



The HERCULES (2004-2018) R&D program on 'green' engines for ships

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HERCULES Coordinator

Presentation to CIMAC Circle at Norshipping 2017

Oslo, Norway, 31st May 2017



SIXTH FRAMEWORK PROGRAMME



SEVENTH FRAMEWORK
PROGRAMME





GREENING: *the process of becoming more active about protecting the environment*

HERCULES is developing **new technologies** for marine engines:

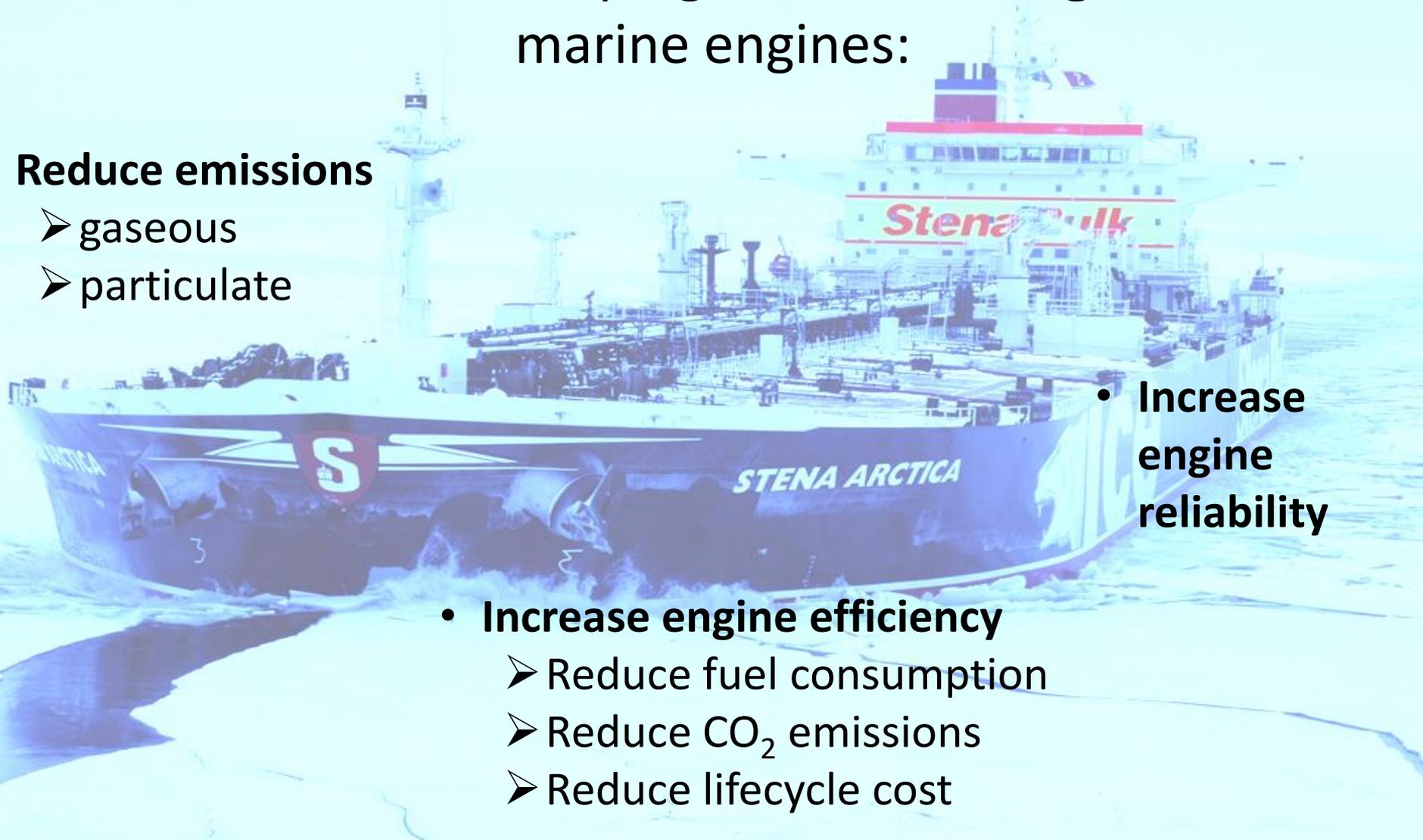
- **Reduce emissions**

- gaseous
- particulate

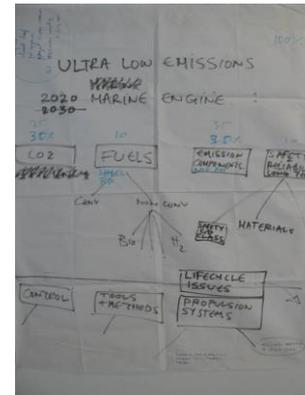
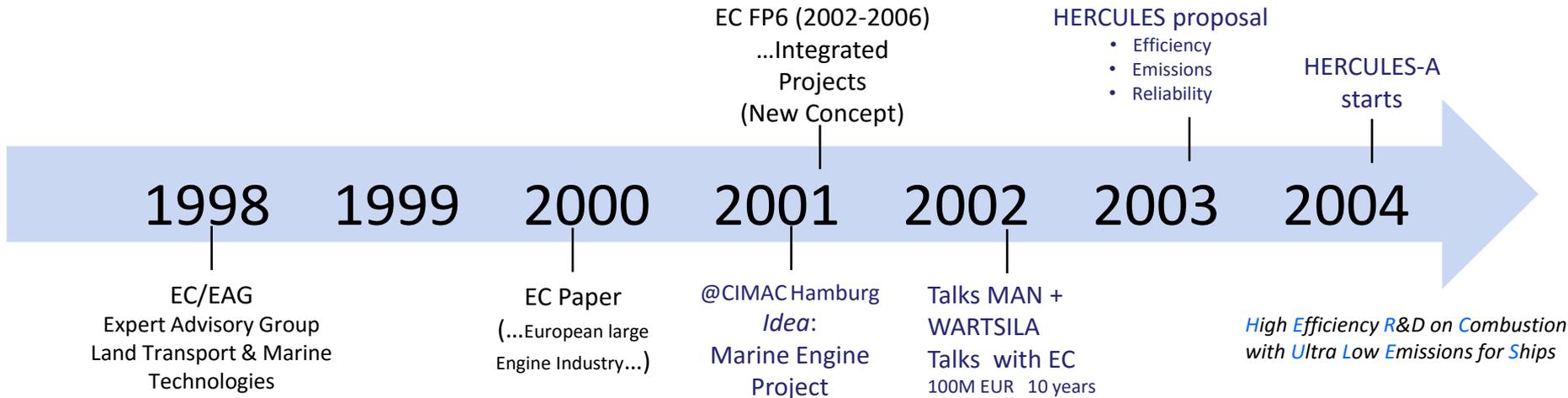
- **Increase engine reliability**

