


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

Prof. Nikolaos P. Kyrtatos,

HERCULES Coordinator

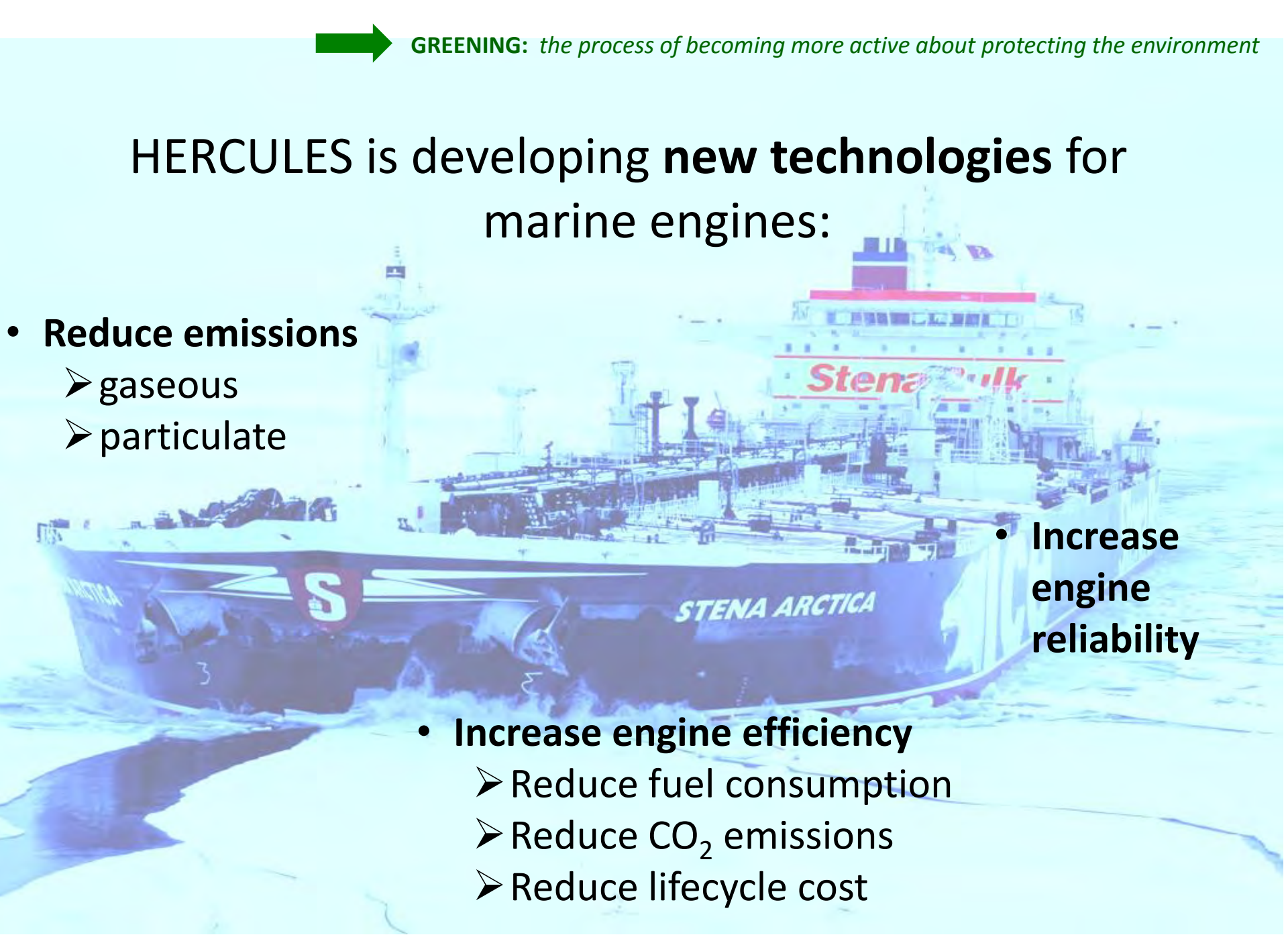
Presentation to CIMAC Circle at Norshipping 2017

Oslo, Norway, 31st May 2017

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 CO_2 emissions
  - Reduce lifecycle cost



HERCULES Mythology

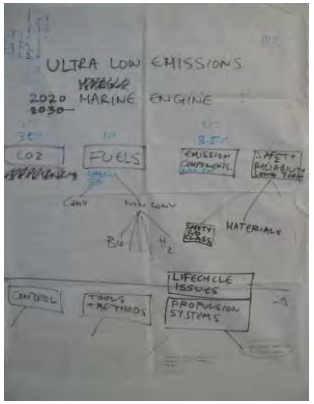
1998 — EC/EAG
Expert Advisory Group
Land Transport & Marine Technologies

1999

2000 — EC Paper
(...European large Engine Industry...)

