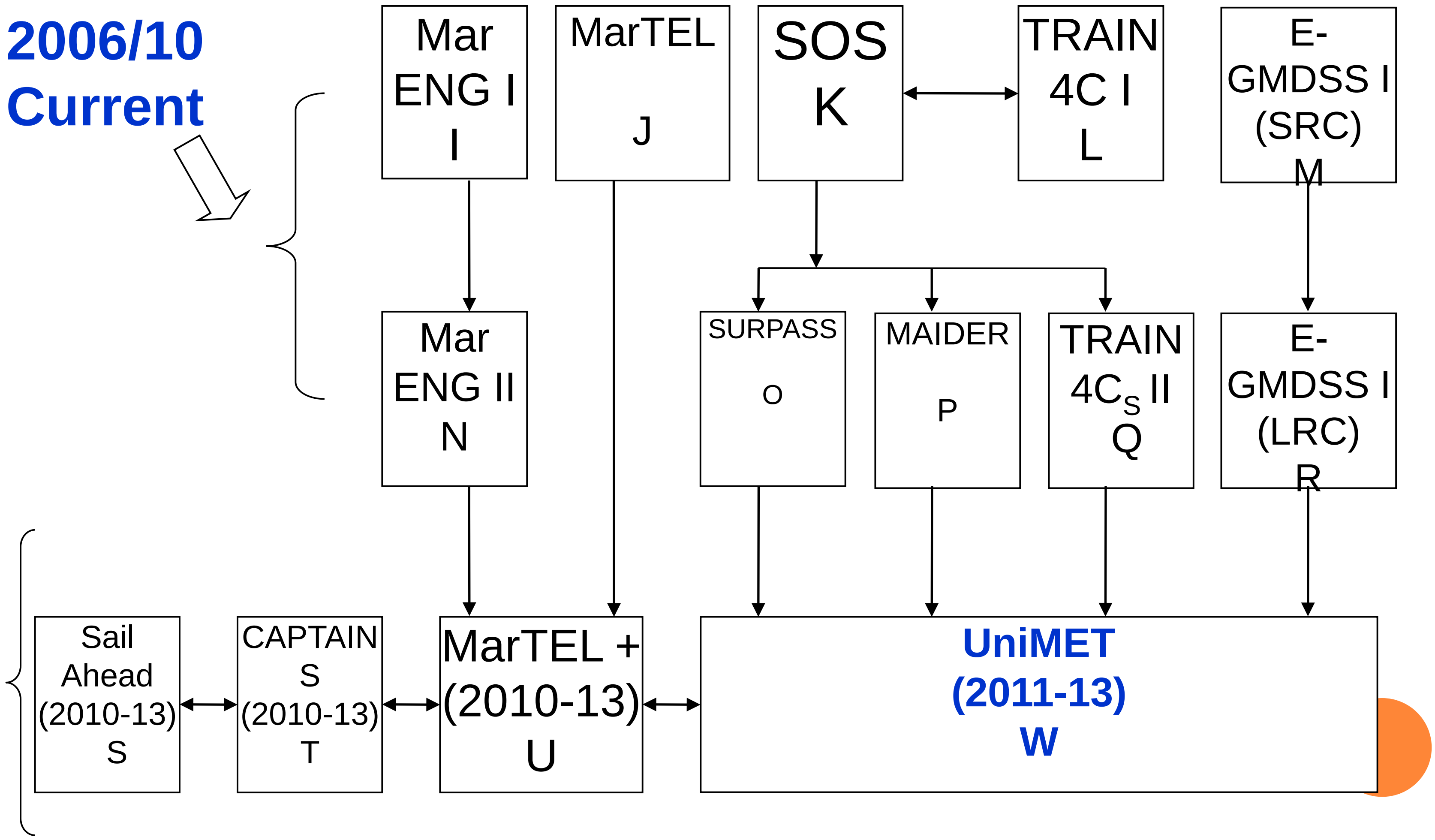
Engine efficiency
Waste heat recovery **6-8%**
Engine controls **0-1%**
Engine common rail **0-1%**
Engine speed de-rating **10-30%**

Hydrodynamics
Hull cleaning **1-10%**
Hull coating **1-5%**
Water flow optimization **1-4%**

KMTC LINE
KMTC
NORDSKY
LIMASSOL
IMO8801345
HYUNDAI
NKK


SPRINTER
WERKENDAM

MariFuture Initiated Funded Projects 2007-2013 – www.marifuture.org



MariFuture Funded Projects 2013-2017 and 2016-2019

MARIFUTURE

- Avoiding Collision at Sea Project ACTS 2013-2015 X
- STCW Revision Implementation 2012-15 Project SeaTALK Y
- Port Security and operation and IdealPort 2013-2017 Z
- Ship Efficiency EBDIG-WFSV and LeanShip 2013-2017 AA
- Making seafaring more attractive Projects SOS and MarÍne 2013-2017 BB

Recently concluded project:

- **MariePRO – Marine Evironement Awareness (IMO Model course revised)**

Current projects 2016-2018/19

- **<u>MariEMS</u>; MariLANG; ACTS Plus**

History

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- http://www.c4ff.co.uk/history/papers/One_dimensional_unified_flow_Program.pdf
- http://www.c4ff.co.uk/history/papers/Incidence_Loss_Model.pdf

HTTP://WWW.C4FF.CO.UK/HISTORY/PAPERS/EARLY_BATH_UNIVERSITY_REPORTS.PDF

HTTP://WWW.C4FF.CO.UK/HISTORY/PAPERS/AUTOTECH_95_PAPER.PDF

HTTP://WWW.C4FF.CO.UK/HISTORY/PAPERS/HIGH_PRESSURE_FUEL_INJECTION_SYSTEM.PDF

HTTP://WWW.C4FF.CO.UK/HISTORY/PAPERS/LLOYDS_SUPPORT.PDF

Hybrid Car and Bus Design

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Drive Time

EVENING MAIL, WEDNESDAY, NOVEMBER 2, 1994 7

GREEN MACHINE

A DREAM bus which doesn't pollute the atmosphere could soon be on the road — thanks to pioneering research at a Birmingham university.

Engineers and academics have teamed up at the University of Central England in Perry Barr to design an environmentally friendly engine that will cut pollution.

The hybrid engine is partly diesel and partly electric and has been dubbed FLEETS — for Friendly Low Energy Efficient Transport Systems.

Prof Reza Ziarati says the engine is designed to run on diesel for long distances but can be converted to electric at the flick of a switch when the driver moves into heavy traffic.

REPORT BY KATIE WATSON

He believes that the design will reduce the level of harmful emissions caused by traffic having to stop and start in jams.

The team, made up of engineers from the Motor Industry Research Association and the university, hopes to start building the bus at the end of the year.

"I think that in about 15 years, cities will no longer allow petrol and diesel cars into their centres," says Prof Ziarati. "People are becoming more aware of the dangers.

"That is why we have concentrated on public transport first — but we also have designs for a van using the hybrid engine.

"It is a race and we want to be the first, not only Birmingham but in the entire country," he says.

Paul Wylie, director of distributions for Royal Mail Midlands, says the company would be very interested in trying out the vans.

"This idea is certainly worth evaluating. We have about 510 vehicles on the roads in the city and we would be prepared to look very closely at this," he says.

West Midlands Travel has also expressed interest in the hybrid bus.

"We are always interested in new developments and we would certainly not close our minds to this," says a spokeswoman for the bus company.

Pollution

"We are aware of the pressure from environmental groups about harmful emissions and pollution, and we do keep an eye on the market for any new developments."

But pressure group Friends of the Earth is in two minds.

"We need more investment in public transport and this bus sounds like a good idea but we need to educate people away from their cars," says campaigns co-ordinator Barbara Cumblidge.

Stop-start

Greenpeace spokesman Charlie Kronick says he cannot see the point of a bus having a hybrid engine.

"Buses spend most of the time in a stop-start situation so they might as well have a purely electric engine," he argues.

Work on the engine is due to start in December and Professor Ziarati hopes that the bus will be ready for demonstration within the next three years.

FIRST EDITION Evening Mail

European Boat Design Innovation Group (EBDIG) – Learning from the Automotive Industry

EU Leonardo Transfer of Innovation Programme

Partners: Coventry University, TU Delft, **University of Genoa**, Ricardo, TUDEV Institute of Maritime studies in collaboration with Centre for Factories of the Future (C4FF)

Website: http://www.ebdig.eu

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Best IRTE Lecture 1995
Best Paper 1996

http://www.c4ff.co.uk/history/papers/Emerging_transportation_system.pdf

Key factors and Limits of Thermal Efficiency

MariFuture - Key Recent Developments

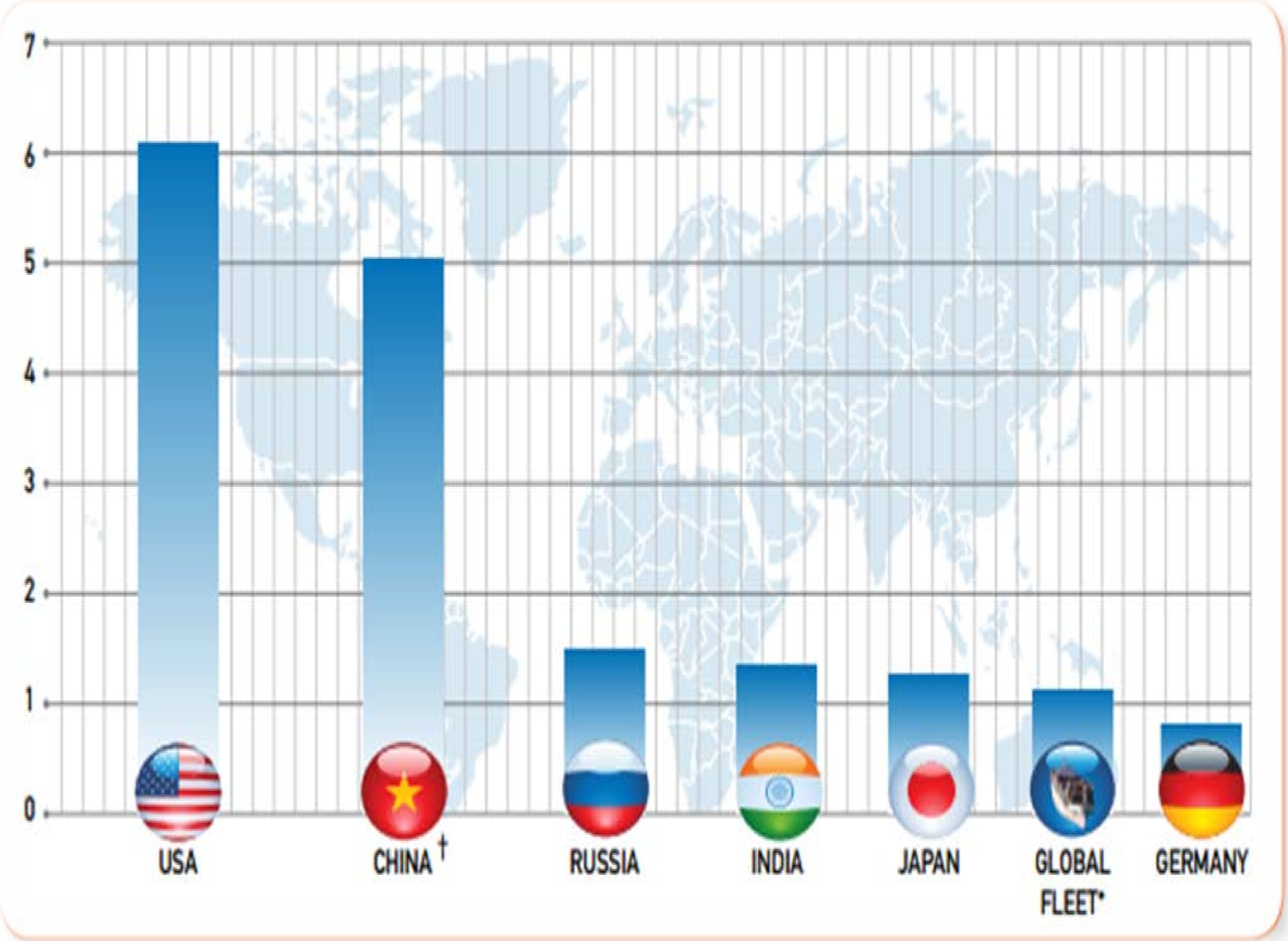
- 2011 An Integrated transport System
- Multi-modal by 2030 – While Paper on Transport
- Connect airports, sea ports, road and railway by 2050 (30% of Road onto Sea)
- Maritime transport emissions reduction of 40% if possible 50% by 2050 compared to 2005 levels
- LNG actions
- Green Paper 2012 - Marine Knowledge 2020
- MILC – 2014/15
- NOx and PMs concerns - 2016
- Recent Work by C4FF

Earth and Pollutions

- **Concerns - <u>exponential rise</u> in CO_2, N_2O, CH_4, etc.**
- **Troposphere** – Earth Blanket; reflects Infrared light and warms the earth; it contains Ozone depleting substances such as man-made pollutants (FluoroCarbons, CFCs, HFCs. Other cooling agents some radioactive.
- **Stratosphere** – Ozone Layer; Filters UVL
- **NO_2 – Almost equal amount from <u>industrial farming</u> when comparing emissions from fossil fuels.**
- $CO_2+H_2O = H_2CO_3$ Carbonic Acid
- Key conventions: Kyoto and Paris - www.marifuture.org
- **But think if there was no diesels, and petrol and coal were used Instead!**

Trees: Good or bad? Which one produces more Oxygen or

in comparison Source: Oceana



Why MariEMS?

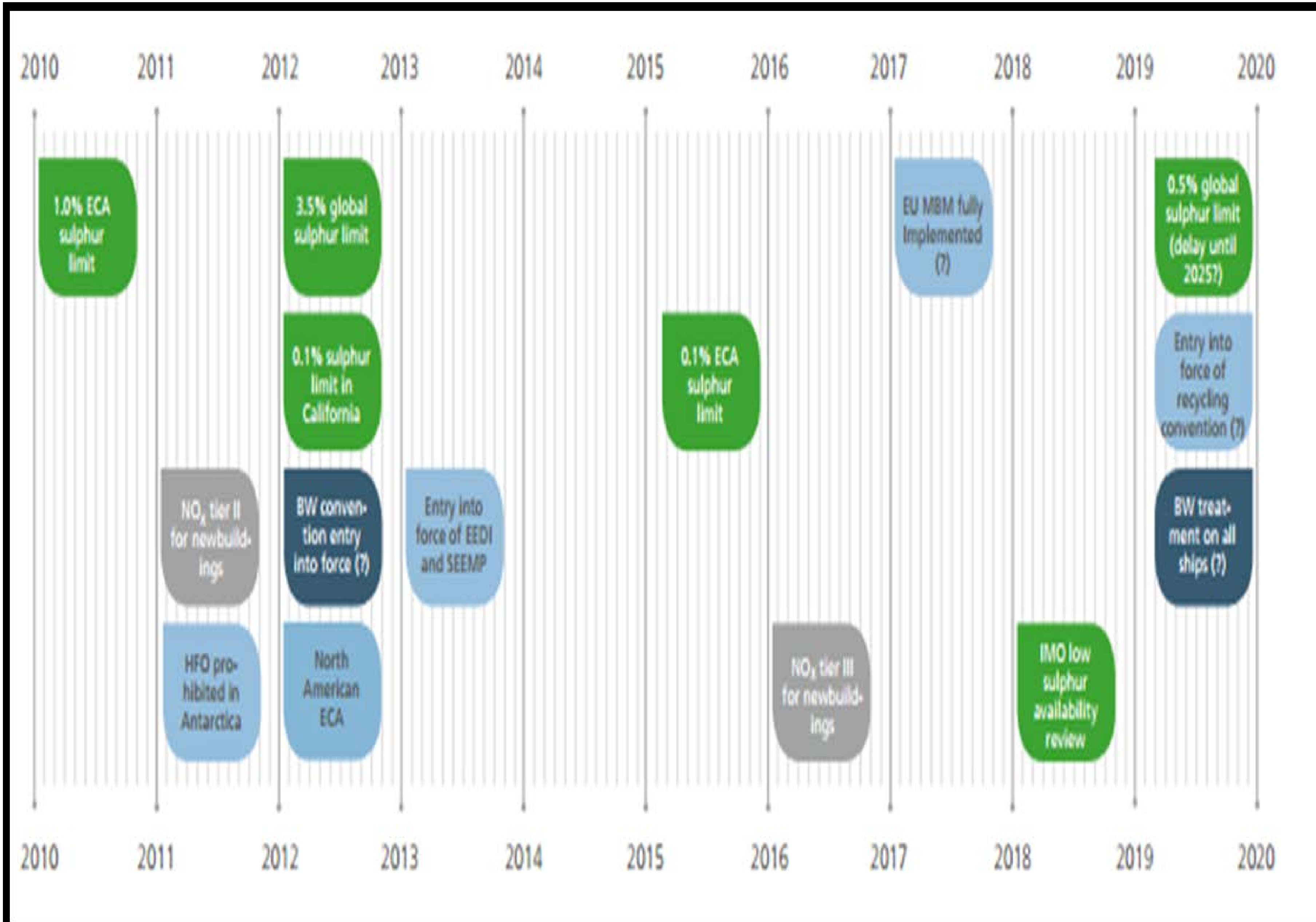
- Maritime Trade accounts for approximately 90% of trade in the world today

- About 870 million tonnes of CO_2 have been estimated to be emitted from the international shipping and it is expected to grow by 200% to 300% by the end of 2050, in the absence of any meaningful regulations - IMO GHG study, Buhang et al (2009)

Yet in 2007 the global shipping industry estimated to have emitted 1,046 million tonnes of CO_2, 3.3 % of global emissions, and in 2015 this reached some 6 % of world total.