- **Increase engine efficiency**

- Reduce fuel consumption
- Reduce CO₂ emissions
- Reduce lifecycle cost



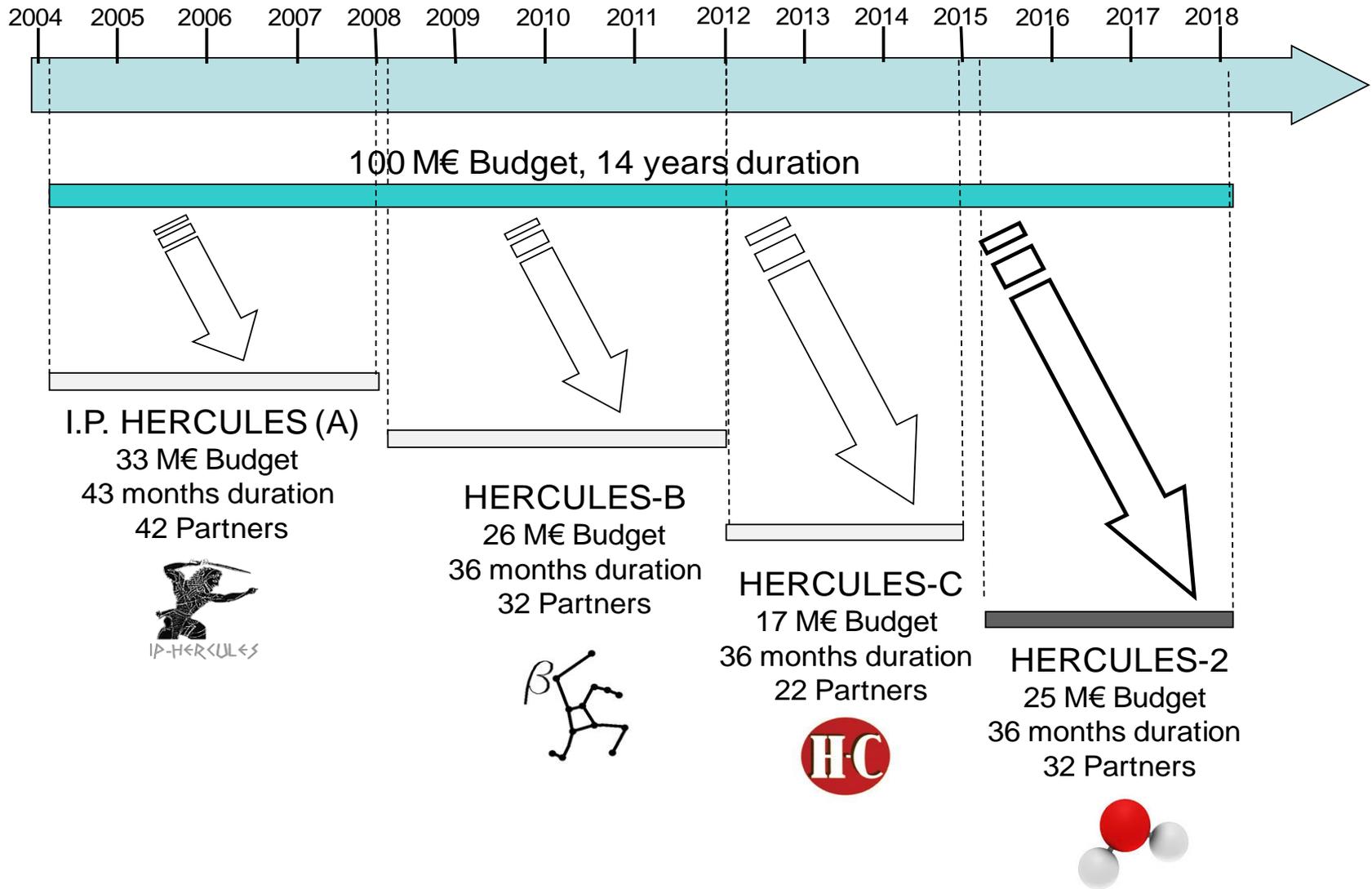
HERCULES Mythology



*Flipchart page
First MAN –
WARTSILA joint
Meeting: Helsinki,
4th July 2002*



HERCULES TIMELINE

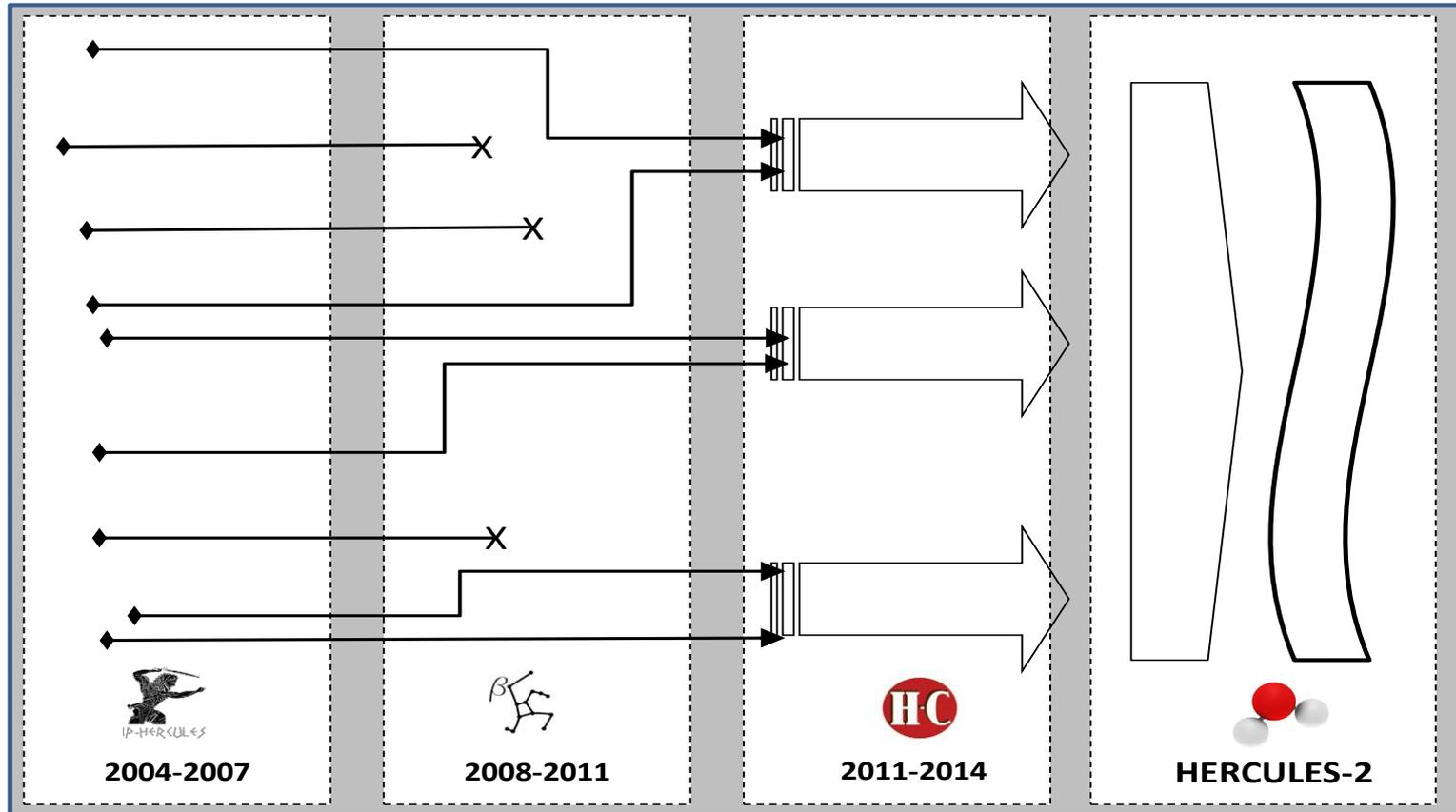


Research

Selection & Development

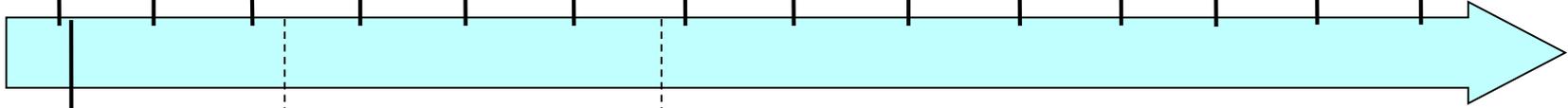
Technology Group Integration

Flexibility & Lifetime optimisation



HERCULES TIMELINE

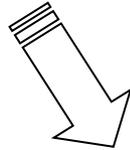
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015



Vision ⇒ R&D Project HERCULES ~100 M€ Budget, 10 years duration



Phase I



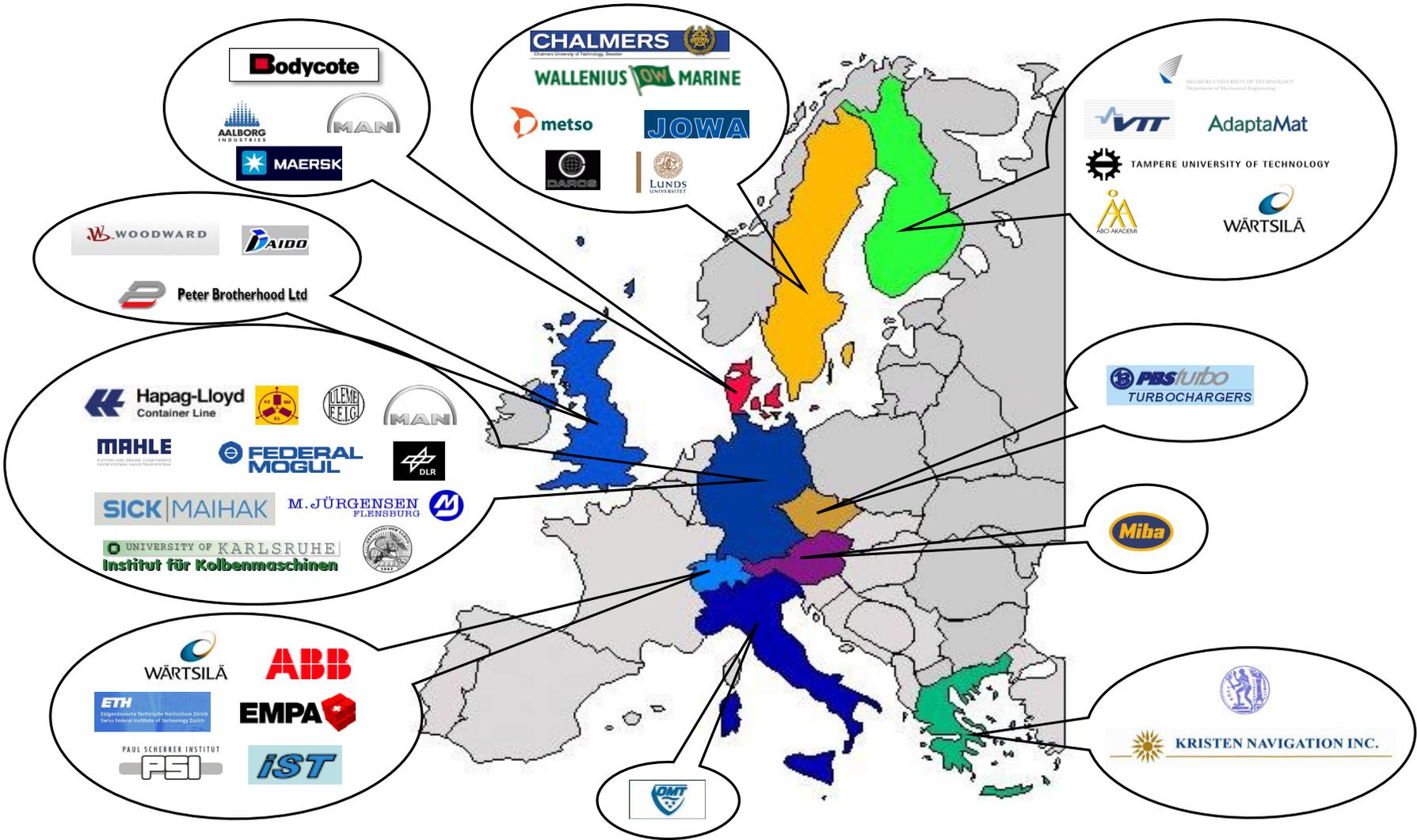
I.P. HERCULES (A)
33 M€ Budget
43 months duration
42 Partners



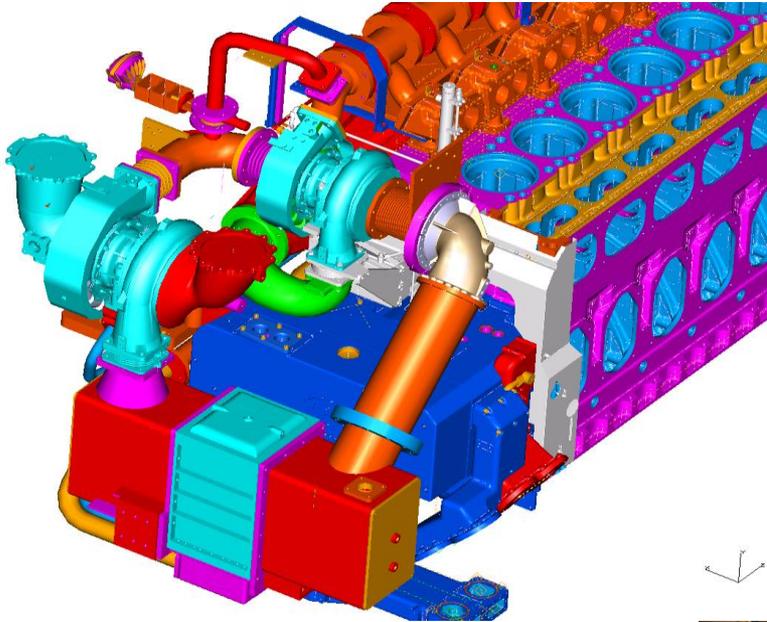
*High Efficiency R&D on Combustion
with Ultra Low Emissions for Ships*