2001 — EC FP6 (2002-2006)
...Integrated Projects
(New Concept)
@CIMAC Hamburg
Idea:
Marine Engine Project

2002 — Talks MAN + WARTSILA
Talks with EC
100M EUR 10 years



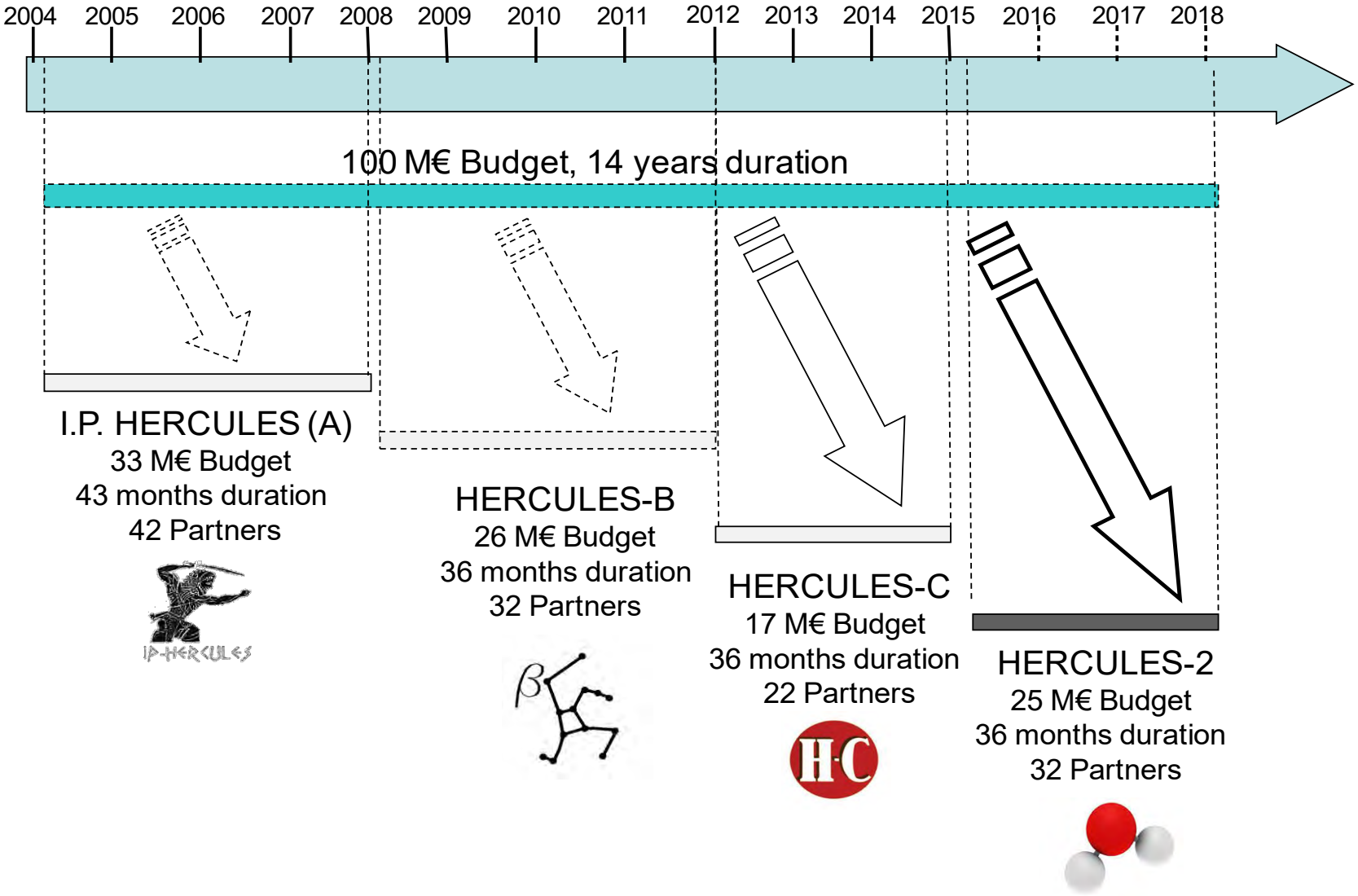
Flipchart page
First MAN – WARTSILA joint Meeting: Helsinki, 4th July 2002