The Industry is taking steps to reduce its Air Pollution and Carbon footprint due to recent and upcoming regulations

Upcoming Maritime Regulations
Source: GL



EU 2050 Objectives

1. Towards Zero Accidents - prevention

- Collision / grounding avoidance (-30%)
- Fire avoidance (-15%)
- Structural breakdown avoidance (-10%)
- Adverse conditions avoidance (-20%)
- Cargo loss avoidance (-50%)
- Damage stability (-20%) – SOLAS Ch. II-1
- Fire resistance (variable)
- Damage stability (-80%) – Flooding, etc.
- Cargo loss avoidance (-50%)

EU 2050 Objectives

- Structural damage resilience - (-20%)
- Excessive motions and accelerations (-30%)
- **Environmental damage (-50%)**
- Inability to return to port (-50%)
- Casualties (-80%)

2. The Eco-Efficient Vessel Emission

Reduction: CO2, Nox and SOx

- **CO2: >80% (-30% by 2020)**
- **NOx: 100% (-80% by 2020)**
- **SOx: 100% (-80% by 2020)**
- **Noise Reduction: -3dB**

Areas/Technologies/Methodologies for Consideration – Source: Dr Kayvan Pazouki and Dr Alan J Murphy

Category	Technology/Measure	NOx	SOx	CO2	PM
Pre-Combustion	Humid Air Motor	-70%	0%	0%	0%
	Air Saturation System	-60%	0%	0%	0%
	Exhaust Gas Recirculation	-35%	0%	0%	0%
	Water in Fuel (Max 20%)	-20%	0%	0%	-40%~-60%
	Low Sulphur fuel (2.7% to 0.5%)	-20%	0%	0%	-80%
	LNG	-60%~-90%	-90%~-100%	-25%	-72%
	Hydrogen	-20%	-100%	-100%	0%
During Combustion	Direct Water Injection	-50%	0%	0%	-50%
	Basic Engine Modificaton	-20%	0%	0%	0%
	Advanced Engine Modification	-30%	0%	0%	0%
Post Combustion	Selectice Catalytic Reduction	-90%	0%	0%	0%
	Plasma Assisted Catalytic Reduction	-90%	0%	0%	0%
	Seawater Scrubber	0%	-75%	0%	-25%
Non Engine/Combustion	Economic Speed	-10%	0%	-20%	-25%
	Weather Routing	Reduce fuel consumption by 10%			
	Onshore Power Supply	-97%	-96%	*	-96%

Enthalpy vs Entropy

- **Enthalpy** - a thermodynamic quantity equivalent to the total heat content of a system. It is equal to the internal energy of the system plus the product of pressure and volume – Conventional Fuels, LNG, GAS, Nuclear!

- **Entropy**- a thermodynamic quantity representing the unavailability of a system's thermal energy for conversion into mechanical work, often interpreted as the degree of disorder or randomness in the system – Reducing losses.

Selective Catalytic Reduction (SCR)

Selective Catalytic Reduction (SCR) is an advanced active emissions control technology system that injects a liquid-reductant agent through a special catalyst into the exhaust stream of a diesel engine. The reductant source is usually automotive-grade urea, otherwise known as Diesel Exhaust Fluid (DEF). The DEF sets off a chemical reaction that converts nitrogen oxides into nitrogen, water and tiny amounts of carbon dioxide (CO2), natural components of the air we breathe, which is then expelled through the vehicle tailpipe.

Part 1 : Engine Optimisations
Review of Experiments

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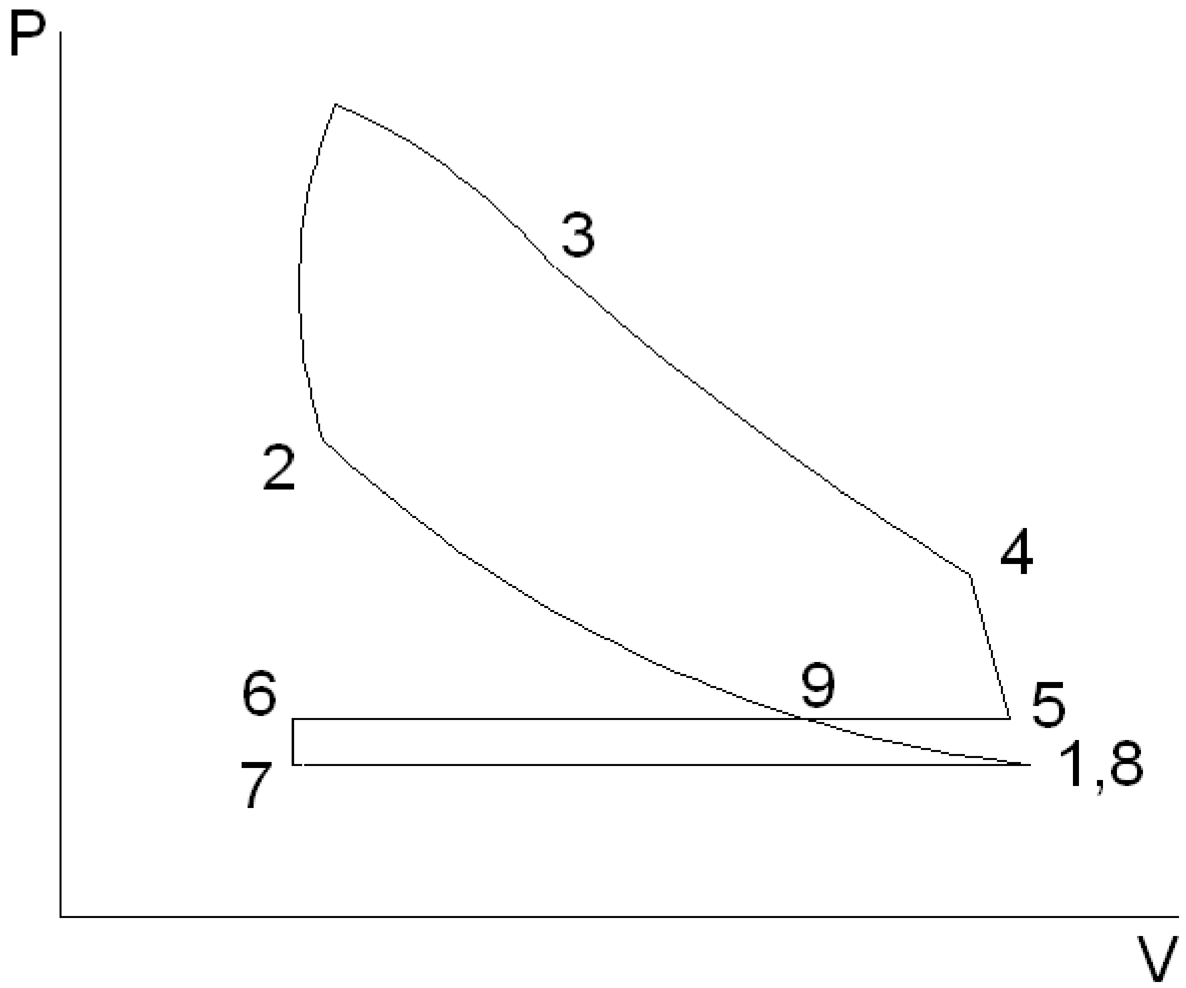
- Thermal efficiency
- Hybrid propulsion
- Alternative fuels (LNG:10% NO_x; 5% SO_2; 75% CO_2; 30% PM)

NB: Low Sulphur Fuel reduces PM by 80%!)

- Fuel cells/batteries (Hydrogen: No CO_2 No SOX & 20% NO_x)
- Catalysts (SCR or PlasmaCR: 10% NO_x)
- Exhaust Gas Recirculation – 35% NO_x reduction
- Exhaust treatment
- Multi-Stage inter-cooling
- Variable Geometry Diesels
- Lighter materials
- Efficient bearings – Air bearing, etc.
- Water injection - 50% NO_x reduction
- Novel injectors High injection pressures
- Common rail systems

Description of the Model – Modified Air Standard Cycle – See Handout



The cycle is subdivided into:

Closed Cycle Considerations:

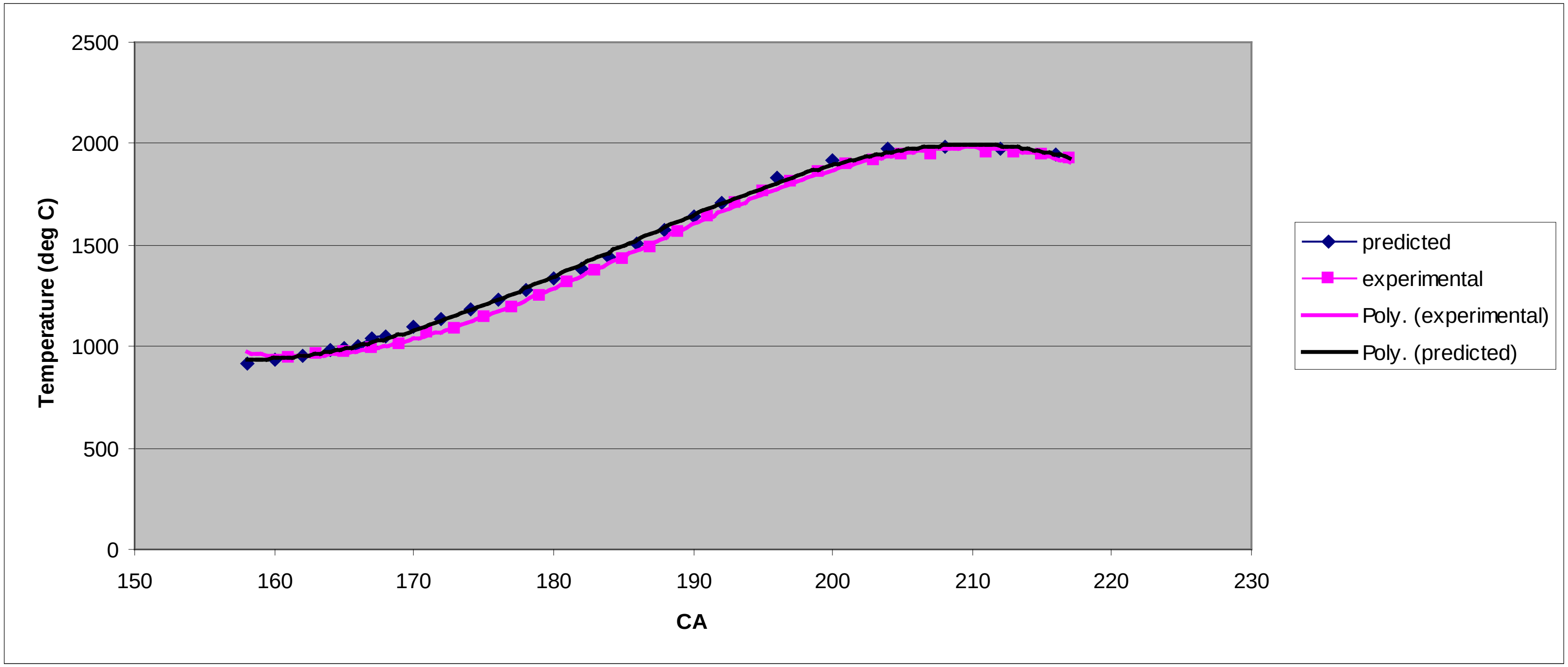
- Compression period (1-2)
- Combustion period (2-3)
- Expansion period (3-4)

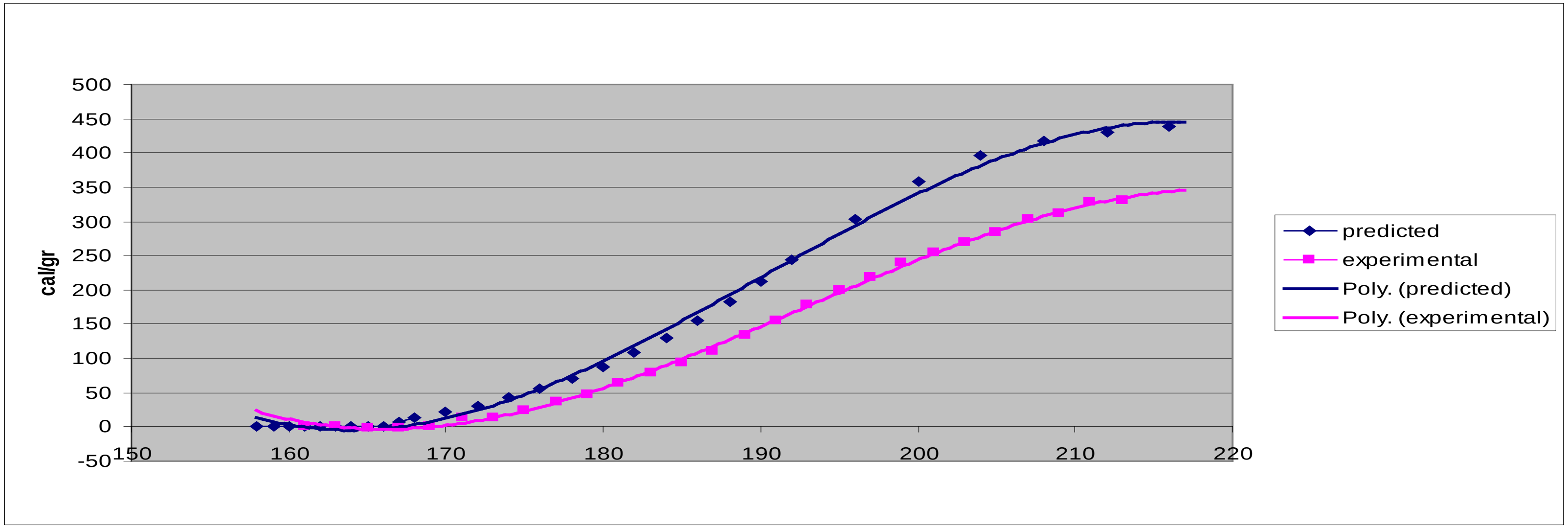
Open Cycle Considerations:

- Blow down period (4-5)
- Exhaust period (5-6)
- Overlap period (6-7)
- Suction period (7-8)
- Pre-compression period (8-9)

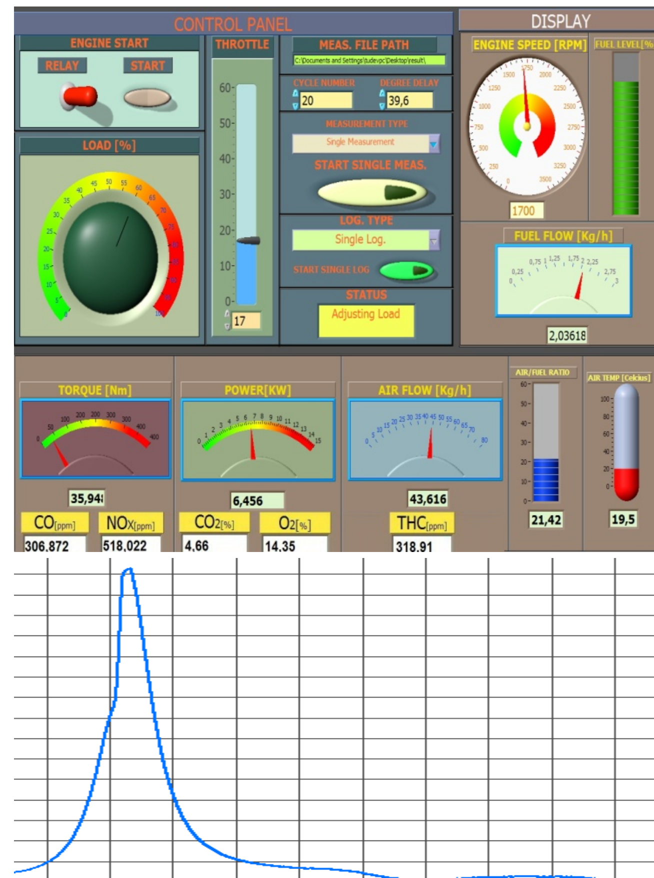
Digital Twining – TUDEV, Turkey

Ziatati et al., 2009, 13th Congress of Intl. Maritime Assoc. of Mediterranean, IMAM 2009





ZIARATI ET AL, (2009), DESIGN AND DEVELOPMENT OF A COMPUTER CONTROLLED MARINE DIESEL ENGINE FACILITY FOR MARITIME ENGINEERING RESEARCH AND TRAINING – IMLA 2009

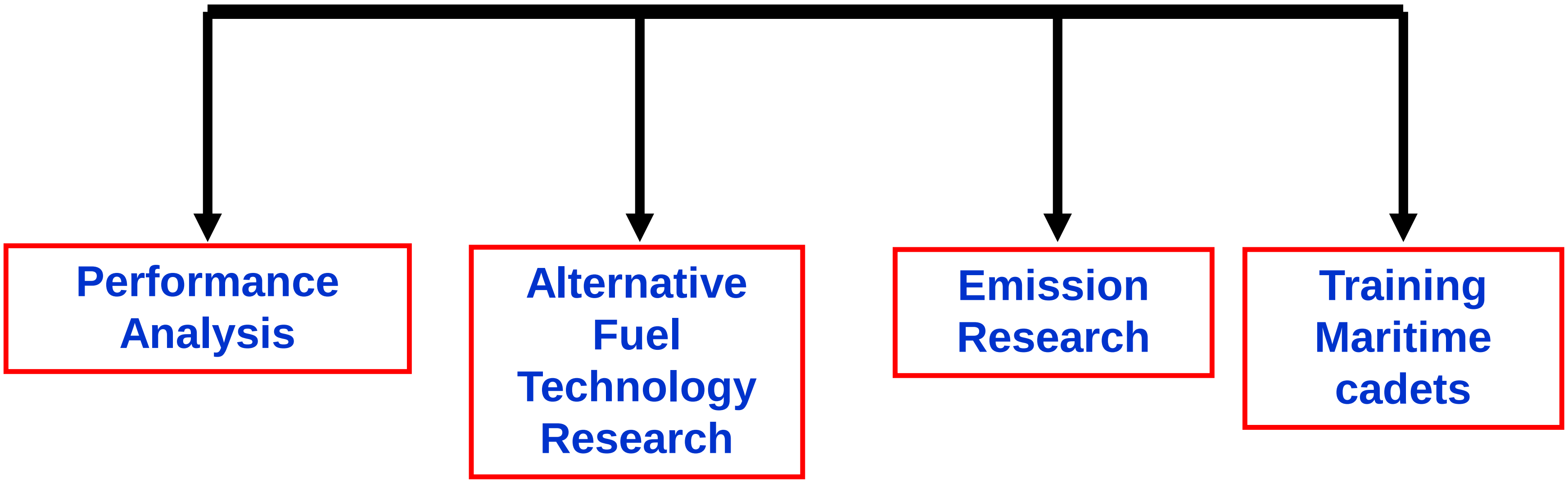


The application of diesel engines in automotive and marine industries and its use as stand alone power units have been rapidly increasing in recent years mainly due to the development and applications of new technologies. These developments on diesel engines are focused on:

- **Improved Performance**
- **Emission control**

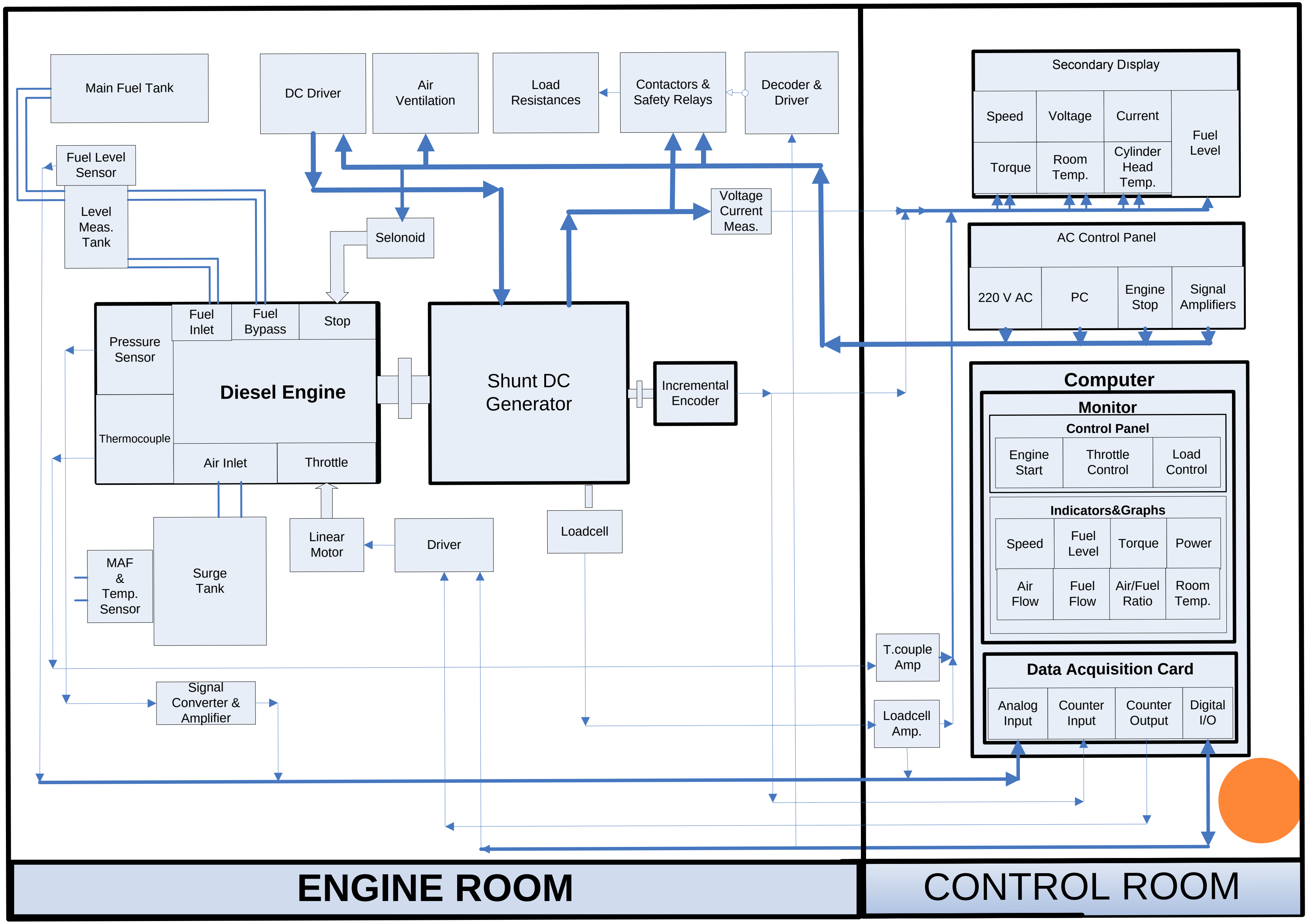
Therefore, a reliable and functional diesel engine test rig is required for research and training of merchant navy cadets.

DIESEL ENGINE TEST RIG CAPABILITIES



This computer controlled diesel engine test laboratory was established at Piri Reis University. The research facility is fully instrumented using a range of sensors and a computerized data processing and analysis system.

Diesel Engine Test Rig Block Diagram



The laboratory is separated into two facilities, one holding the instrumented engine and the other computing and display units with a view to improve safety and to decrease noise.

ENGİNE ROOM

1. Diesel Engine
2. DC Generator
3. Inlet air surge tank
4. Air mass flow meter
5. Load rezistances panel
6. Rezistance box
7. Emission analyser
8. Encoder
9. Load cell
10. Generator fan
11. Micro stepping motor
12. Engine air inlet
13. Exhaust
14. Driver
15. Amplifier (for pressure sensor)
16. Pressure sensor cooling pump and tank
17. Pressure sensor
18. Fuel tank
19. Fuel level sensor
20. Main fuel tank
21. Selenoid for engine stop

Control Room

1. Screen for engine controls and indicators
2. Screen for graphical output
3. Data acquisition connection box
4. Keyboard and mouse
5. Indicator panel
6. Electrical control panel

Generator

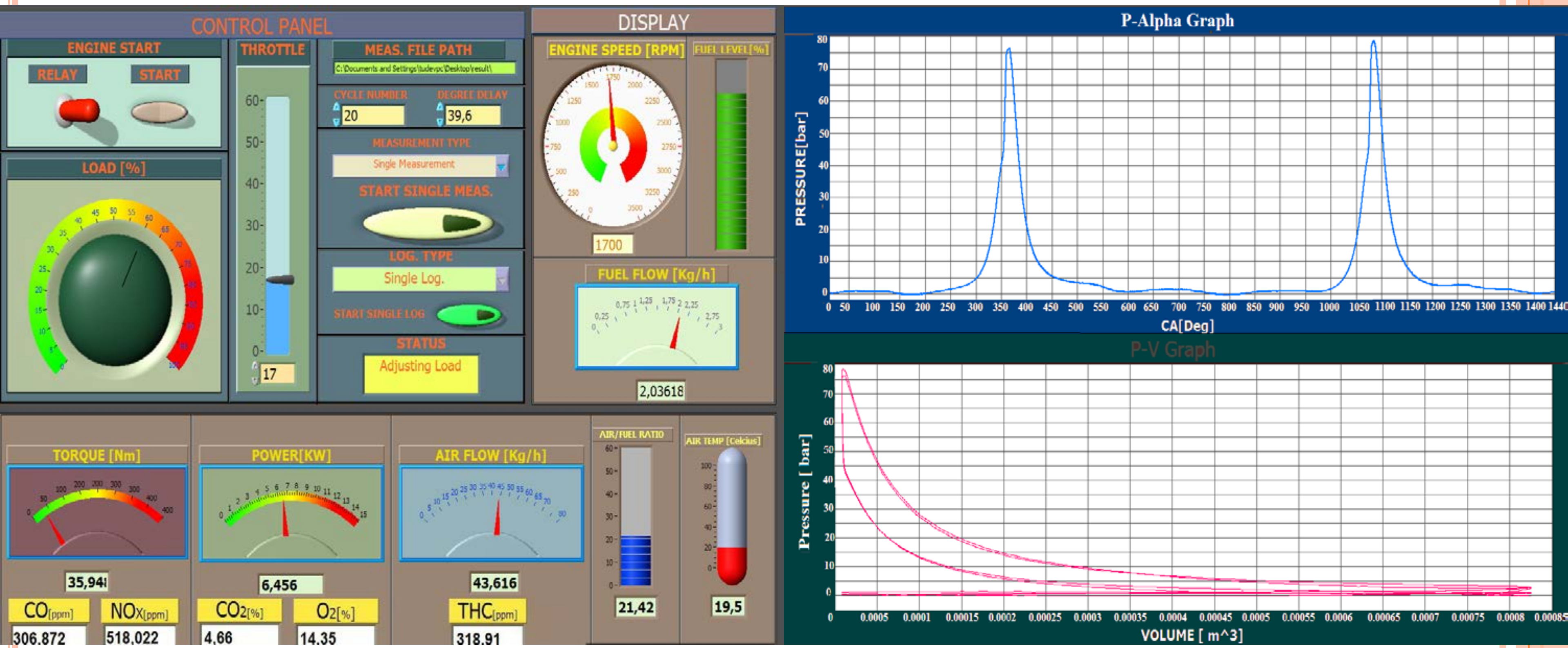
Diesel Engine	
Make	Antor 4LD 820
No. Of Cylinders	1
Volume	817 cm^3
Engine Speed	2600 rpm
Power	17 HP
Max. Power	5 Kg-m @1600 rpm
Generator	
Type	Shunt DC
Armature Current	38 A
Armature Power	15 kW
Field Voltage	200 V
Field Current	2,8 A
Max. Speed	3500 rpm

GRAPHICAL USER INTERFACE

A graphical user interface program was developed using Labview®. This program has several control functions, it displays measurement results and records the data on the hard disk. The graphical user interface consists of three parts;

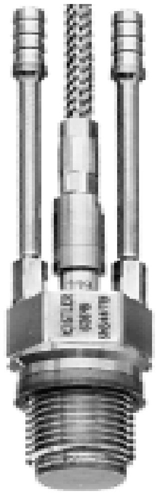
- Control panel,
- Indicator panel,
- Chart panel.

GRAPHICAL USER INTERFACE

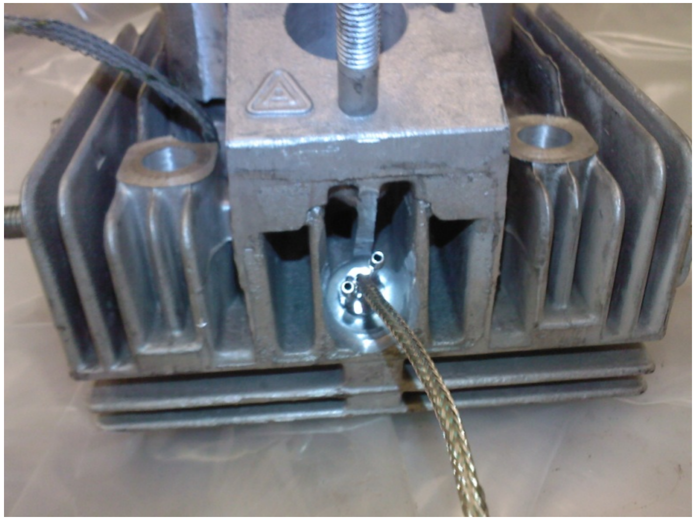


Cylinder Pressure Measurement

A piezoelectric pressure sensor is mounted in the cylinder head and connected to a charge amplifier to measure the cylinder pressure. Cylinder pressure is measured using the trigger signal from encoder’s zero pulse and at a sample rate (0,1º).