TIP3-CT-2003-506676

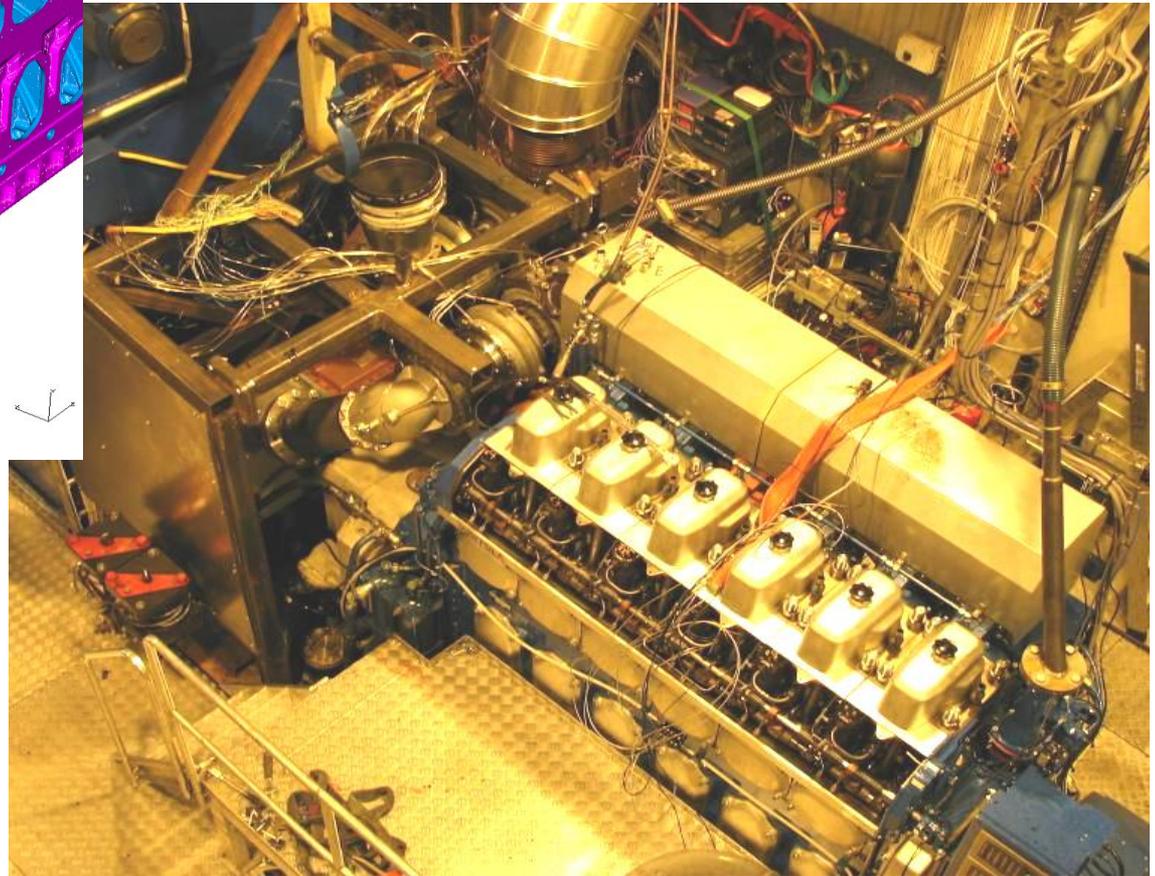




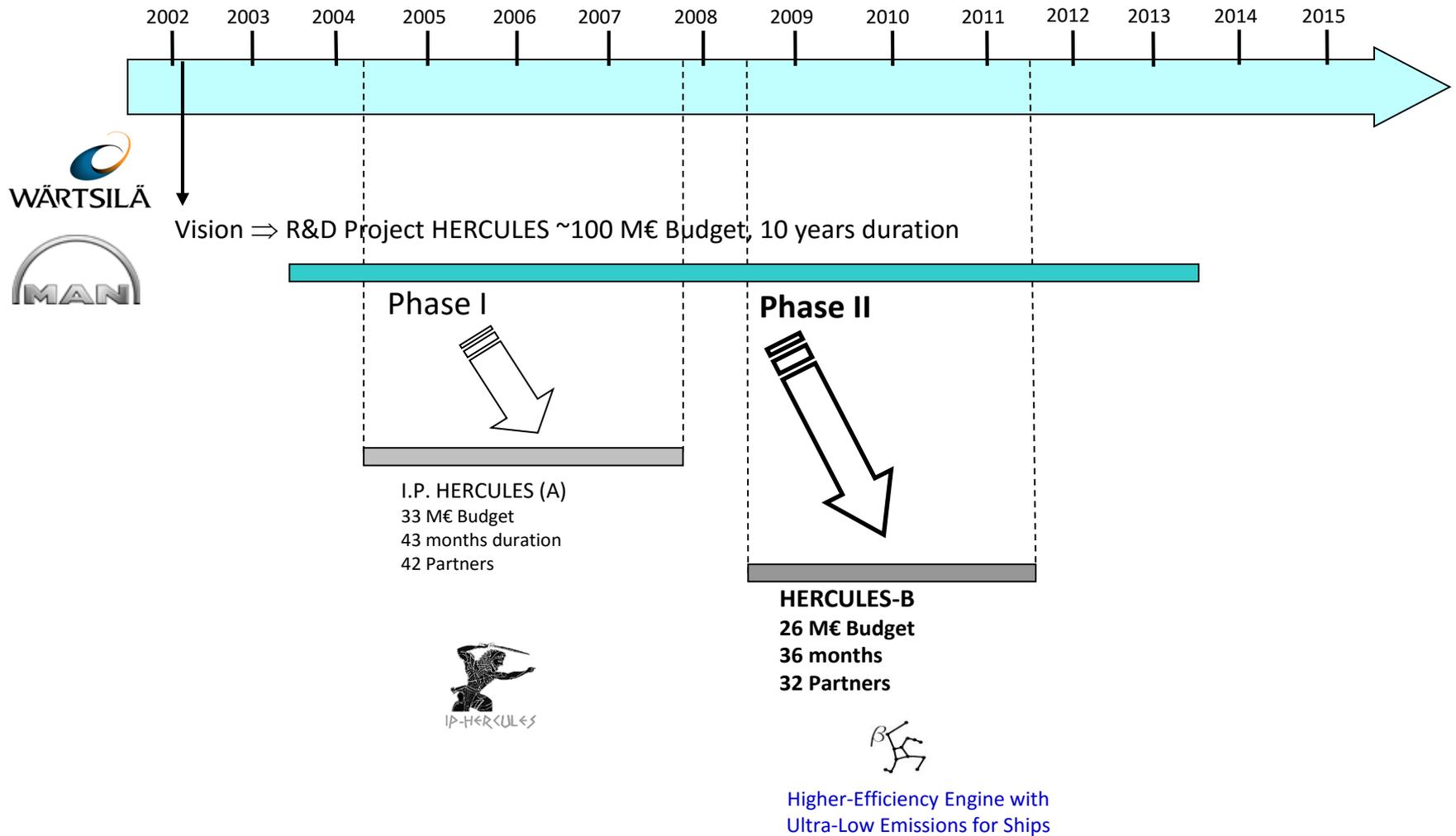
Two-stage turbocharged 4-stroke engine



CIMAC 2007 Congress: Best paper award !

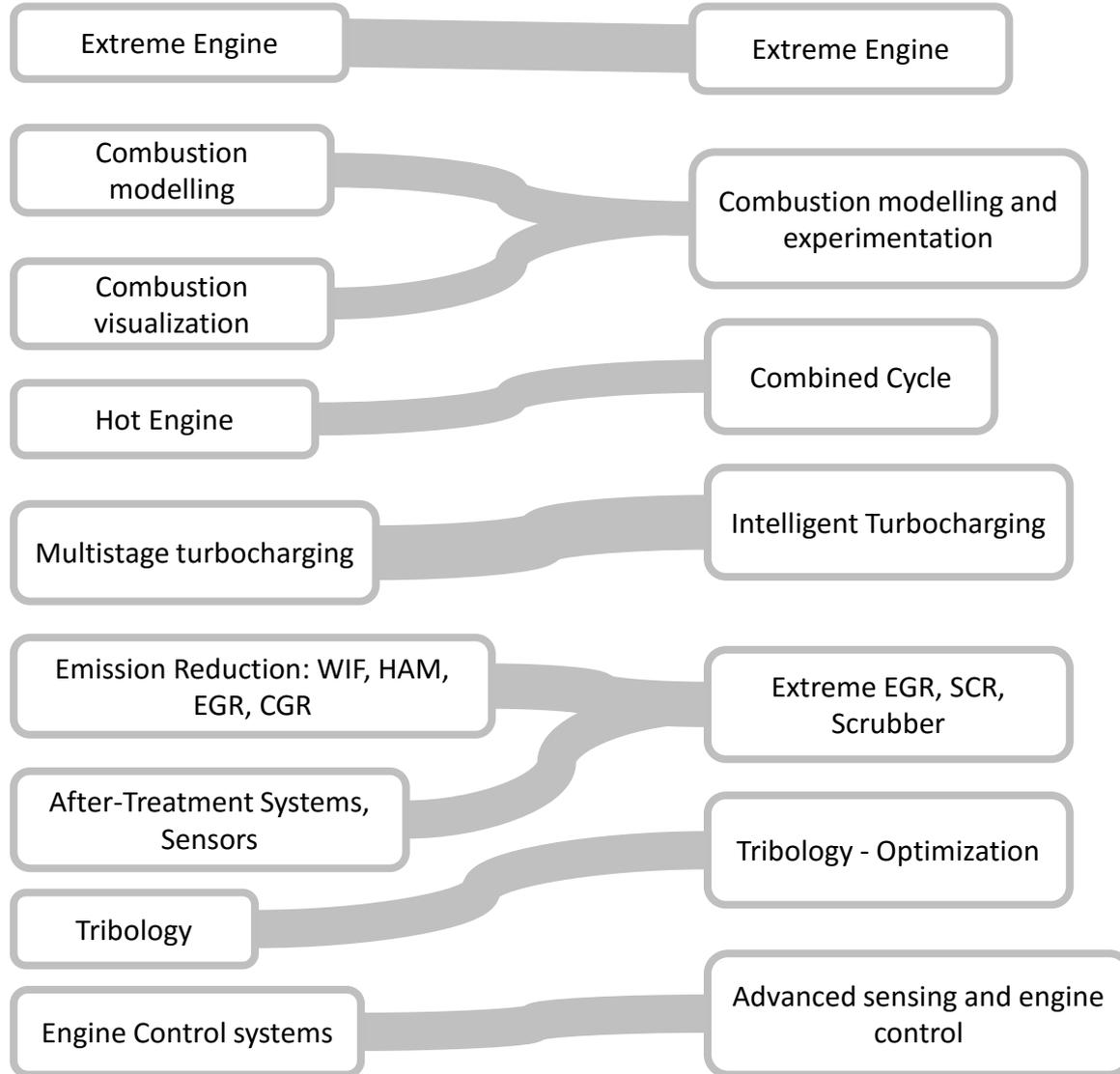
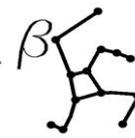