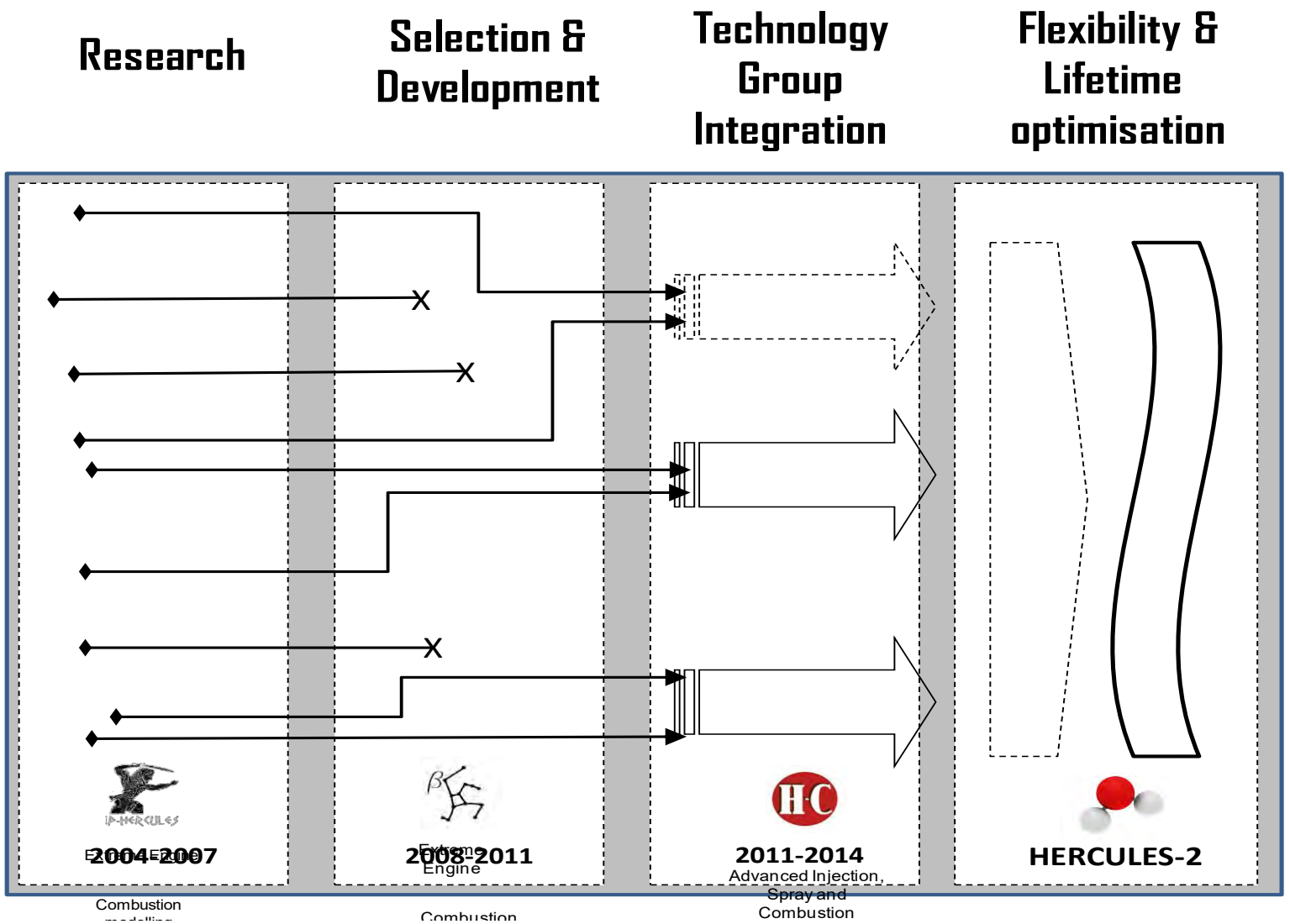
2003 — HERCULES proposal
- Efficiency
- Emissions
- Reliability

2004 — HERCULES-A starts

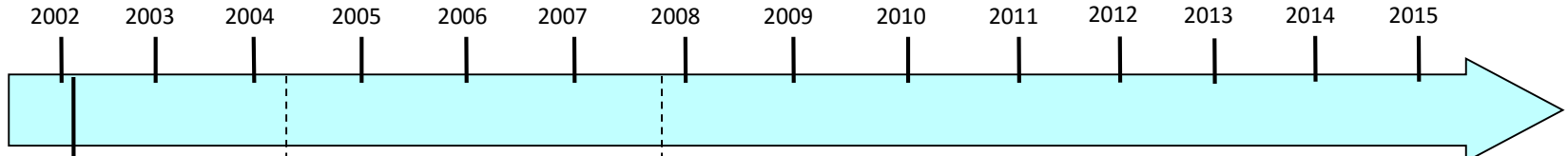
High Efficiency R&D on Combustion with Ultra Low Emissions for Ships

HERCULES TIMELINE




Research
Selection & Development
Technology Group Integration
Flexibility & Lifetime optimisation
2004-2007
Combustion
2008-2011
Engine
Combustion
2011-2014
Advanced Injection, Spray and Combustion
HERCULES-2