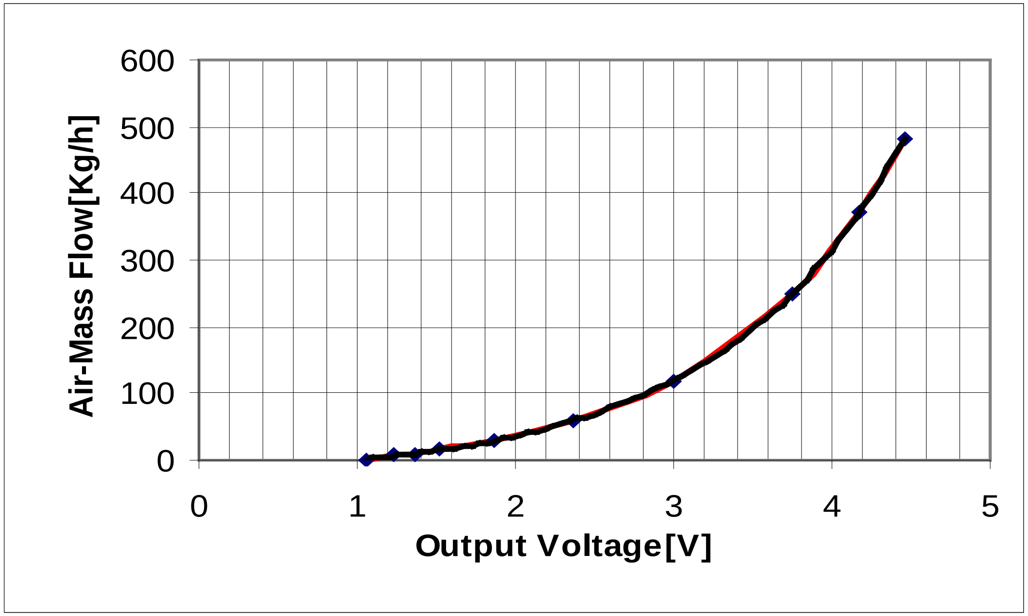
Pressure sensor



Pressure sensor mounted on the cylinder head

Air Flow Measurement

Air flow and inlet air temperature are measured using Bosch mass air flow meter (MAF)

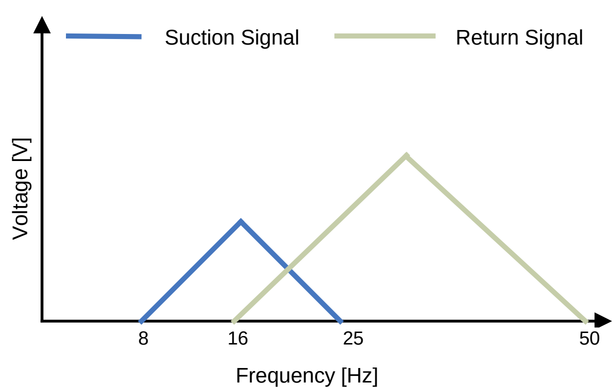


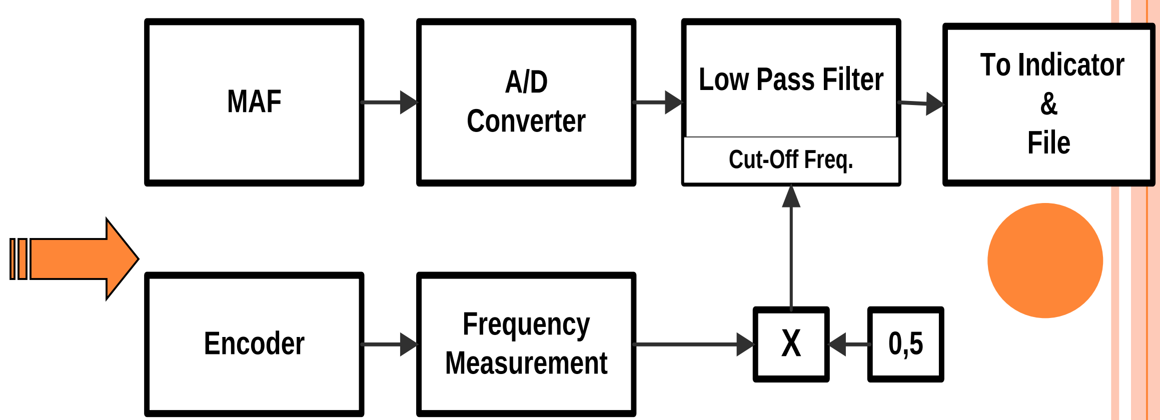
MAF's output voltage according to the air flow is shown above.

Air Flow Measurement

Problem: Since single cylinder diesel engine is used, some amount of suction air returns back to the surge tank again

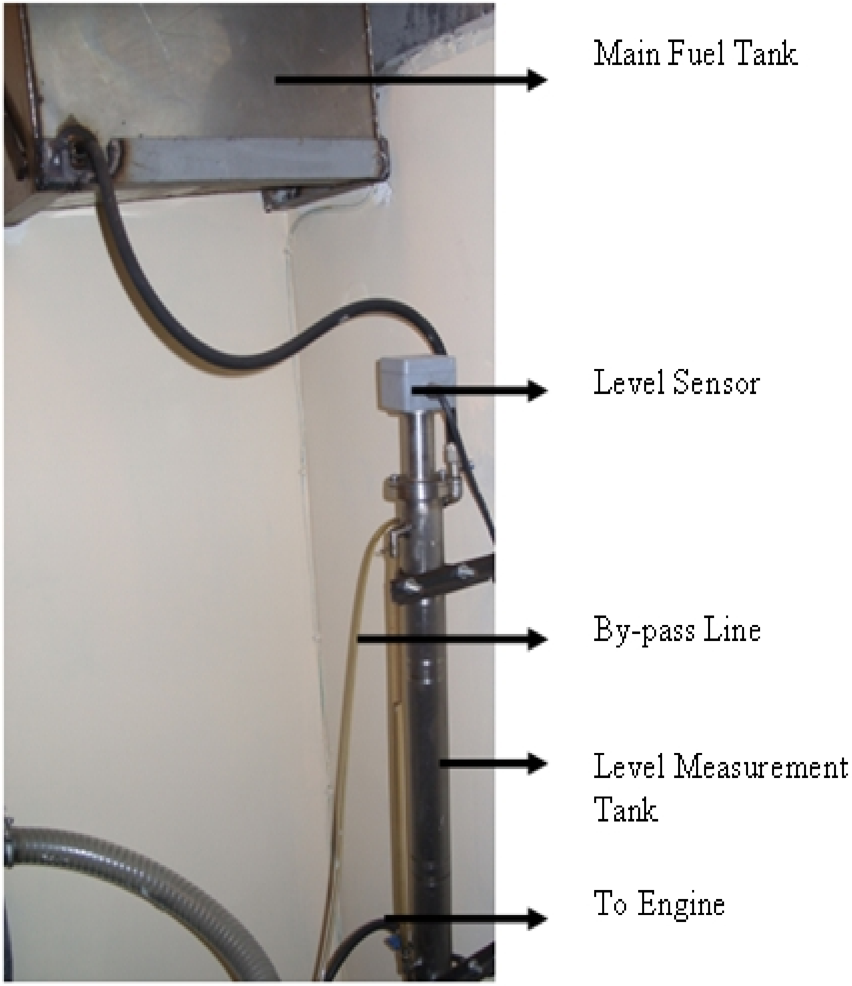
Solution: Suction signal frequency has to be the half of the engine speed frequency. Therefore, the MAF output is examined in frequency spectrum to realize filter for return signal. Low pass filter whose cut-off frequency is changed according to engine speed is used to measure suction air flow.



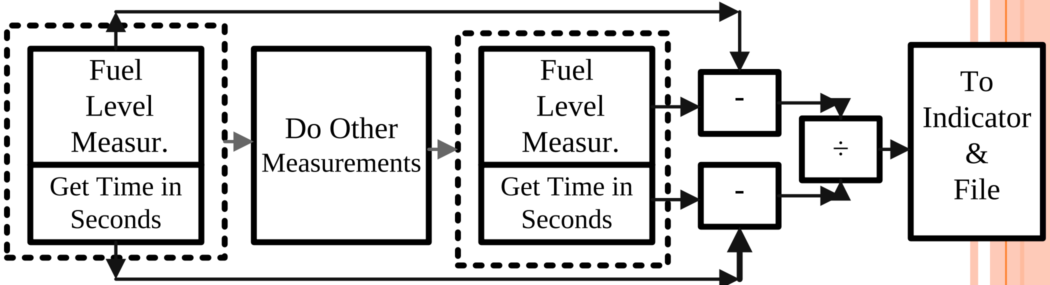


Fuel Flow Measurement

A level sensor is mounted in a cylindrical fuel tank to measure fuel flow

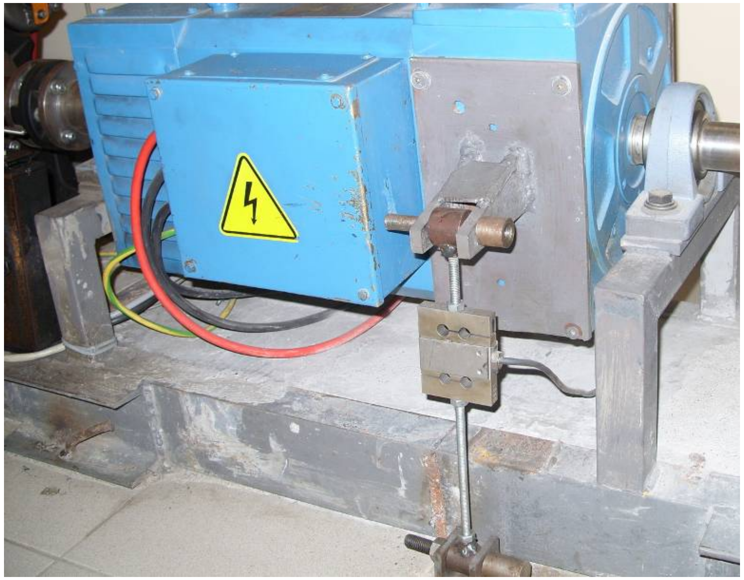


The block diagram for fuel flow measurement can be seen below:



Torque and Power Measurements

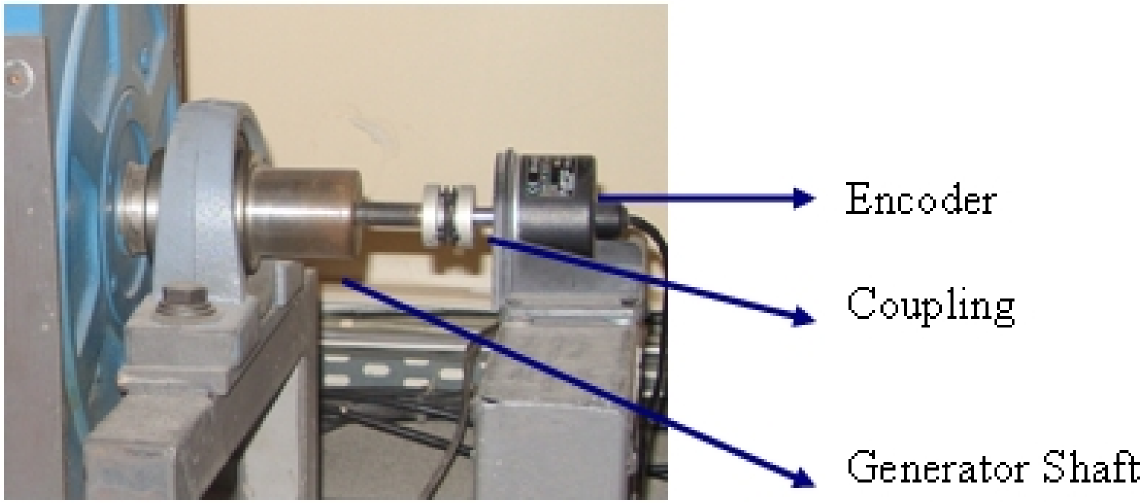
- A loadcell is mounted to DC generator’s frame to measure the break torque
- Armature current being consumed by load resistances is directly proportional to rotational force of field winding fixed generator body. For this principle, break torque can be measured from generator’s body.



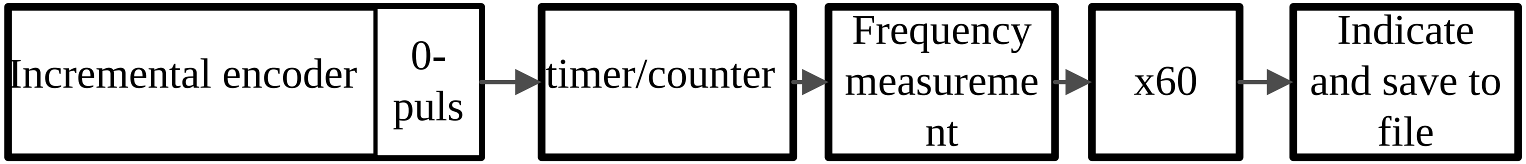
Load cell

Engine Speed Measurement

An encoder with a resolution of 3600 puls/rev is used.