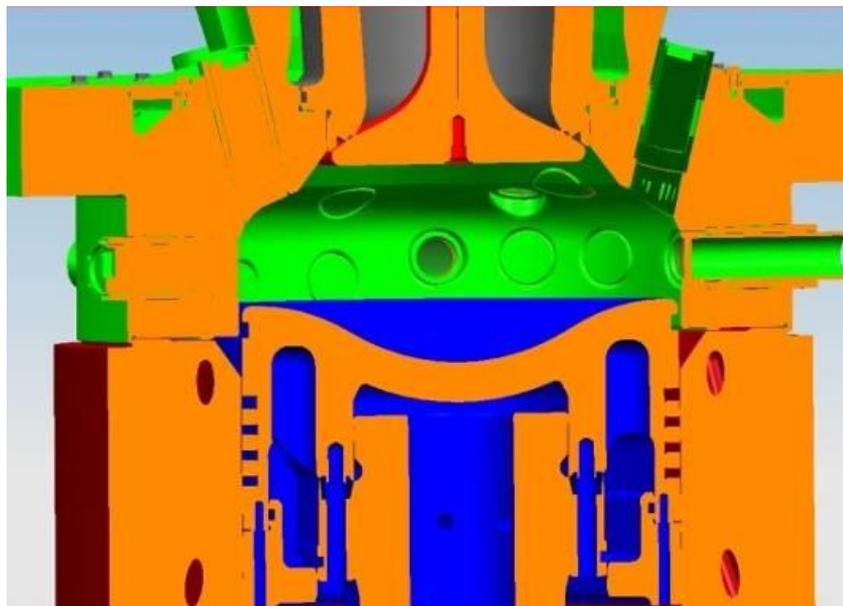
HERCULES TIMELINE



SCP7-GA-2008-217878







Optical cylinder covers for 2-stroke

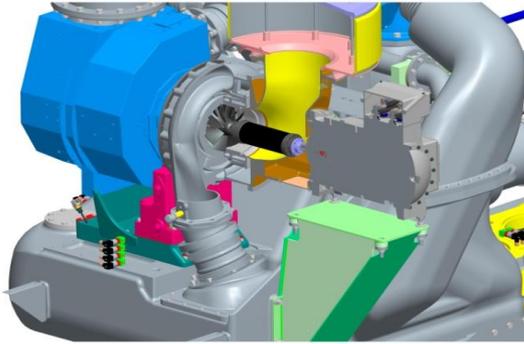




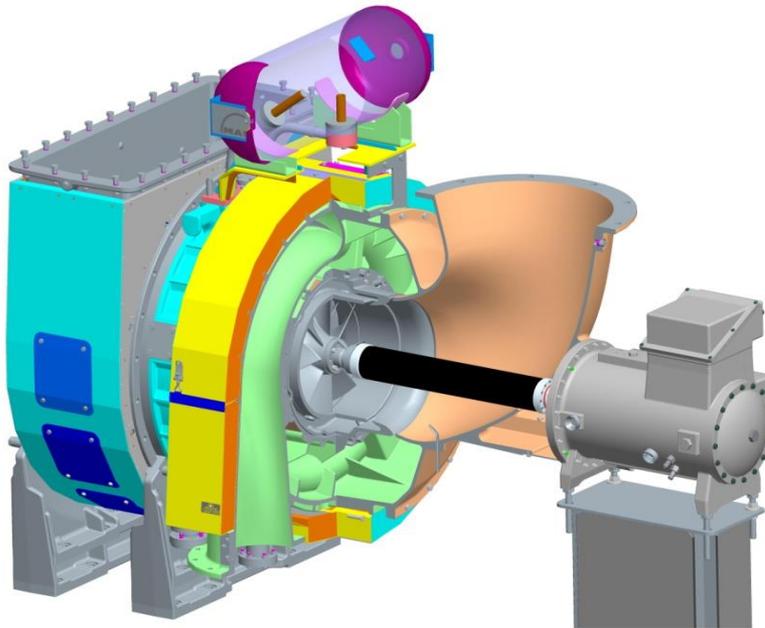
T/C with variable compressor inlet guide vanes



T/C with variable turbine nozzle vanes

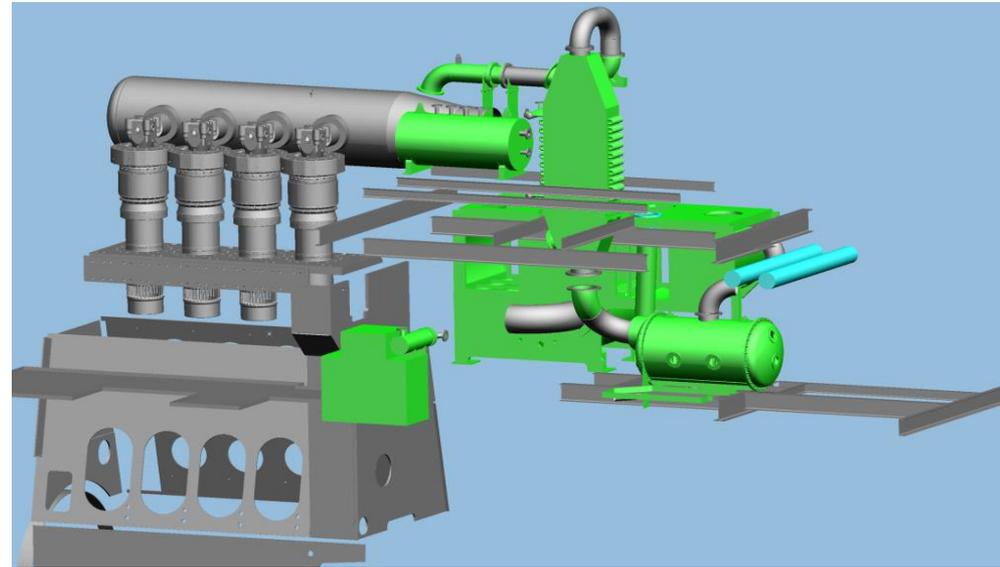
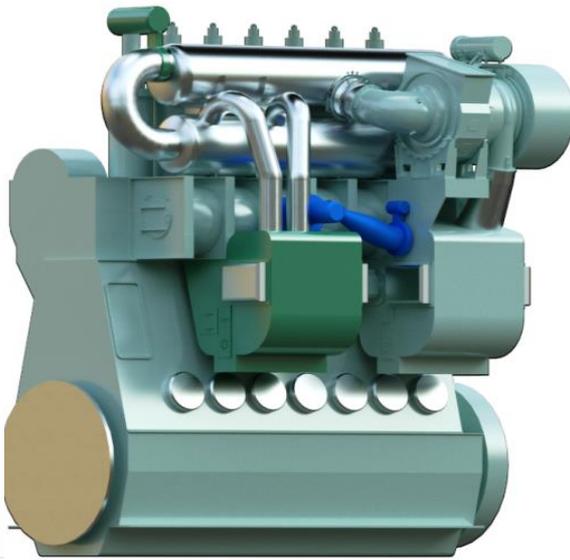


PTI / PTO





High Pressure Boiler installed on 4T50ME-X

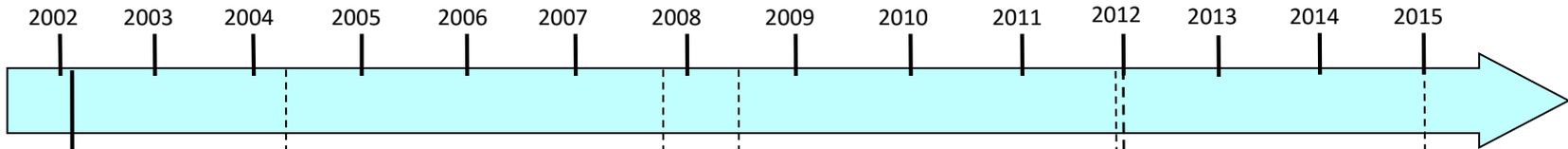


Towards HERCULES-C

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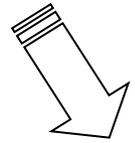
HERCULES Programme



Vision ⇒ R&D Project HERCULES ~100 M€ Budget, 10 years duration



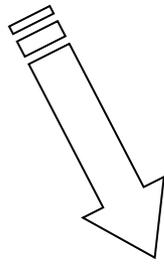
Phase I



I.P. HERCULES (A)
33 M€ Budget
43 months duration
42 Partners



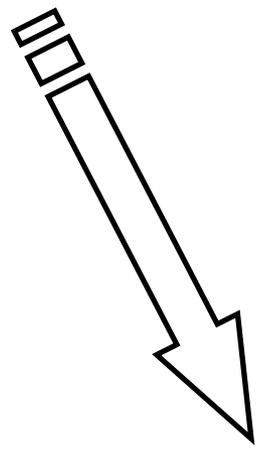
Phase II



HERCULES-B
26 M€ Budget
36 months duration
32 Partners



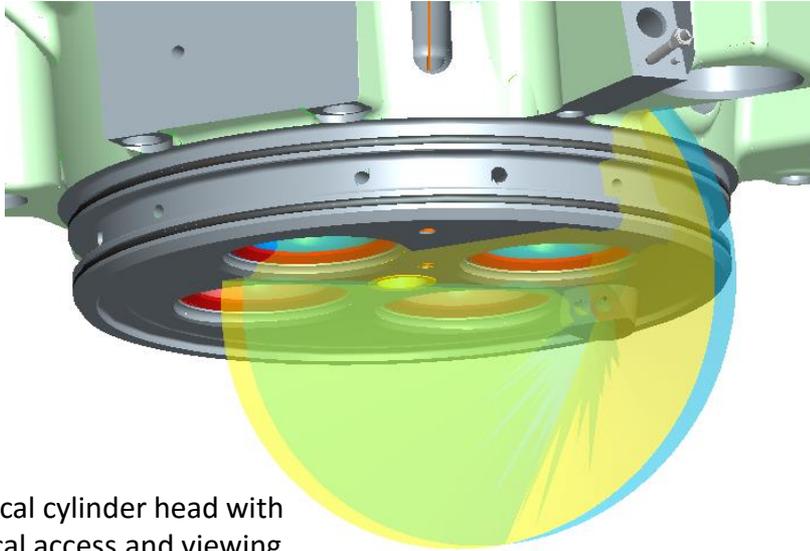
Phase III



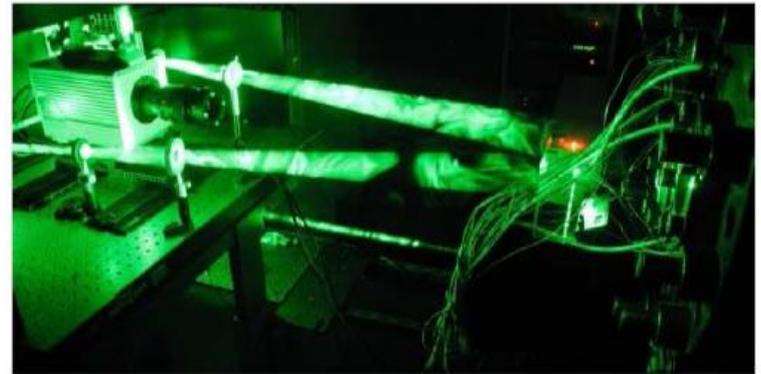
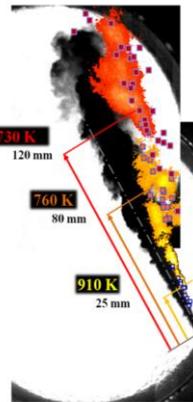
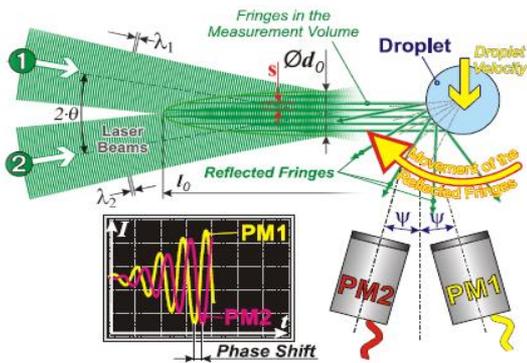
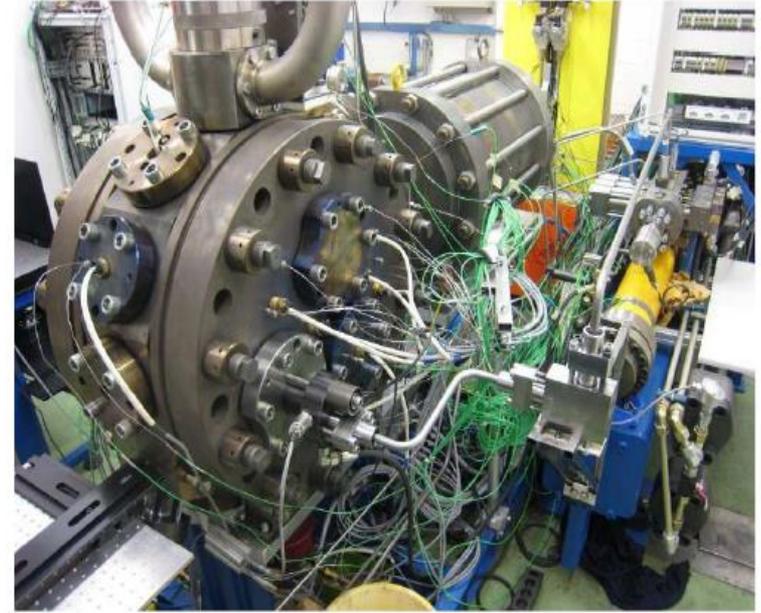
HERCULES-C
17 M€ Budget
36 months duration
22 Partners