HERCULES TIMELINE



WÄRTSILÄ

MAN

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

IP-HERCULES

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

TIP3-CT-2003-506676

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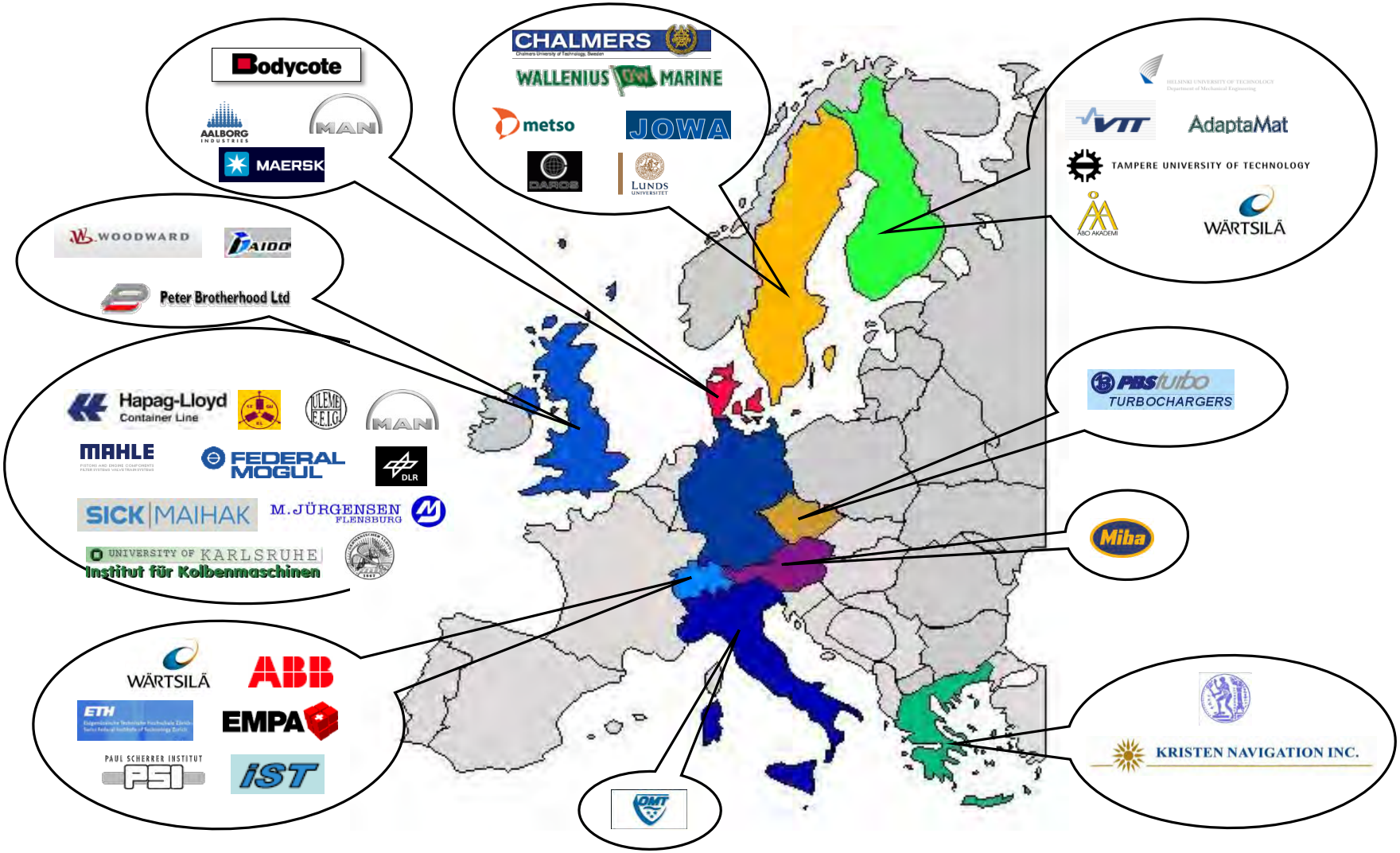
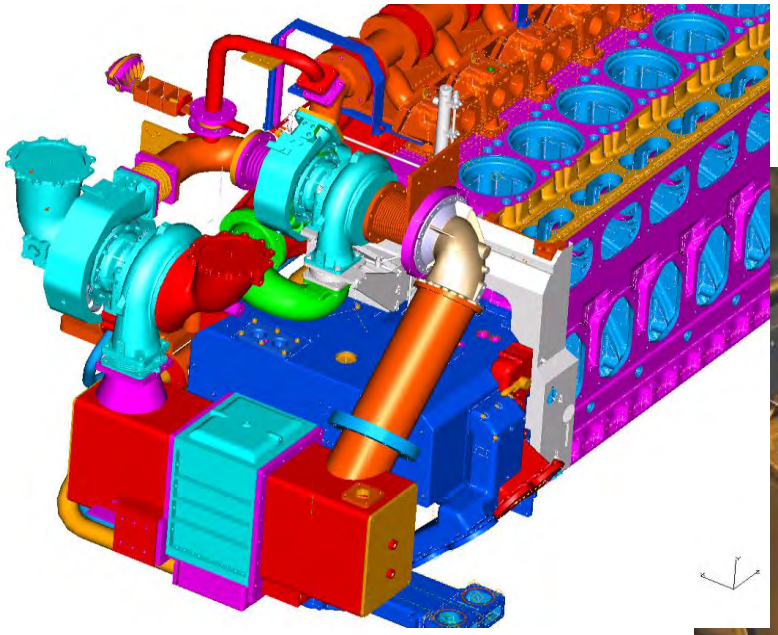
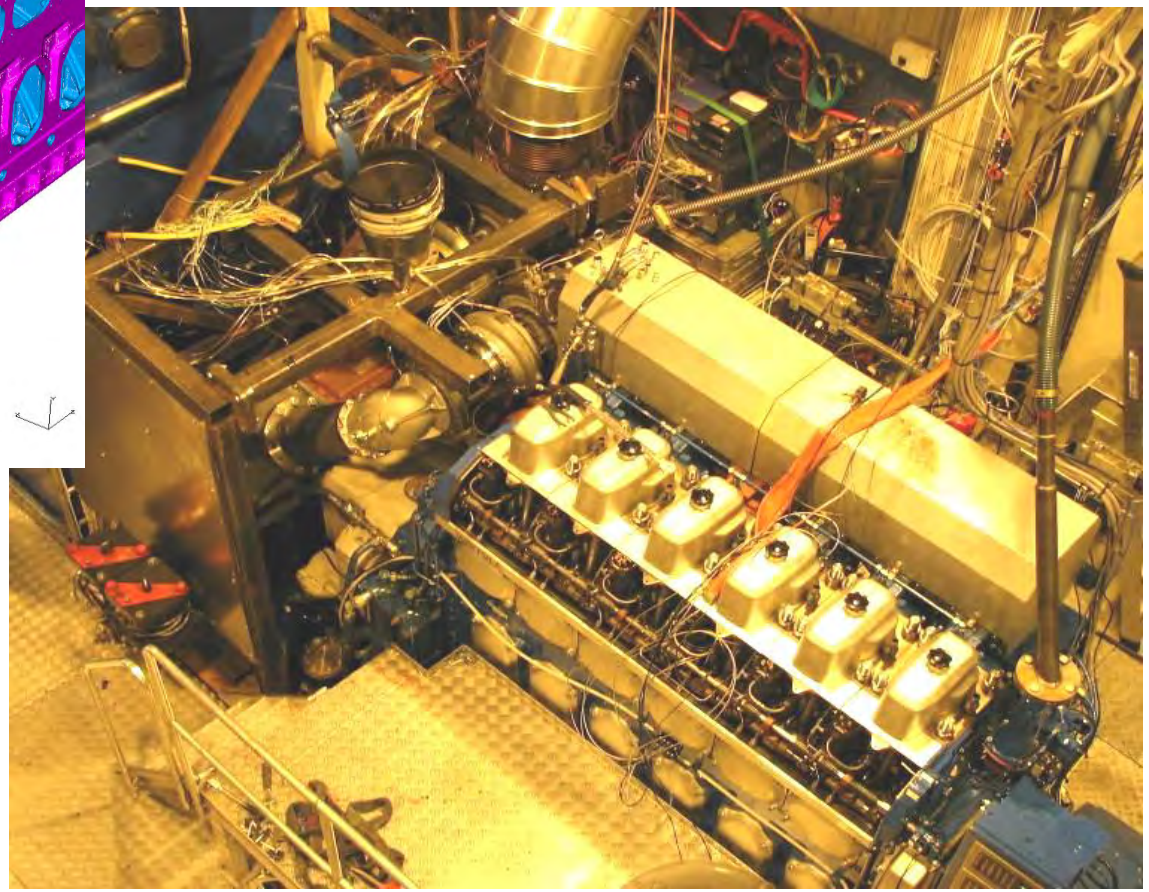