Incremental Encoder



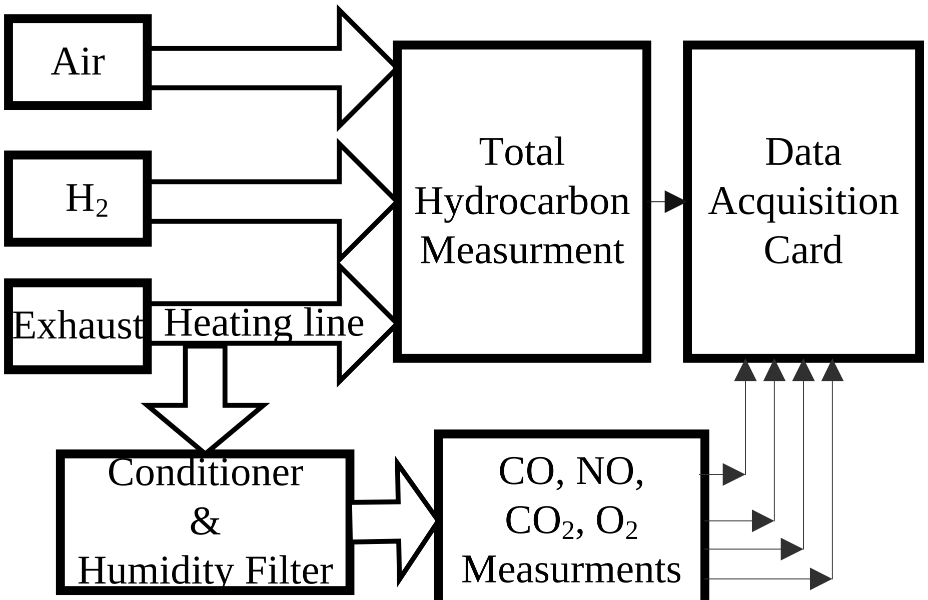
Engine Speed Measurement Block Diagram

Exhaust Emission Measurement

•Siemens Ultramat 23 NDI (non-dispersive infrared) analyser measures CO, CO2, NOx and O2 emissions

•Siemens Fidamat 6 FID (flame ionization detection) analyser measures THC (total hydrocarbons) emissions

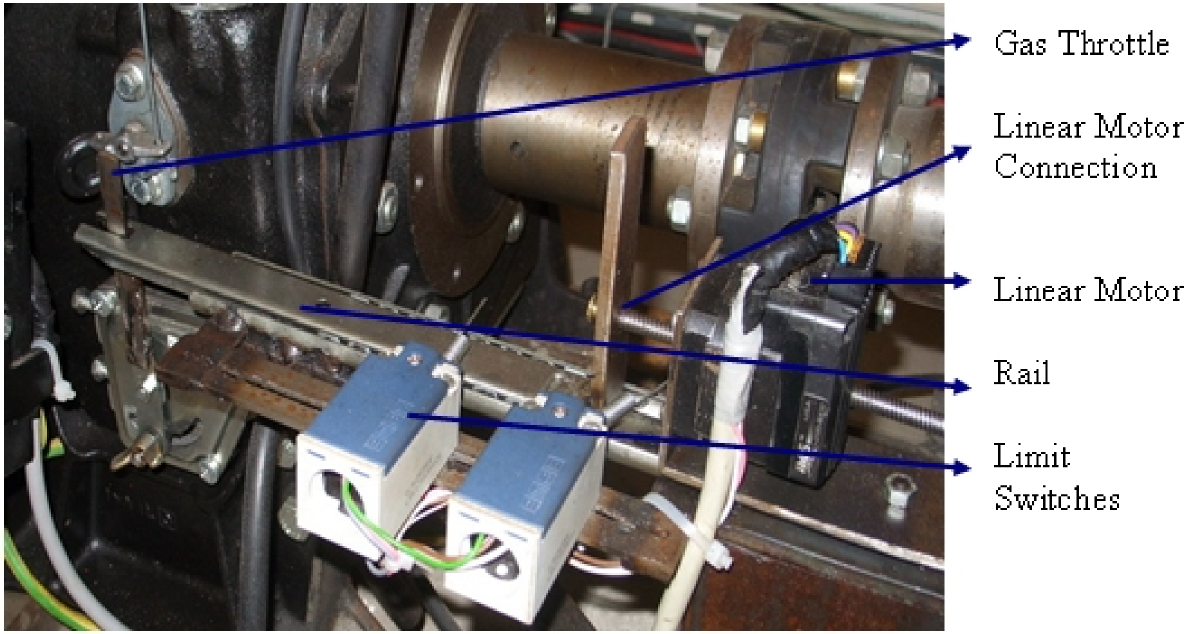
•The exhaust gas passes through a heated line to avoid condensation.



CONTROLLERS
Throttle Control

- Throttle is controlled by using micro stepping motor with linear actuator

- Data acquisition card's counter/timer and digital output is connected to micro stepping motor driver to enable motion and its direction

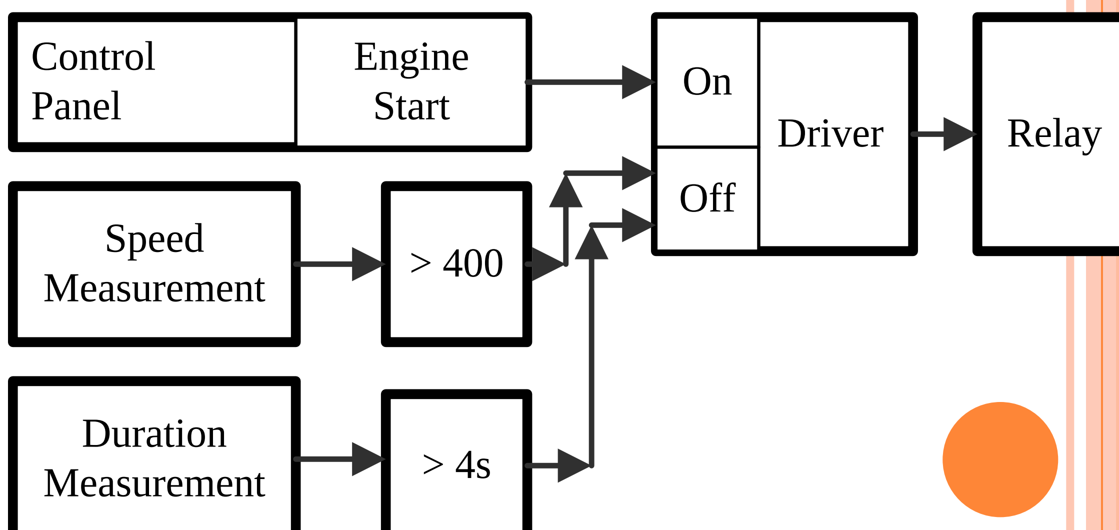


LOAD AND START/STOP CONTROLLERS

There are 16 resistances (1 kW each) which are controlled by the data acquisiton card.

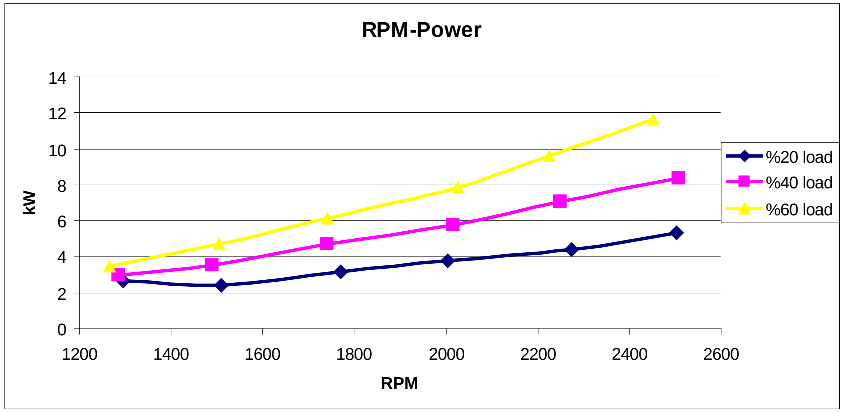
A relay and its driver are connected to data acquisition card which are used to start the engine.

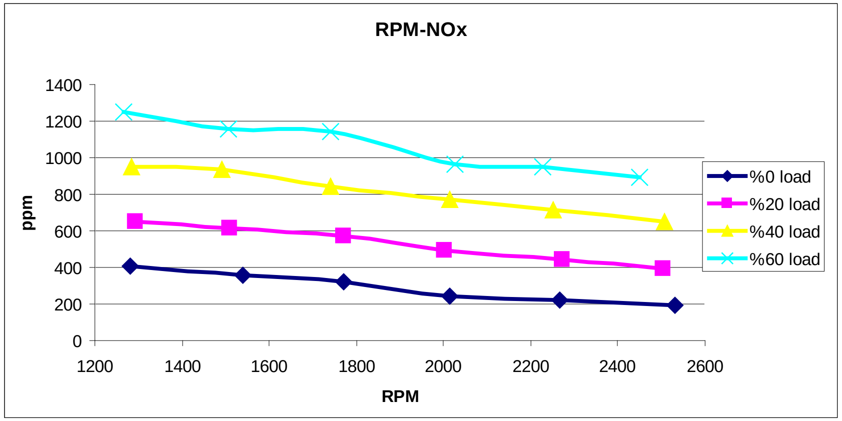
A solenoid is connected to the engine's stop valve to stop the engine from the control room.

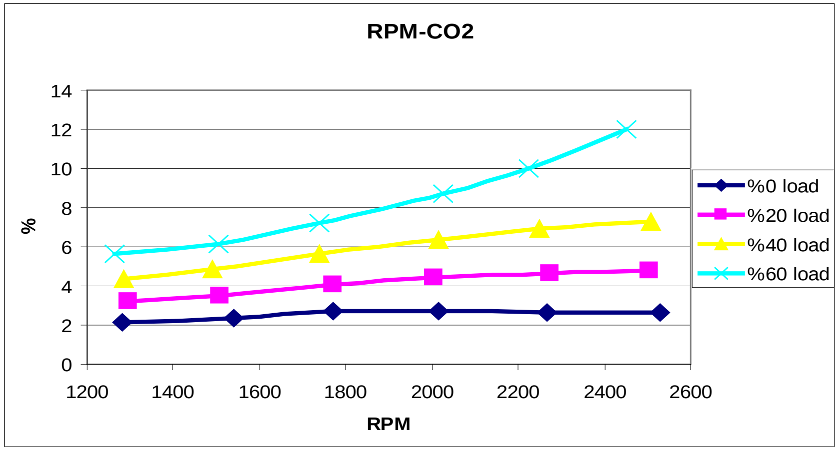


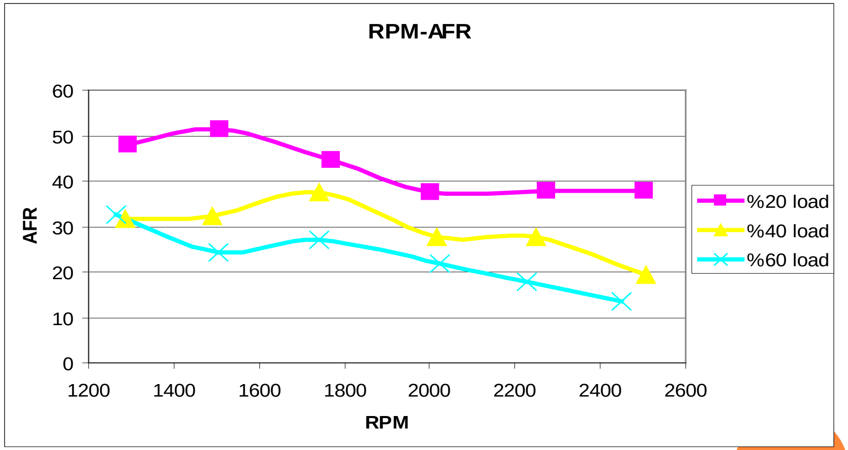
RESULTS

Sample results obtianed from the engine test rig are below :



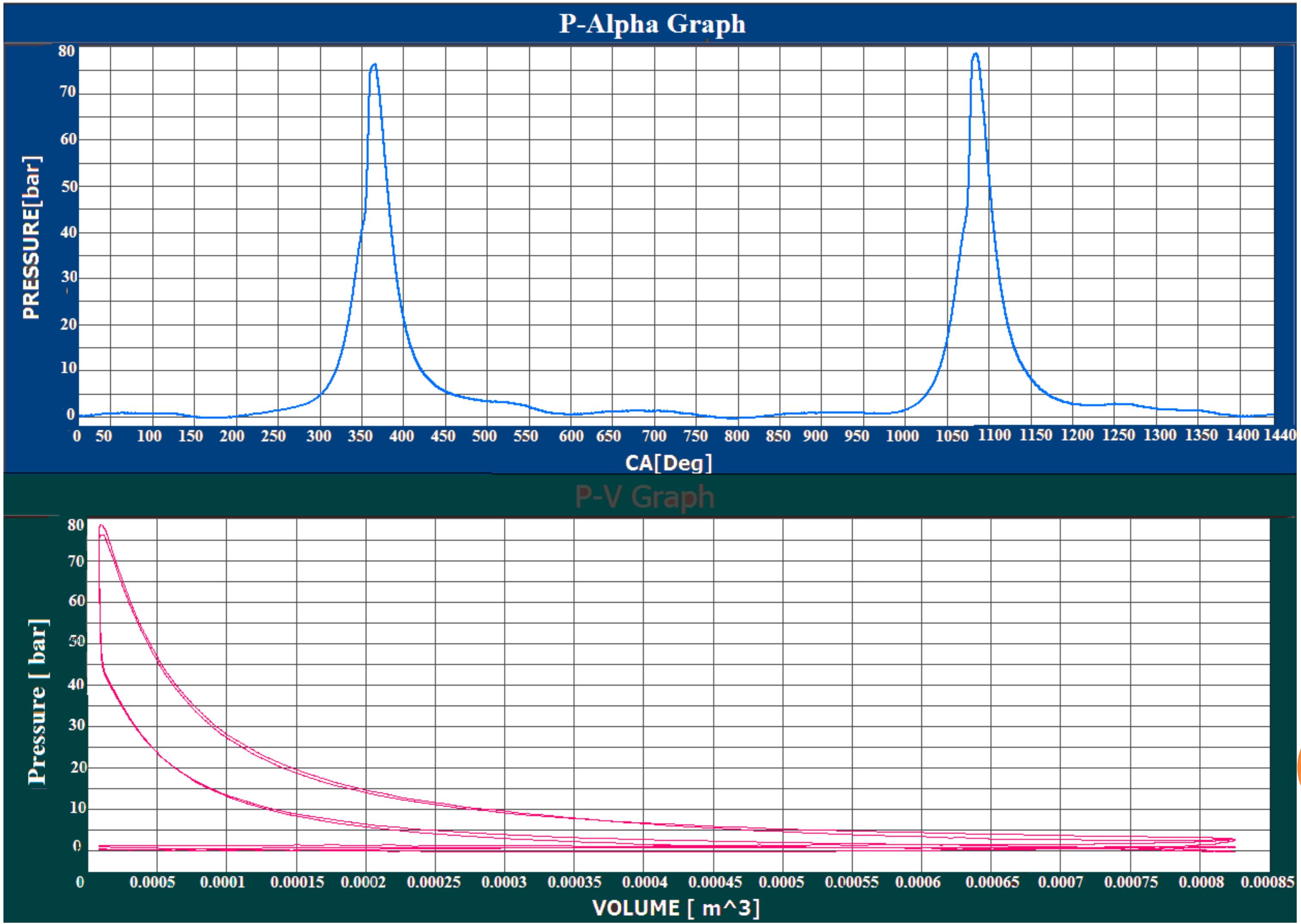






RESULTS

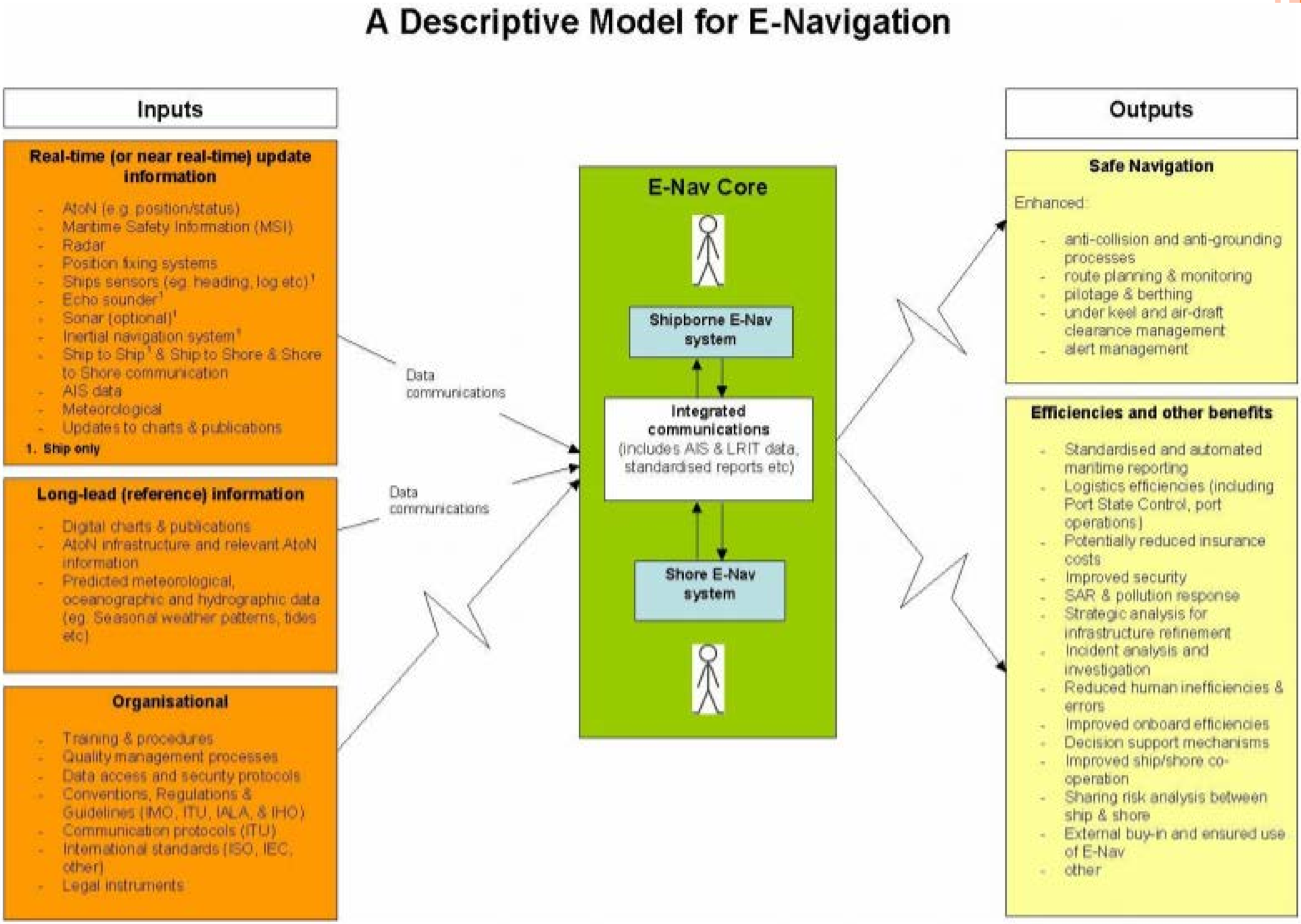
Also pressure data versus crank angle and indicator diagram of the diesel engine can be seen below:



E-Navigation

- This inspired the development of new technologies such as Automatic Identification System (AIS), Electronic Chart and Information System (ECDIS) Integrated Bridge and Navigation Systems, Automatic Radar Plotting Aids (ARPA), Long Range Identification and Tracking (LRIT) systems, Vessel Traffic Services (VTS) and the Global Maritime Distress Safety System (GMDSS). The aim was to develop a strategic vision for the utilization of existing and new navigational tools, in particular electronic tools, in a holistic and systematic manner. The proposed solution was named e-navigation.