Objective # 1: Substantial reduction in fuel consumption (WPG1, WPG2, WPG4)



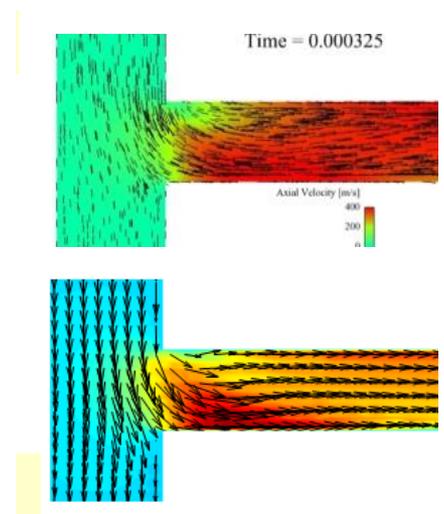
Optical cylinder head with optical access and viewing range



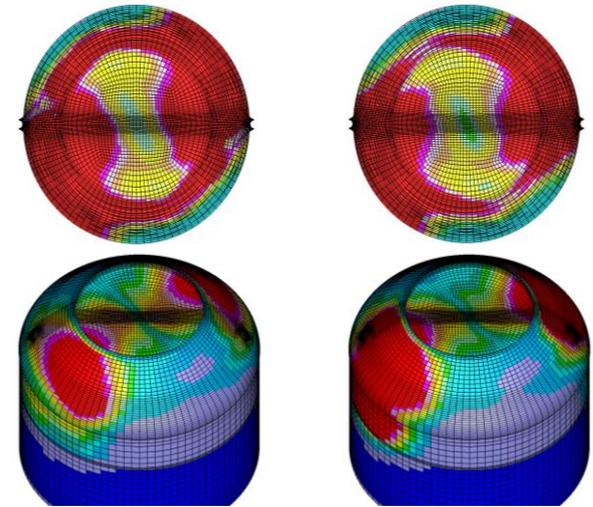
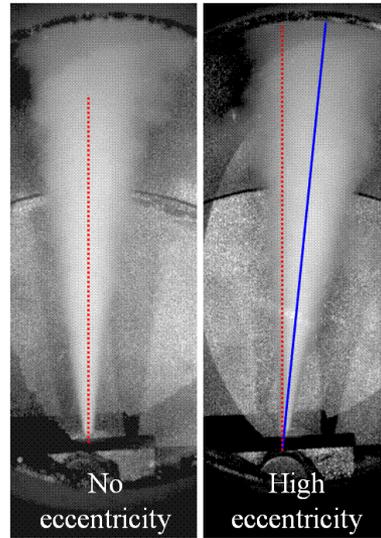
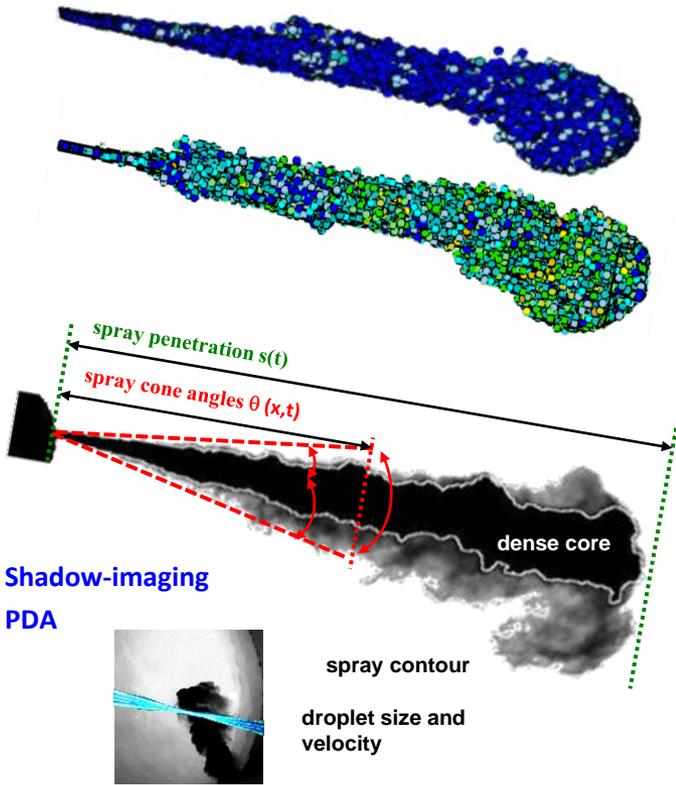
WP 3: Injection, Spray Formation and Combustion

(TIMESPAN: SHORT=S, MEDIUM=M, LONG=L)

WORK PACKAGE GROUP	ITEM	TIME
WPG2 Fuel Injection Models & Experiments	Models for flow and cavitation applicable to large engine injectors	M



CFD investigations of the nozzle internal flow



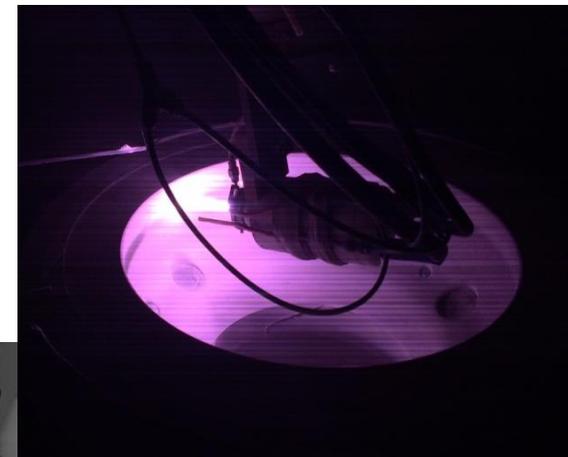
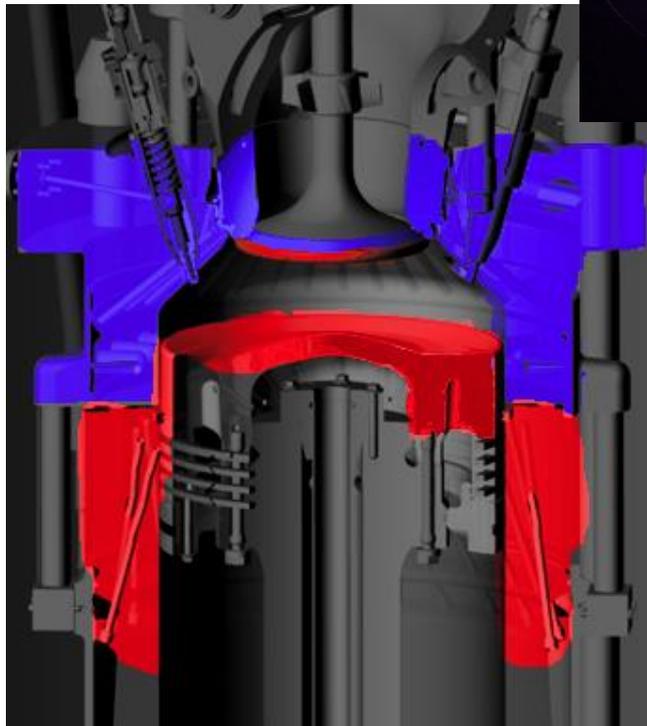
Nozzle bore eccentricity investigation

(TIMESPAN: SHORT=S, MEDIUM=M, LONG=L)

WORK PACKAGE GROUP	ITEM	TIME
WPG5 New Materials & Tribology	Low friction and wear engine piston rings	S
	Increased performance main engine bearings	M
	Thermal Barrier Coatings for piston crowns	M