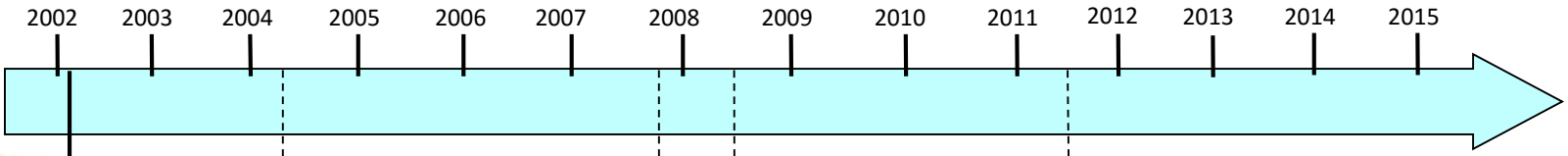
Two-stage turbocharged 4-stroke engine



CIMAC 2007 Congress: Best paper award !



HERCULES TIMELINE



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IP-HERCULES

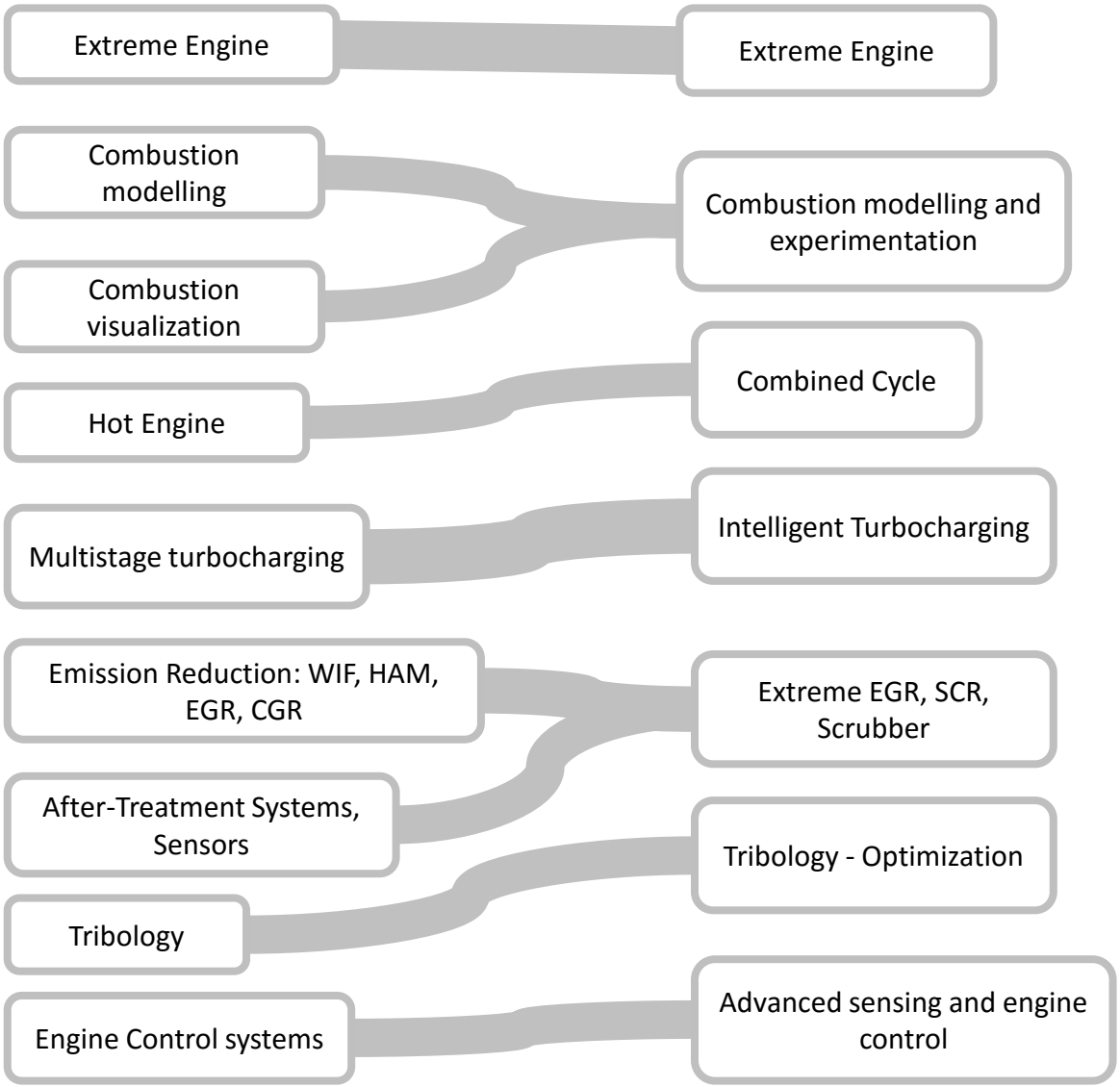
Phase II

HERCULES-B
26 M€ Budget
36 months
32 Partners

Higher-Efficiency Engine with
Ultra-Low Emissions for Ships

SCP7-GA-2008-217878


IP-HERCULES


Extreme Engine
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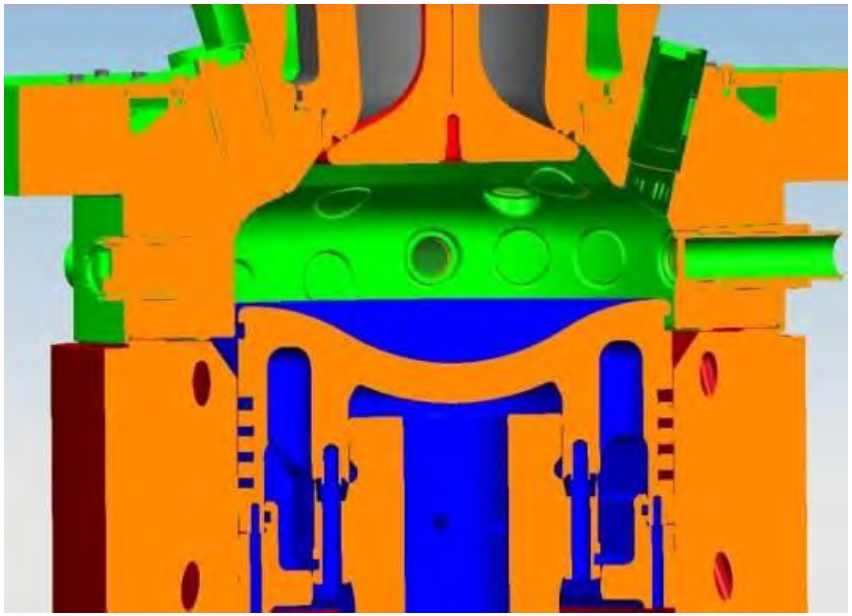
Combustion modelling