DIAGRAMMATIC PRESENTATION OF E-NAVIGATION



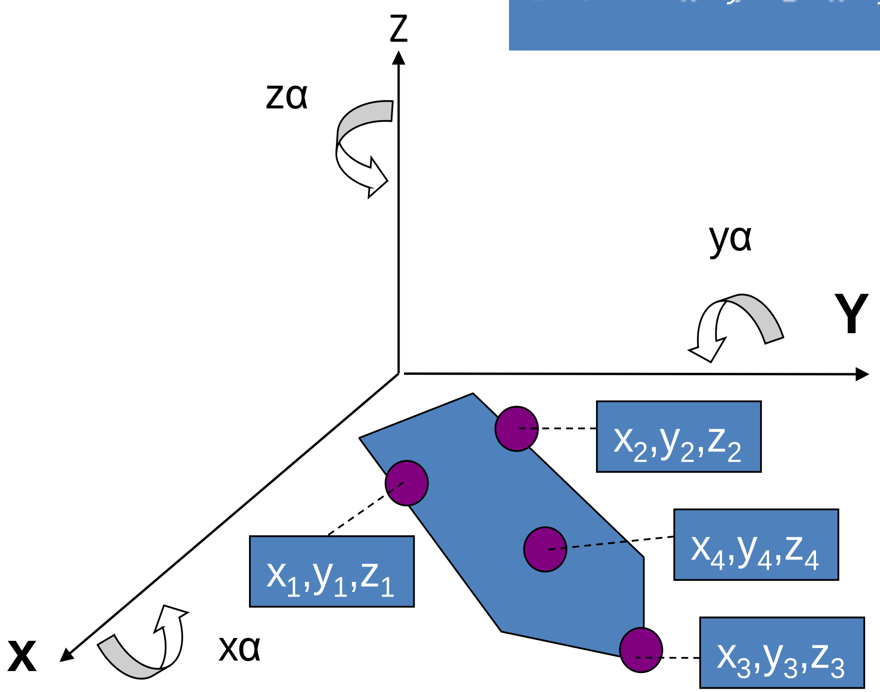
EFFICIENCY THROUGH LESS POLLUTING AND LEANER ENGINES AND OTHER MEANS OF REDUCING FUEL CONSUMPTION AND EMISSIONS

Ship AutoSet Systems

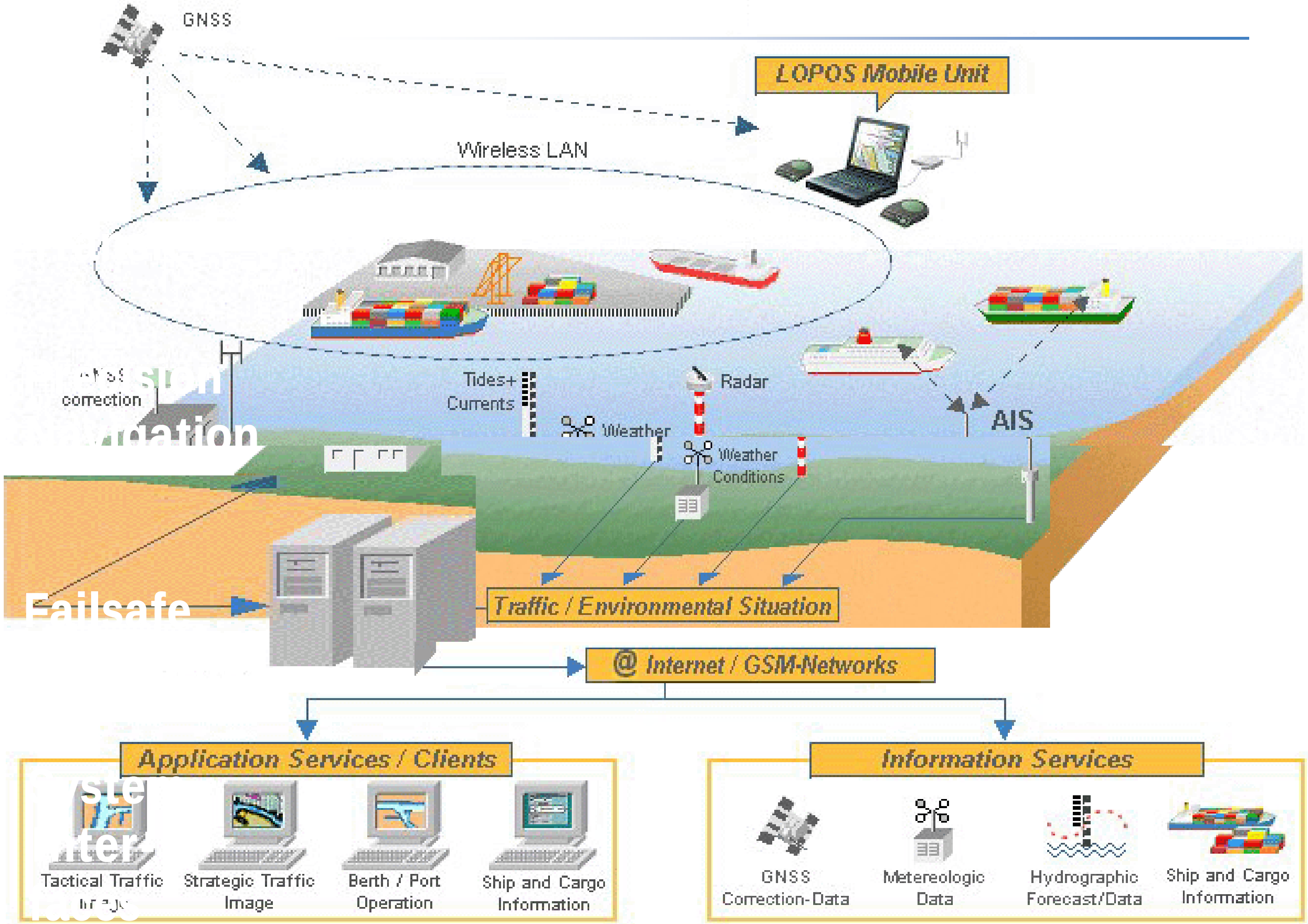
Data fusion from internal sources

State object vector:

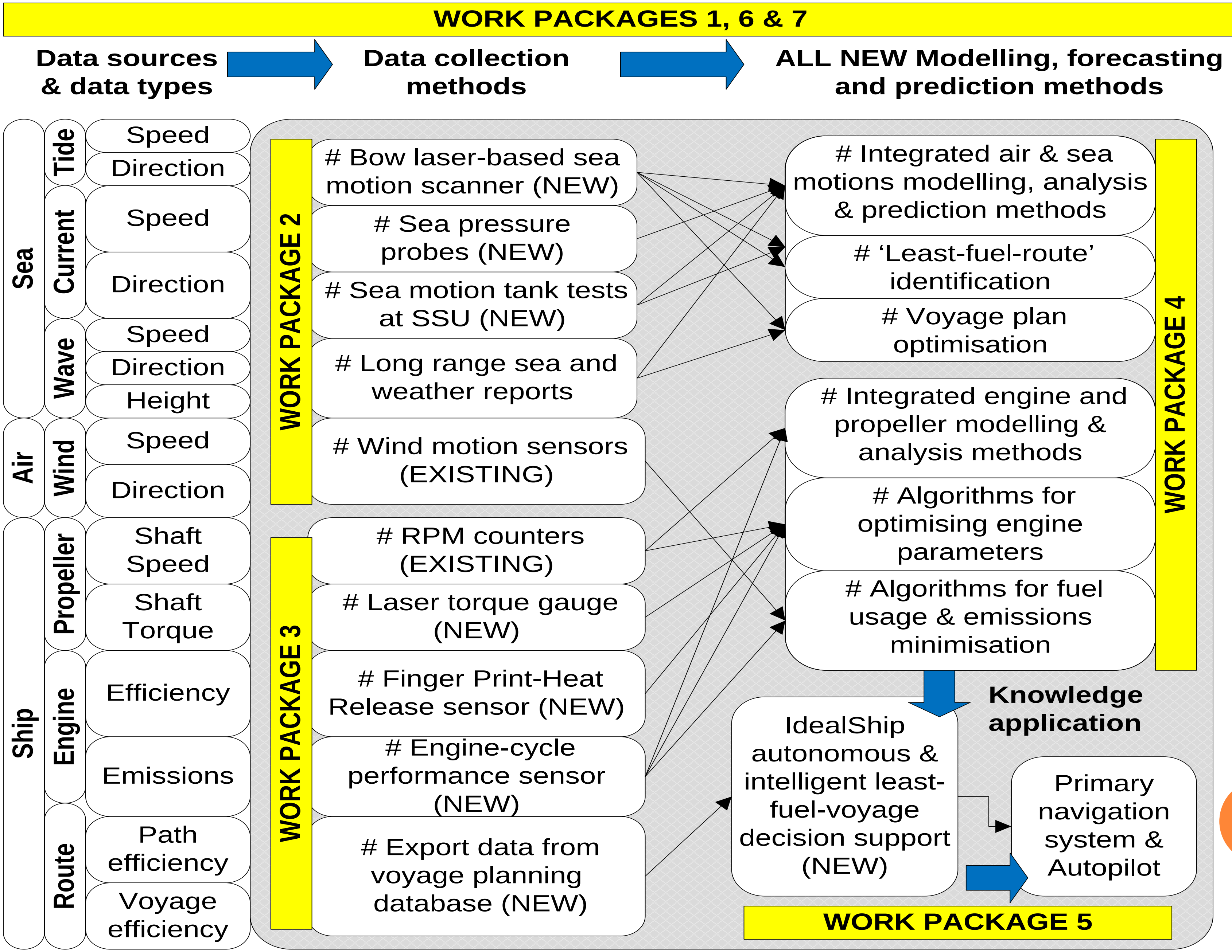
$[x\ y\ z\ V_x\ V_y\ V_z\ a_x\ a_y\ a_z]$



Example: Technology



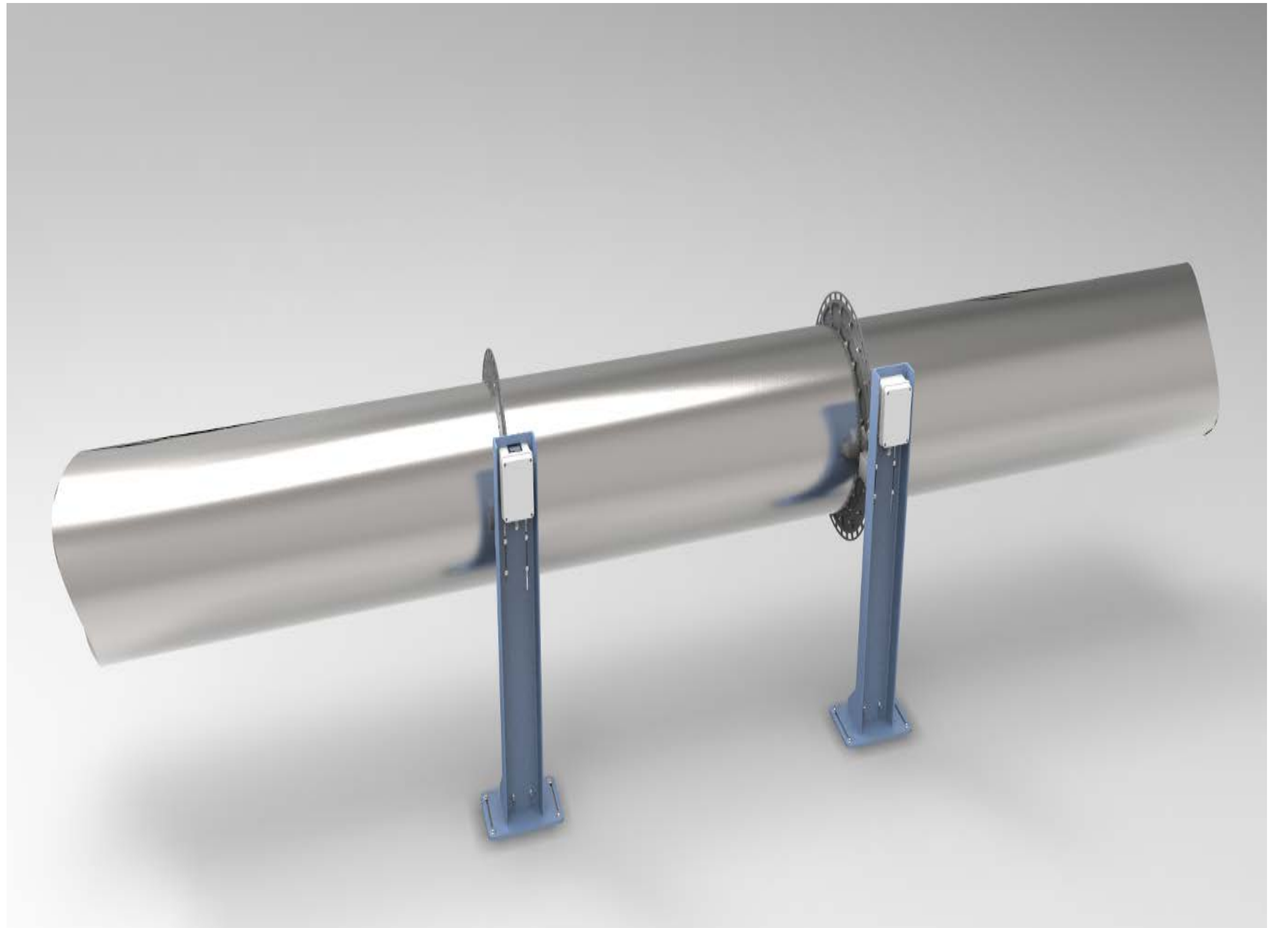
AutoSet Work Packages



Novel torque Measuring system

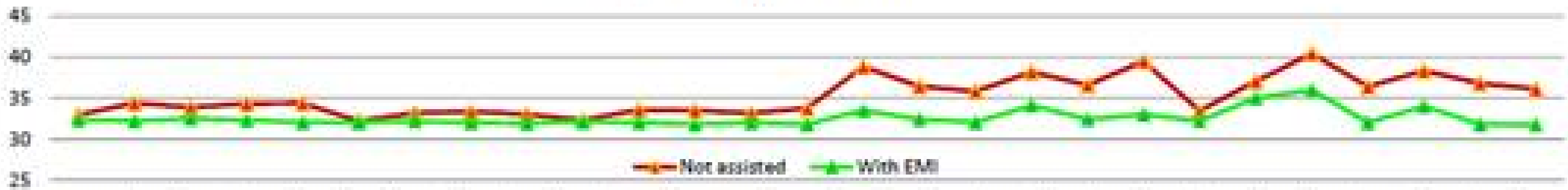
- The C4FF Torque measuring system is mounted on intermediate shafts after the thrust bearing. When a shaft is subjected to a change in thrust due to increased motion resistance, the result is a small strain at the shaft surface. Stain gauses (laboratory setting) and low power lasers (on board) accurately detect these small displacements, in both axial and radial directions. The measured values are transferred continuously from the rotating shaft to the stator part through wireless data connection. Power transmission from the stator to the rotating shaft is performed by means of induction. The stator part consists of a power transmission coil, a data signal receiver and a control box equipped with digital or analogue output connections. These outputs are be linked directly to the vessels data network, monitoring- or