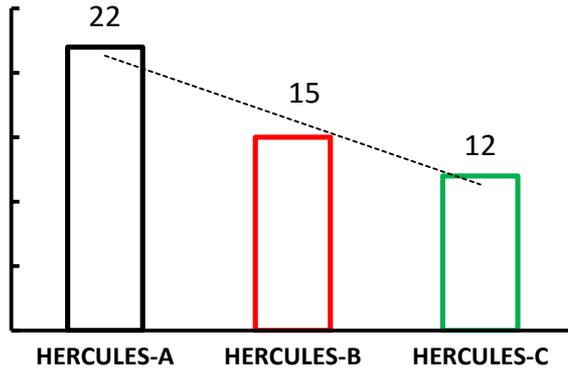


Thermal Barrier Coatings

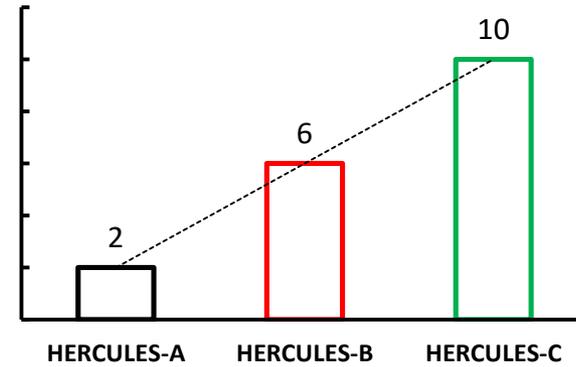


Productivity , HERCULES-A to HERCULES-C

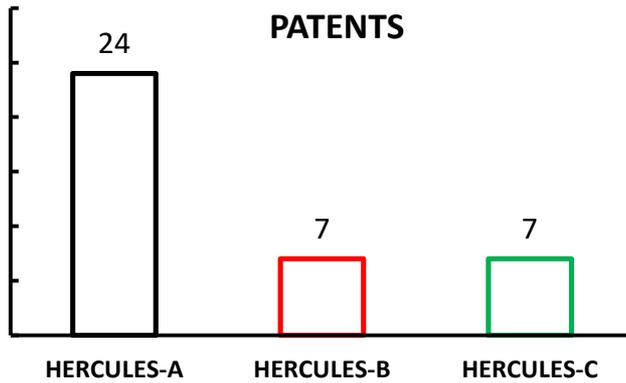
PROTOTYPES



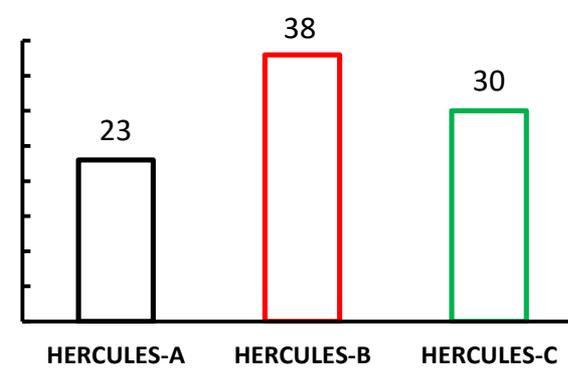
PRODUCTS



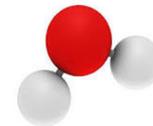
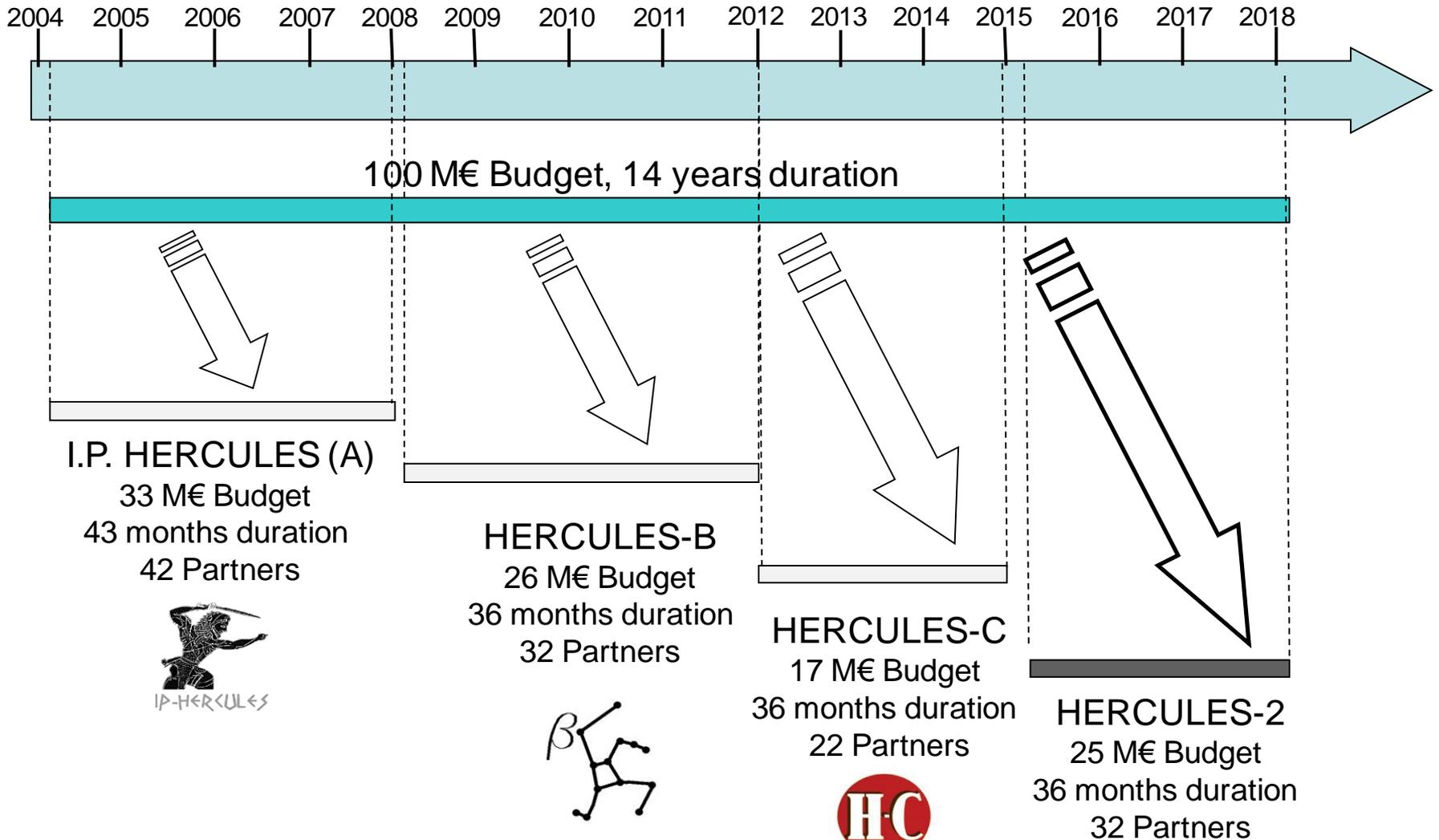
PATENTS