Combustion visualization
Combustion modelling and experimentation
Hot Engine
Combined Cycle
Multistage turbocharging
Intelligent Turbocharging
Emission Reduction: WIF, HAM, EGR, CGR
After-Treatment Systems, Sensors
Extreme EGR, SCR, Scrubber
Tribology
Tribology - Optimization
Engine Control systems
Advanced sensing and engine control

Nikolaos Kyritsis



Optical cylinder covers for 2-stroke

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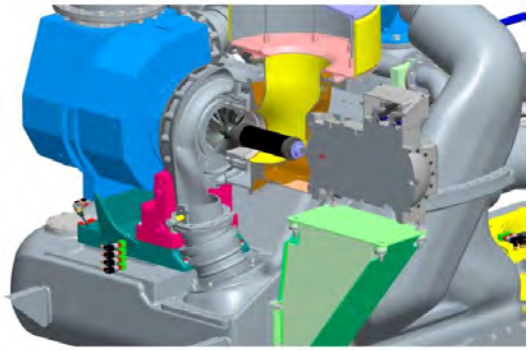
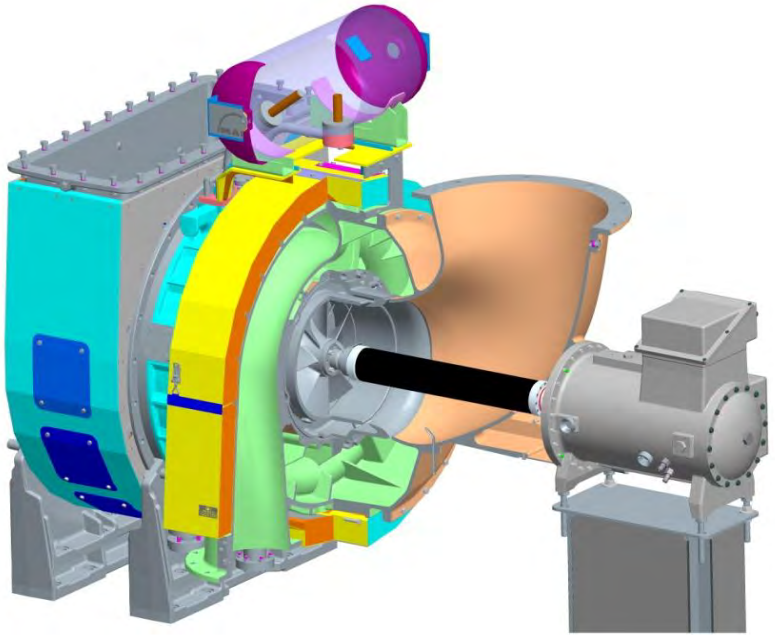