Torque Meter



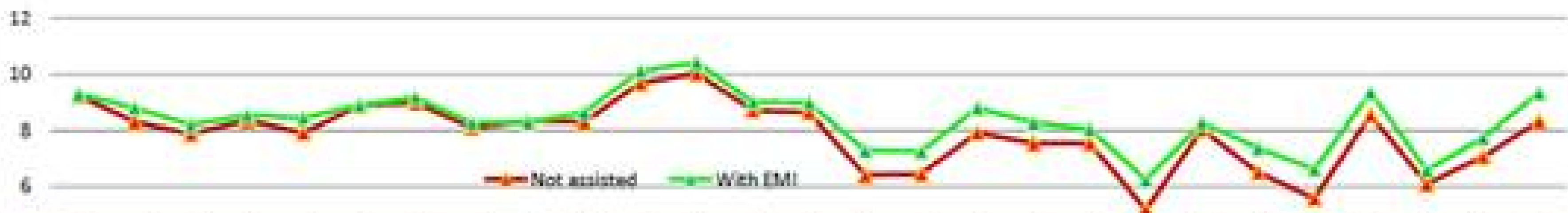
Actual Results - Savings

Daily Consuption Tons x 24h



Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Not assisted	33	34,4	33,9	34,3	34,4	32,2	33,2	33,4	33	32,8	33,6	33,3	33,2	38,8	38,9	36,5	35,8	38,2	36,6	39,5	33,4	37,2	40,4	36,4	38,4	36,8	36,1
With EMI	32,8	32,2	32,5	32,8	32,1	32	32,2	32	31,9	32,1	32	31,8	32	31,8	33,5	32,4	32	34,1	32,4	33	32,2	35	36	32	34	31,8	31,7
Wind	SSW 7	SW 7	6	6	SSW4	SSE4	SSE/5	SSE7	SSE7	S5	NNE6	SSE3	3	N6	W6	6	SSW4	6/5	7/6	7/6	NNE 4	4/5	5	6	7	5	5
Wave	SSW6	SW 6	5	5	SSW4	SSE3	SE3	SSE6	SSE4	S4	NNE4	SSE3	3	N5	W7	5	SSW3	NW5	NW6	/5	NNE3	/5	4	5	SW5	4/3	3

Ratio Mls x Tons



Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Not assisted	9,23	8,31	7,88	8,36	7,92	8,88	8,98	8,1	8,31	8,3	9,69	10	8,72	8,65	6,41	6,45	7,92	7,54	7,54	5,19	8,04	6,5	5,59	8,54	6,1	7,06	8,32
With EMI	9,29	8,8	8,2	8,55	8,49	8,89	9,17	8,27	8,29	8,64	10,1	10,4	9,01	8,98	7,3	7,28	8,8	8,28	8,09	6,24	8,27	7,38	6,62	9,35	6,59	7,74	9,34

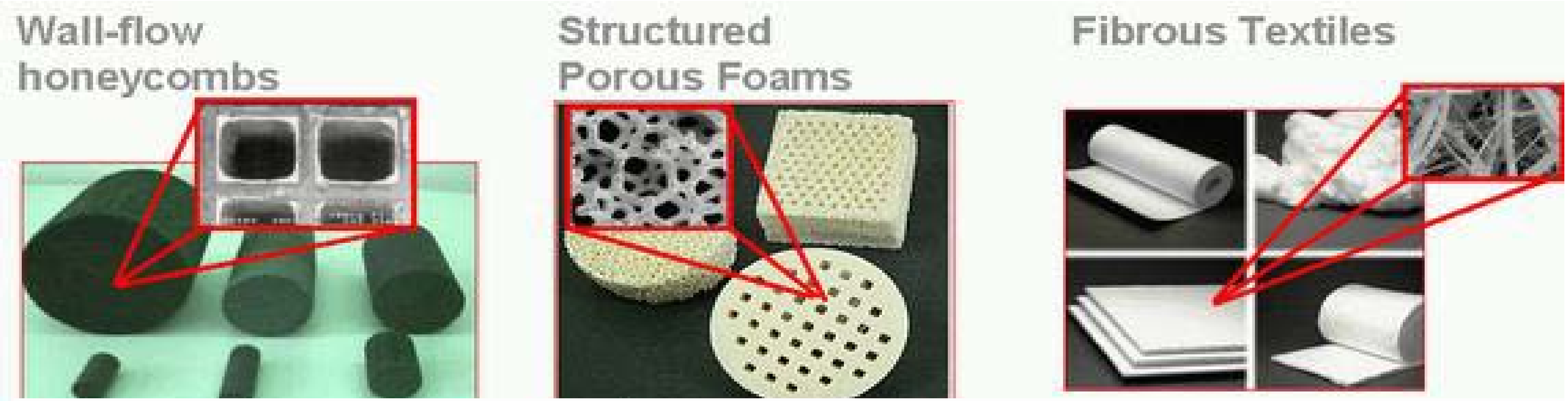
Key Areas for Research

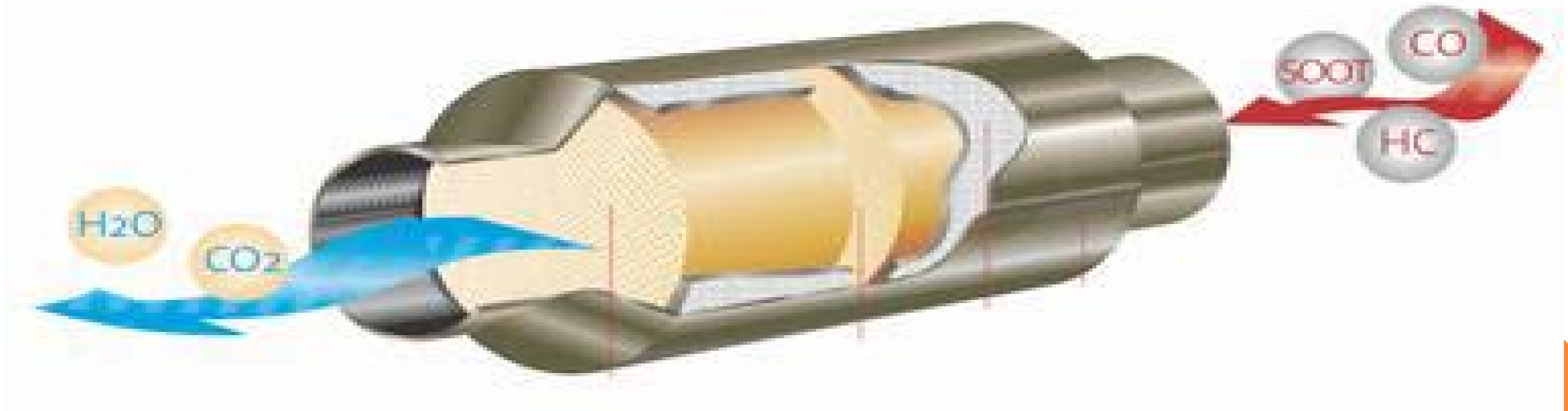
- Low carbon and renewable fuels - LNG and methanol – Short to Medium term
- Hybrid/Electric drives - novel energy storage and DC power and control systems – Short, medium and long term, newer transport systems
- **Development of combined system to reduce engine pollution – Short term with immediate impact**
- Ship design – reducing frictional resistance – Short, medium and long term
- Micro and nano scale Engineering; Novel coating; Equilibrium and non-equilibrium fluid dynamics – to reduce turbulent drag – short term

Development of combined system to reduce engine pollution

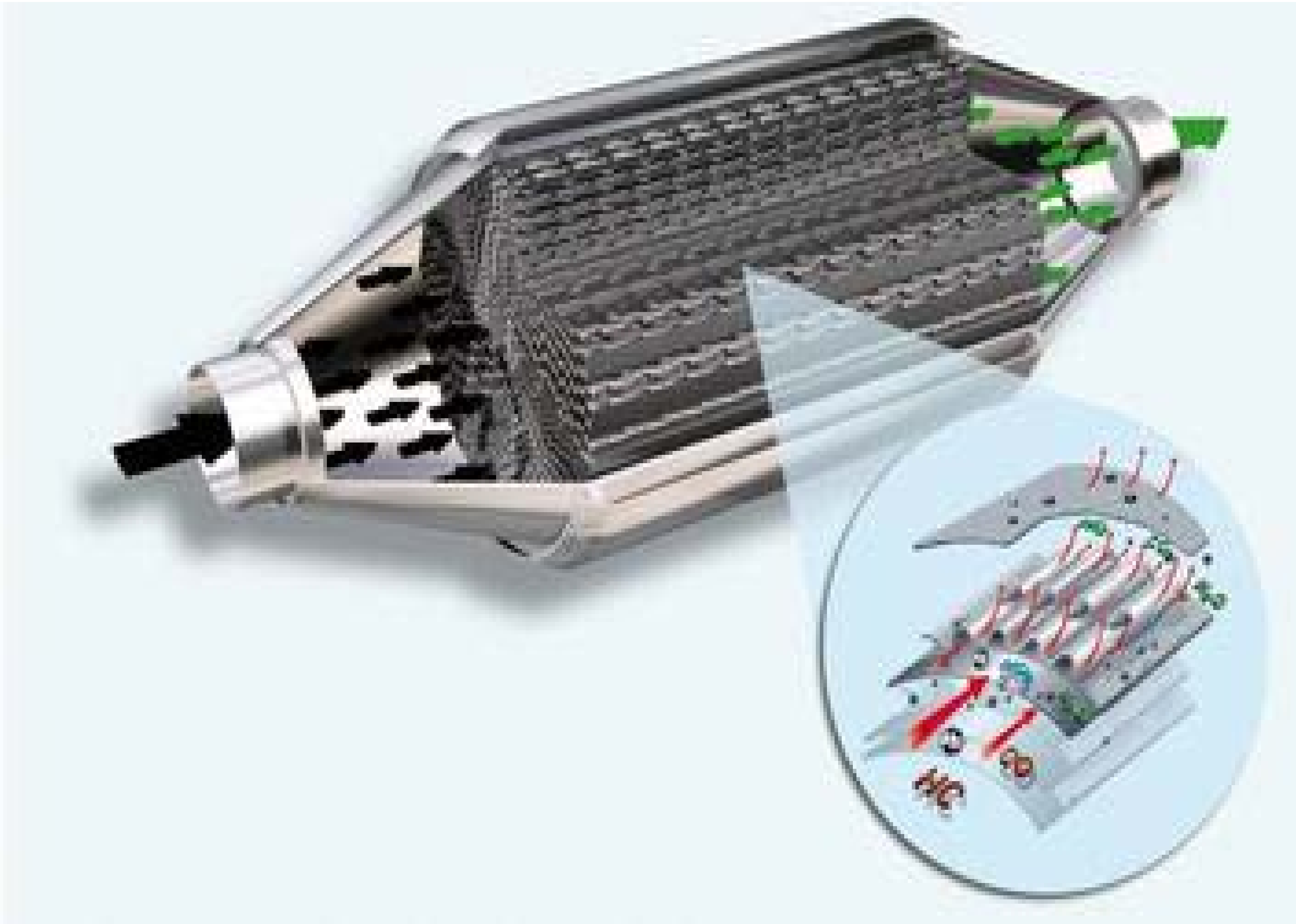
- Dynamization – Quantum Physics
- Running conditions to reduce specific particulates
- Novel NOx recirculation and burning systems
- 3-stage inter-cooling
- Variable Geometry turbocharging
- Water injection
- Variable timing
- Engine-Engine component matching
- Lighter engine components
- Dual fuel, novel mixing engines (HCCI/PCCI/RCCI)
- After treatment, exhaust configuration and use of electric booster
- SCR processes (NOx conversion) and PDF (PM) filters
- Some or all above

Different Filter configuration and aluminum titanate (As against Silicon Carbide) Filter system