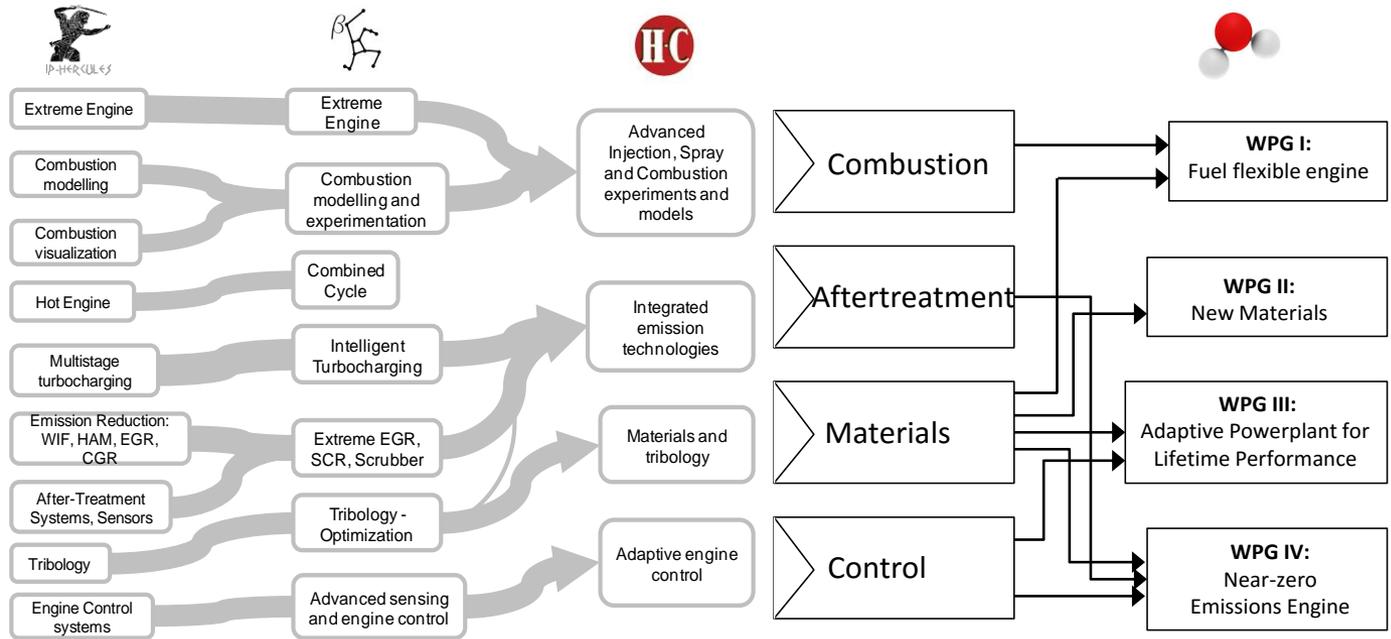


PUBLICATIONS



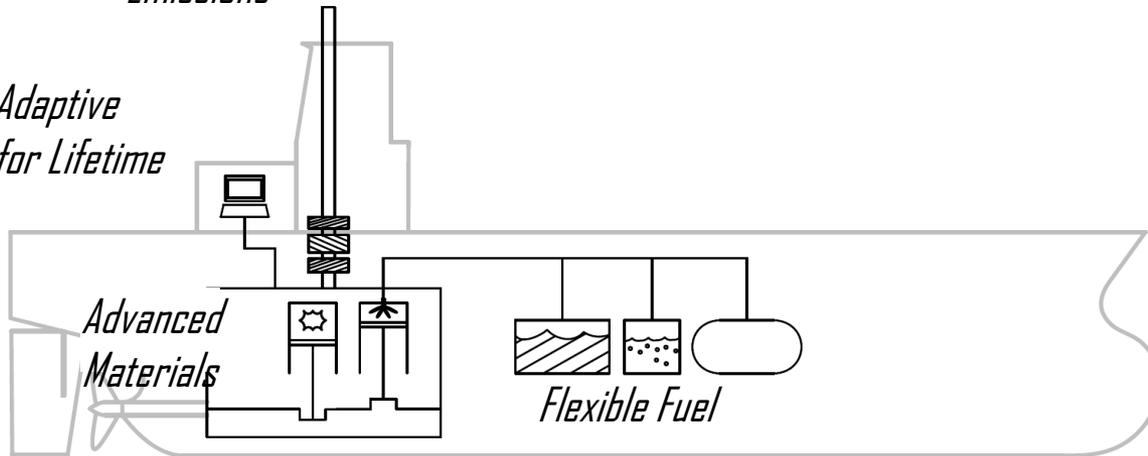
HERCULES TIMELINE



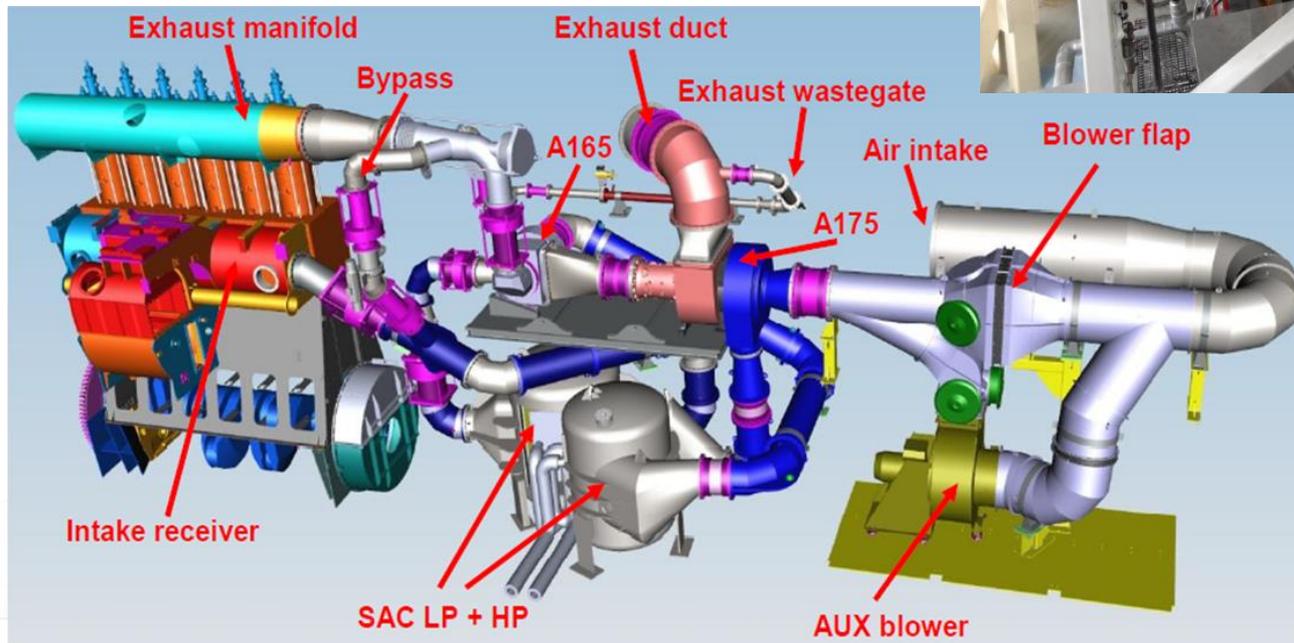
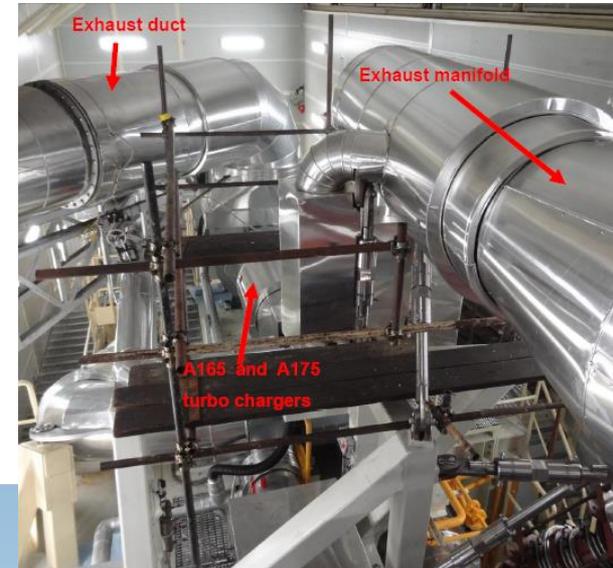


Near Zero Emissions

Adaptive for Lifetime

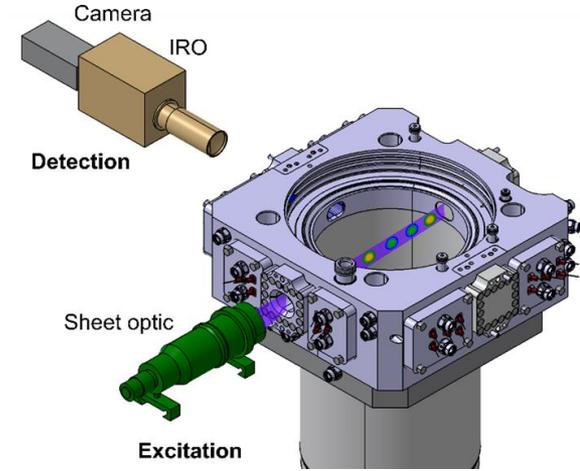
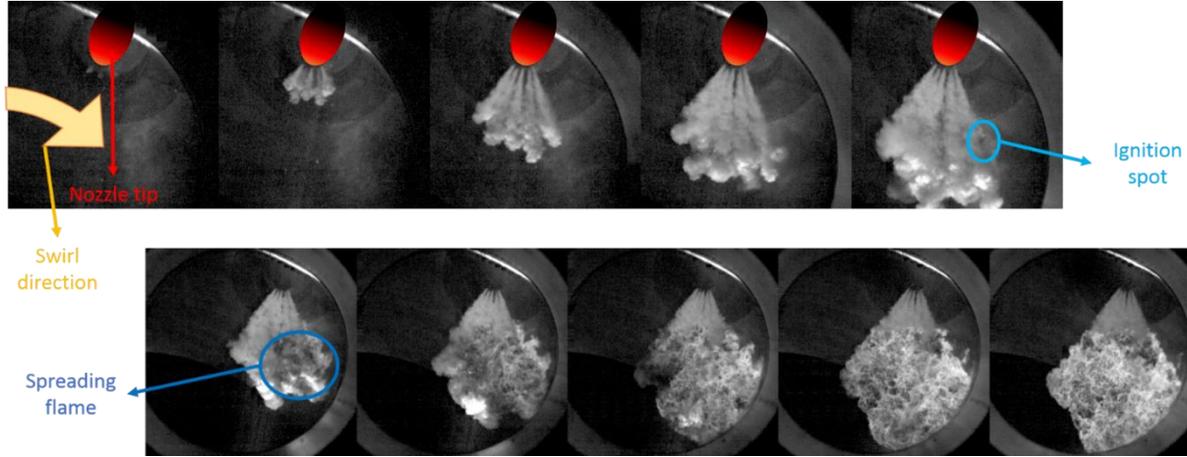


Full scale experimental setup for complete variability of turbocharging system combined with EGR

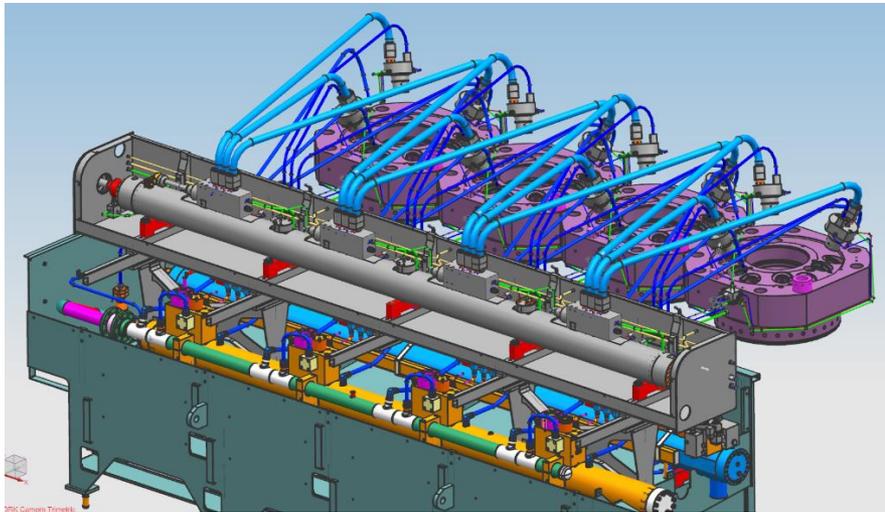




Fuel flexible engine



measuring mixture distribution



engine with fuel flexible injection system

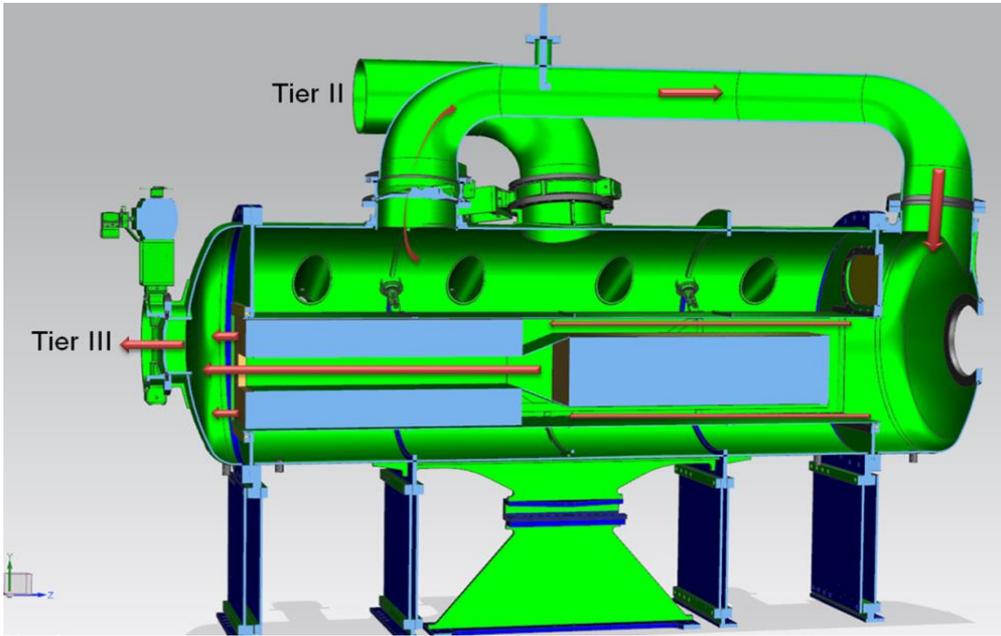




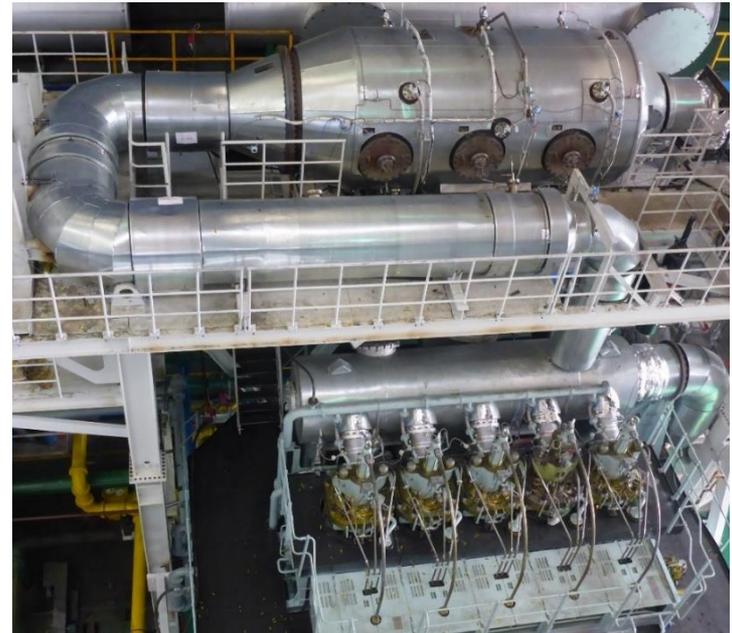
Nikolaos Kyriakos

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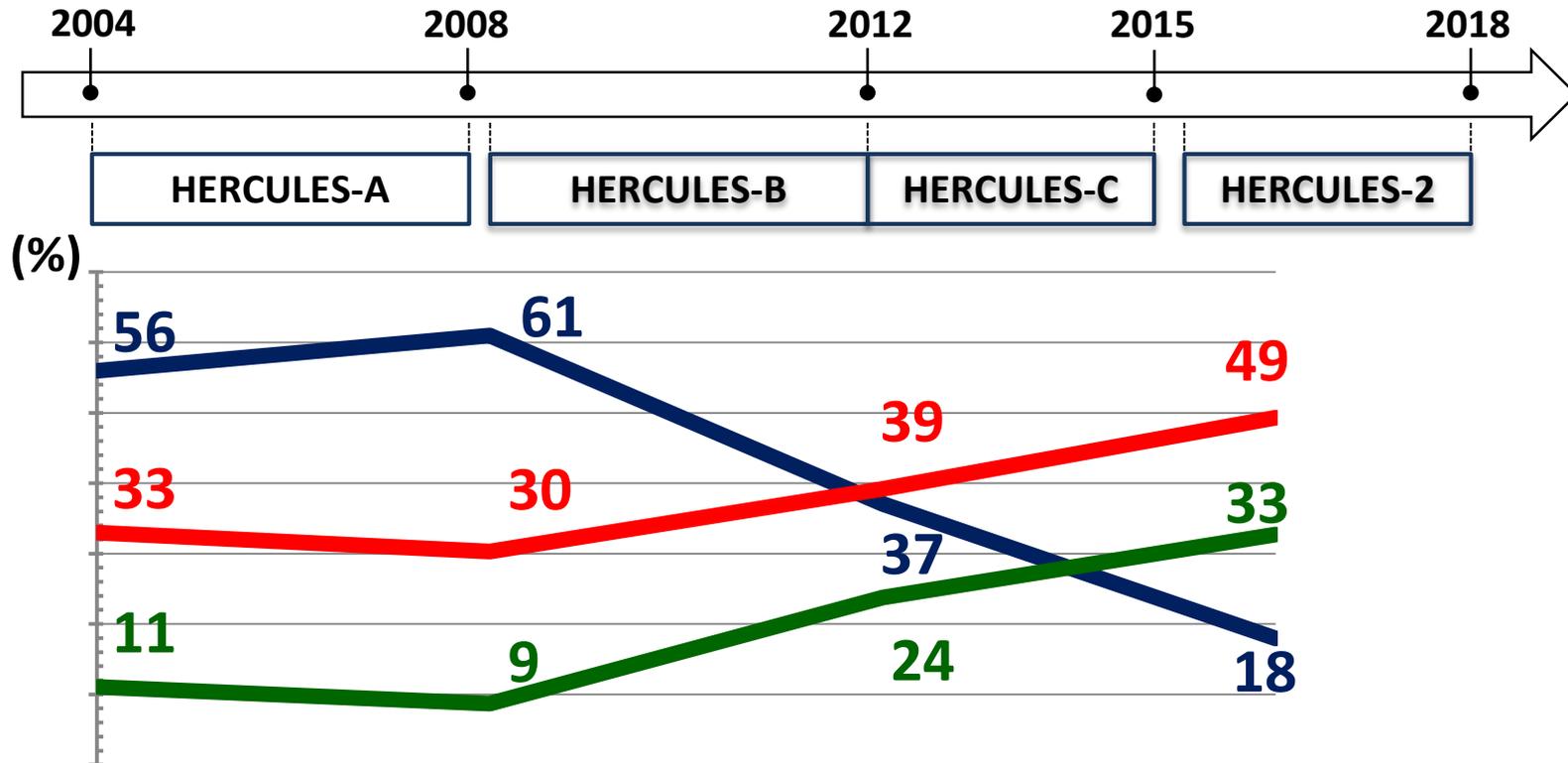
HERCULES Programme



Engine integrated HP SCR
inside exhaust receiver



Percentage **allocation of budget** into 3 main areas of R&D in the 4 HERCULES Projects (189 subprojects)



% of individual project budget

Total 102 M€

— Efficiency

43%

— Emissions

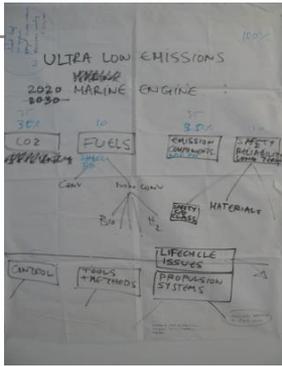
38%

— Reliability & Lifetime

19%



HERCULES R&D 2002 Estimate and Spending TOTAL



2002 allocation estimates for 100 Meur

(merge)

H-A,B,C,2 Results 2016

CO ₂ (EFFICIENCY)	30%	37%	EFFICIENCY	43%
FUELS	10%			
EMISSIONS	35%	40%	EMISSIONS	38%
RELIABILITY LIFETIME CONTROL	10% 5% 5%	23%	RELIABILITY LIFETIME	19%
METHODS, TOOLS	5%			

100%



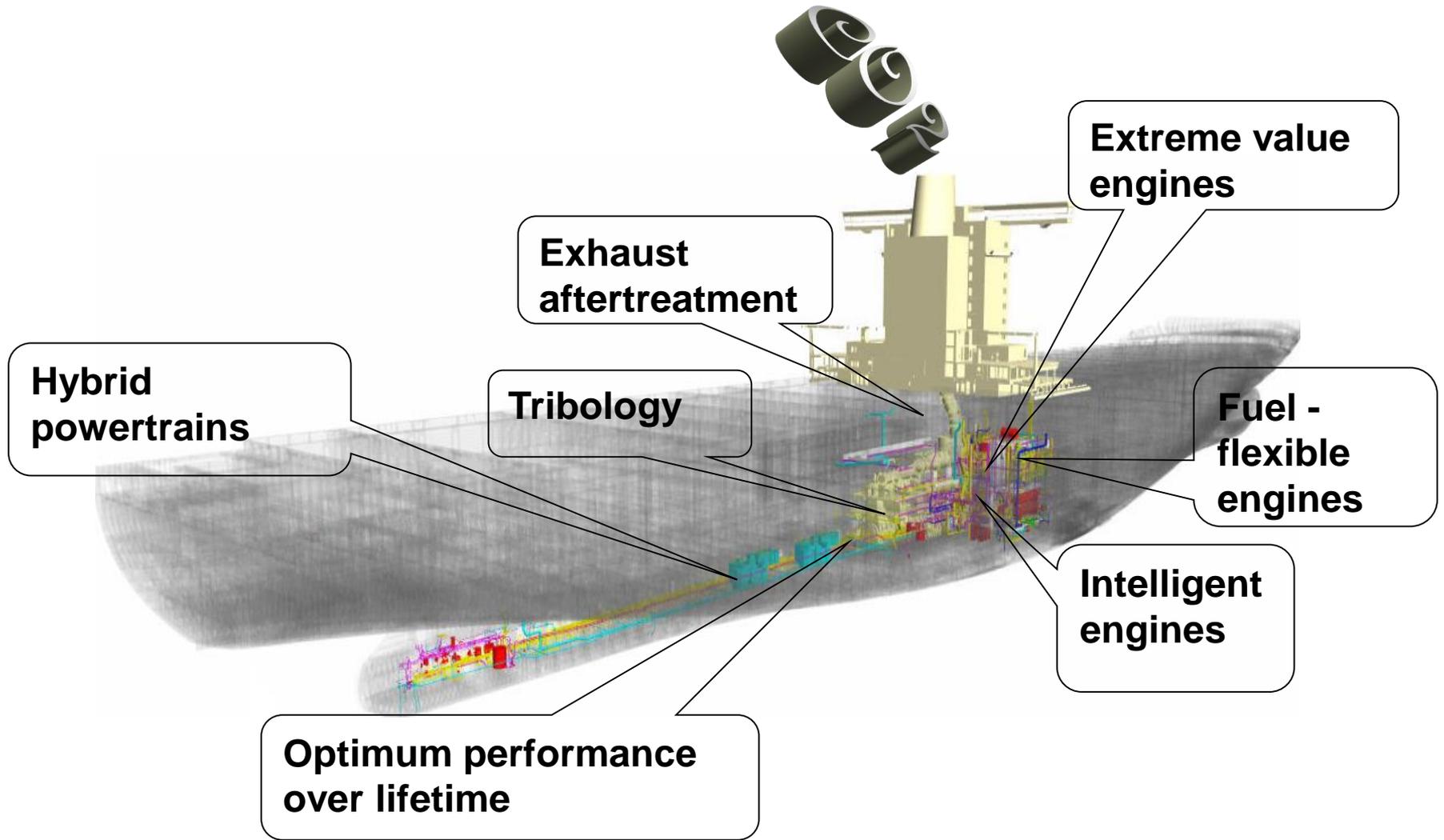
Several **resulting technologies** from the HERCULES programme related to **large marine engines** are:

- 1. Multi-stage Turbocharging (+Variable Valve Timing),**
allowing higher performance and improved **economy**.
- 2. Power Take In/Out and Flexible Turbocharger (+Variable Geometry),**
allowing improved **economy** over the operating range.
- 3. Increased maximum cylinder pressure, BMEP,**
leading to improved **economy**.
- 4. Cylinder auto-tuning & Injection optimization**
for improved performance, improved **economy**, reliability and **emissions**.
- 5. Water-In-Fuel, Water injection,**
for reduced NOx **emissions**.
- 6. Selective Catalytic Reduction-SCR** for exhaust NOx **emissions** aftertreatment.
- 7. Tribology and Lubrication** improvements and advanced Materials,
for improved **economy** and reliability.
- 8. Waste Heat Recovery** from Hot Engine,
for improved **economy**.
- 9. Exhaust Gas Recirculation,**
for reduced NOx **emissions** , with scrubbers and high pressure exhaust boiler.



<i>TECHNOLOGY AREA</i> <i>TECH ITEMS</i>	COMBUSTION	TURBO CHARGING	EMISSIONS ATU	MATERIALS FRICTION	MONITOR CONTROL OPTIMIZATION
Multi-Turbo/ VVT		✓			✓
PTI/PTO		✓			✓
Increased Pmax. Cyl.	✓	✓		✓	✓
Cylinder auto-tuning					✓
Water-in-Fuel	✓		✓		
SCR			✓		✓
Tribology				✓	
WHR- Hot Engine				✓	✓
EGR			✓		✓
Cylinder cut-out					✓
Dual Fuel /Multi Fuel	✓				✓

Near future R&D in ship propulsion engines



- The longevity of alliances is often used as proxy of their performance.
- The HERCULES alliance of 14 years has been demonstrably successful
- Many results of R&D already matured into products.
- Much of the 100M budget was spend towards **greening**.
- If efficiency increases achieved are applied, the 100 M is soon regained.
- Intelligent monitoring/control/optimization is a clear direction for future development.



Compilation of the HERCULES Program 82 Partners



SIXTH FRAMEWORK PROGRAMME



SEVENTH FRAMEWORK PROGRAMME

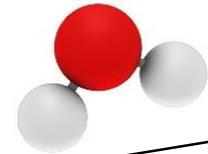
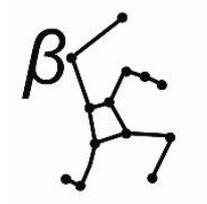


HORIZON 2020



NATIONAL TECHNICAL UNIVERSITY OF ATHENS

End of Presentation



SIXTH FRAMEWORK PROGRAMME



SEVENTH FRAMEWORK PROGRAMME



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