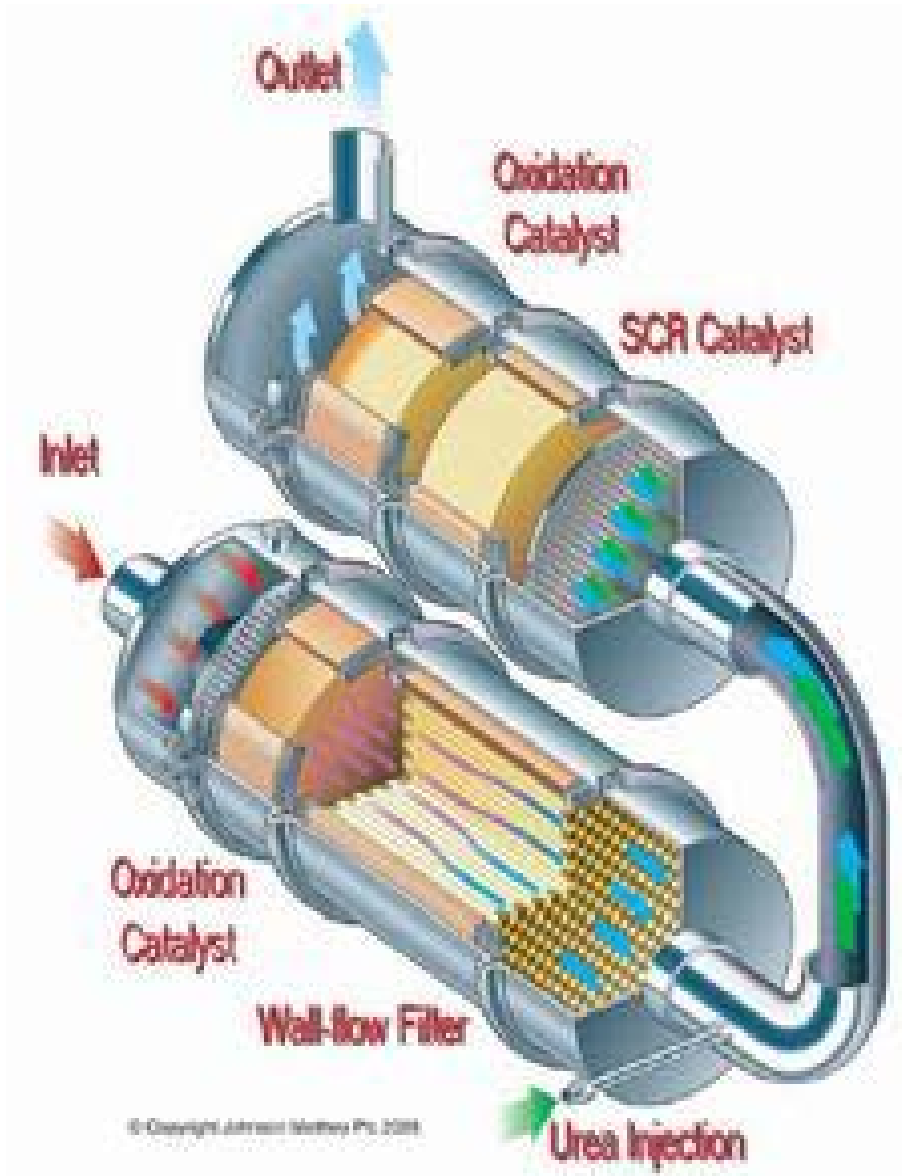




PARTIAL FLOW FILTER, WHICH CAPTURES PARTICULATES COMING OUT OF THE EXHAUST

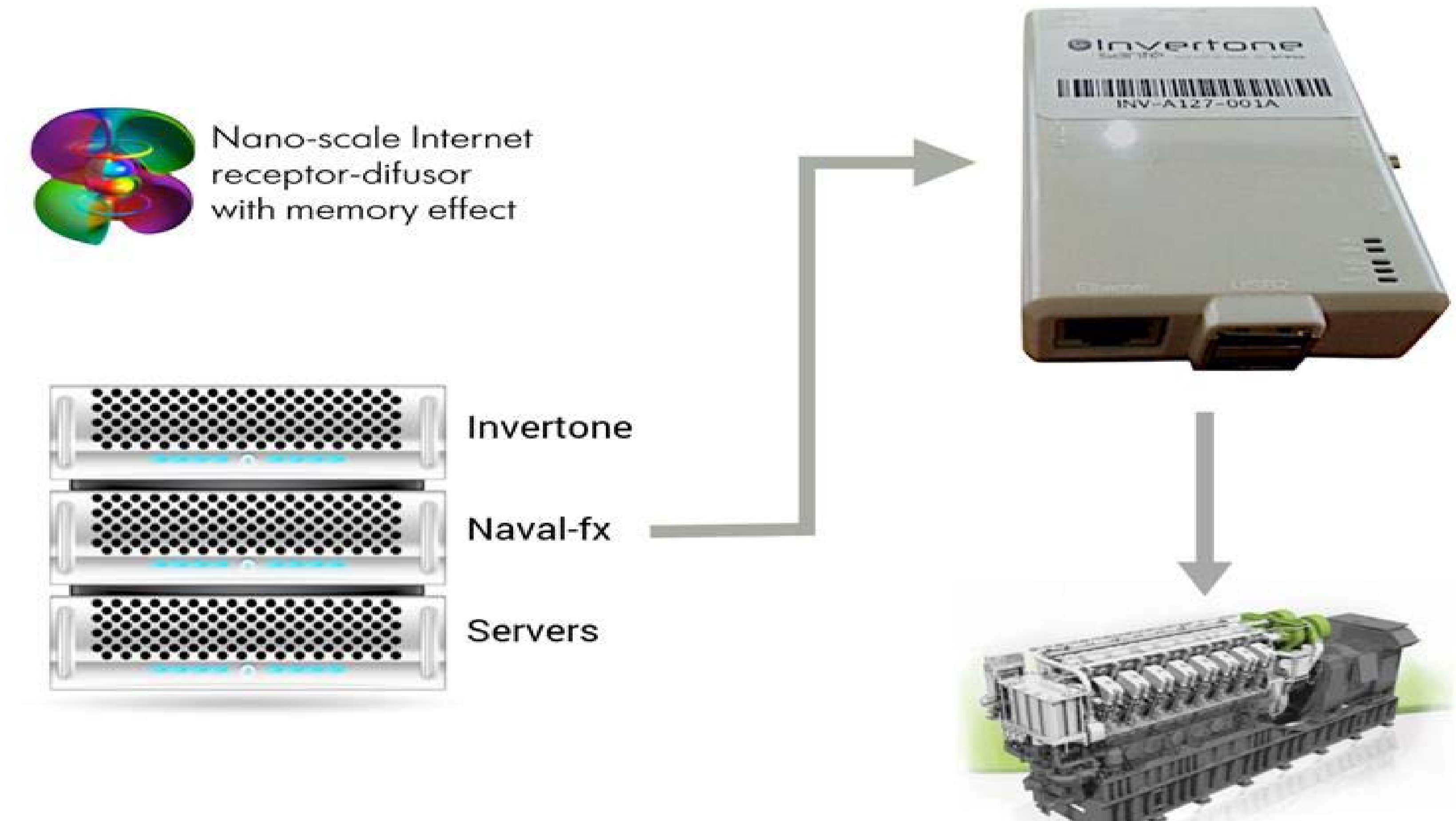


A VARIANT OF THE CRT CONCEPT (SCRT), RELATED TO CATALYTIC DPF REGENERATION

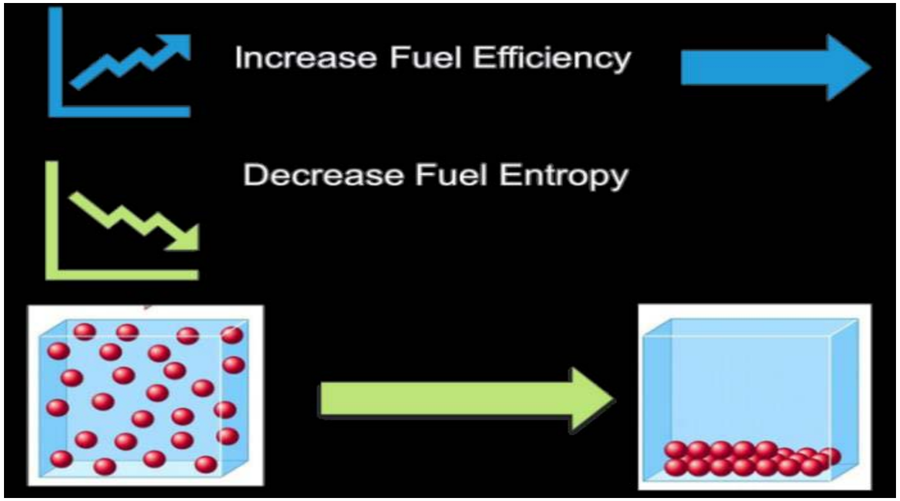


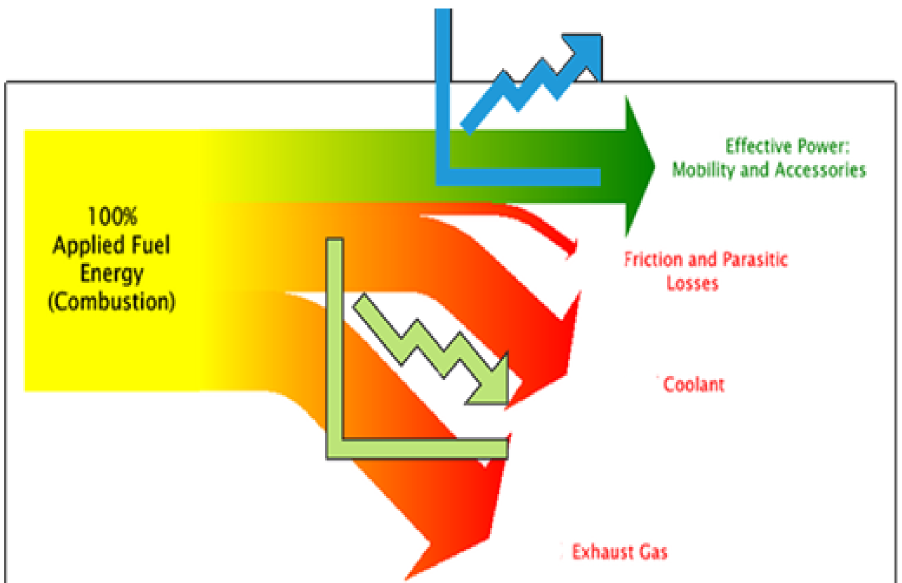
Receiver- Diffuser located in the Engine Room with internet access

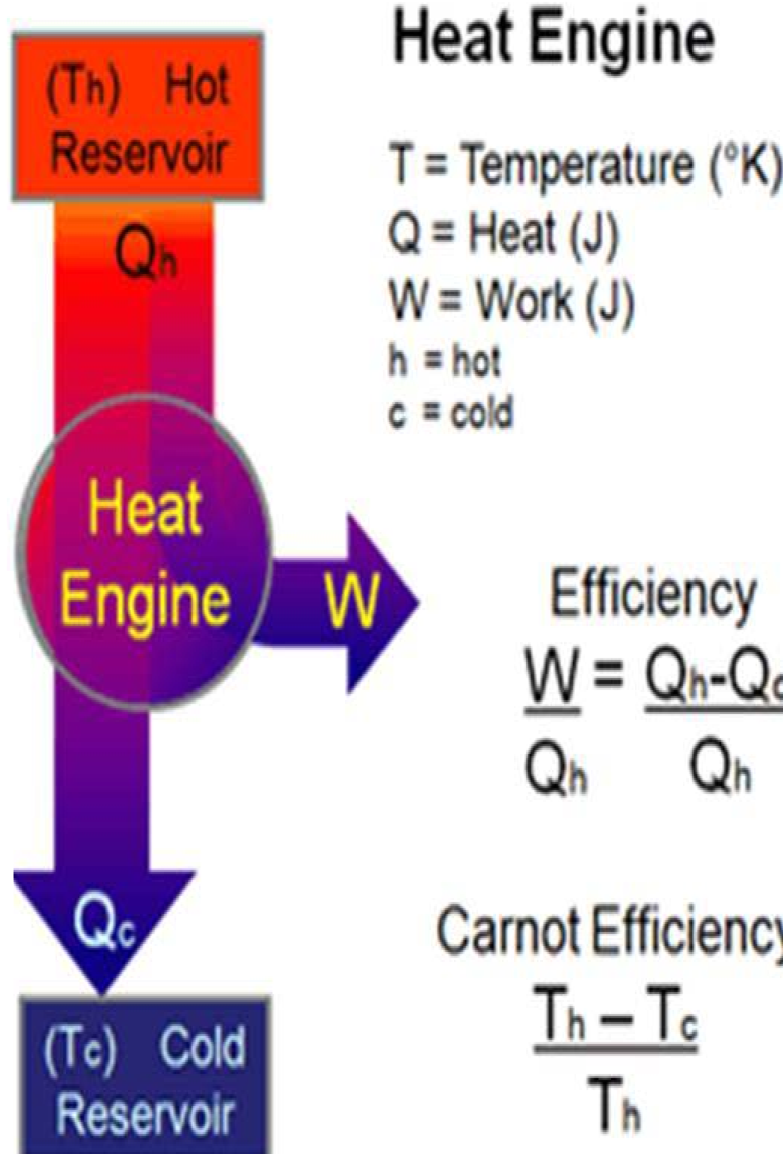
In case of a loss of signal, the system will remain active during a period of 60 days (effect memory), which allows reconnection.



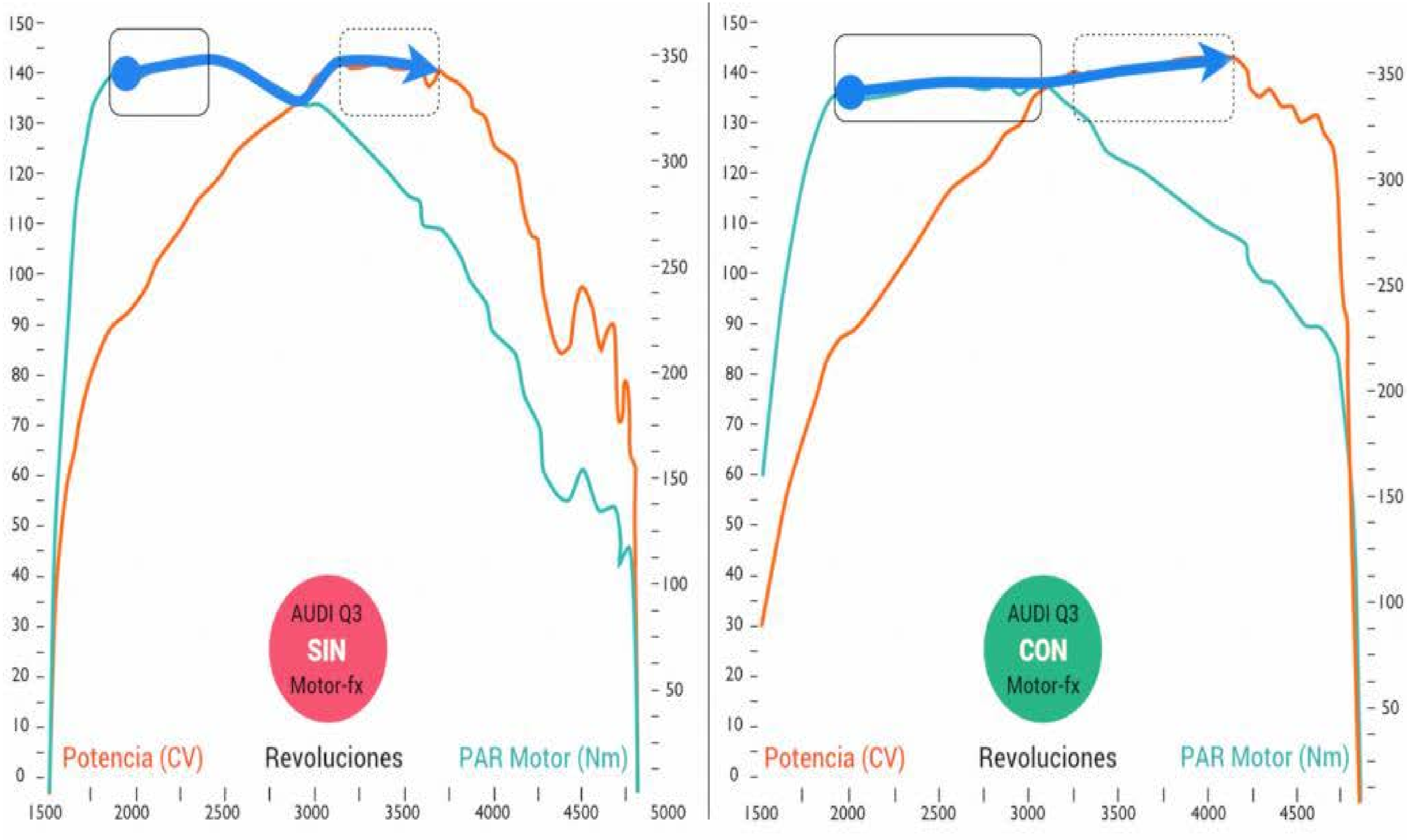
HOW IT ACTS ON FUEL? FROM







CURVES ANALYSIS: AFTER DYNAMIZING, THE OBTAINED TORQUE AND POWER CURVES HAVE CONSIDERABLY INCREASED ITS MAXIMUM RANGE (FLAT ZONE IN THE CENTER), WHICH DEFINES A MORE ELASTIC ENGINE, WITH LESS NEED TO CHANGE GEARS, FACT THAT DIRECTLY REPRESENTS A CONSUMPTION REDUCTION.



C4FF

Developing the Future

THANK YOU FOR YOUR ATTENTION

ON BEHALF OF ALL MARIEMS PARTERS