T/C with variable compressor inlet guide vanes

PTI / PTO



T/C with variable turbine nozzle vanes

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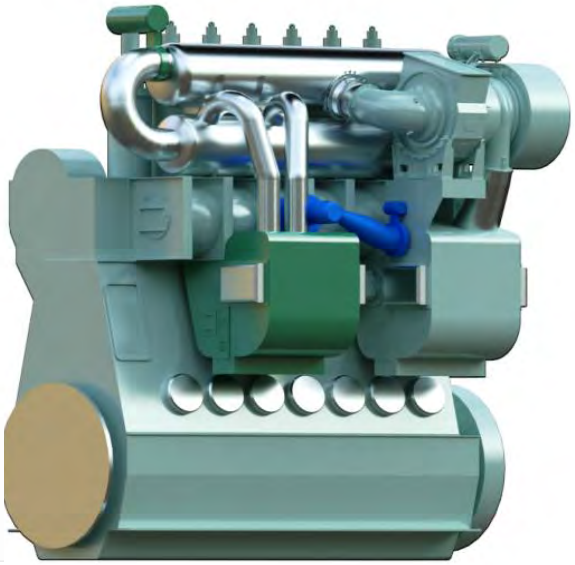
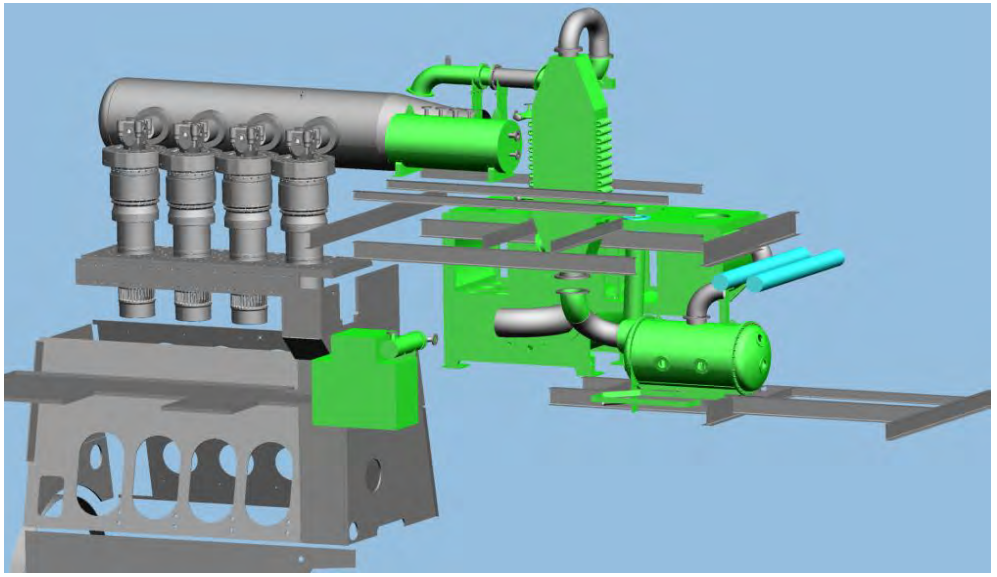
High Pressure Boiler installed on 4T50ME-X





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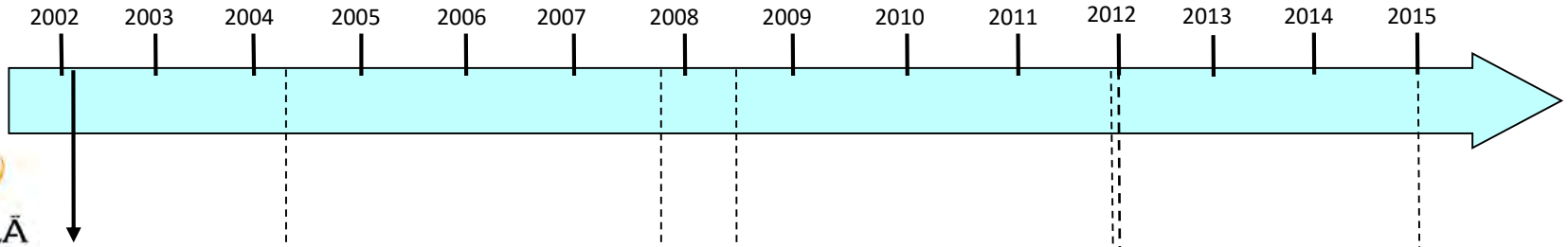

WÄRTSILÄ

MAN

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

Phase I

Phase II

Phase III

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IP-HERCULES

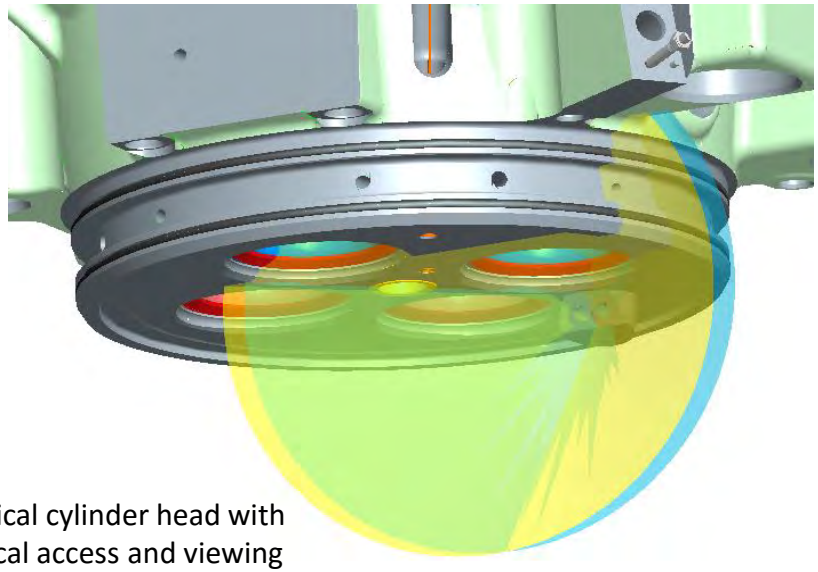
HERCULES-B
26 M€ Budget
36 months duration
32 Partners

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

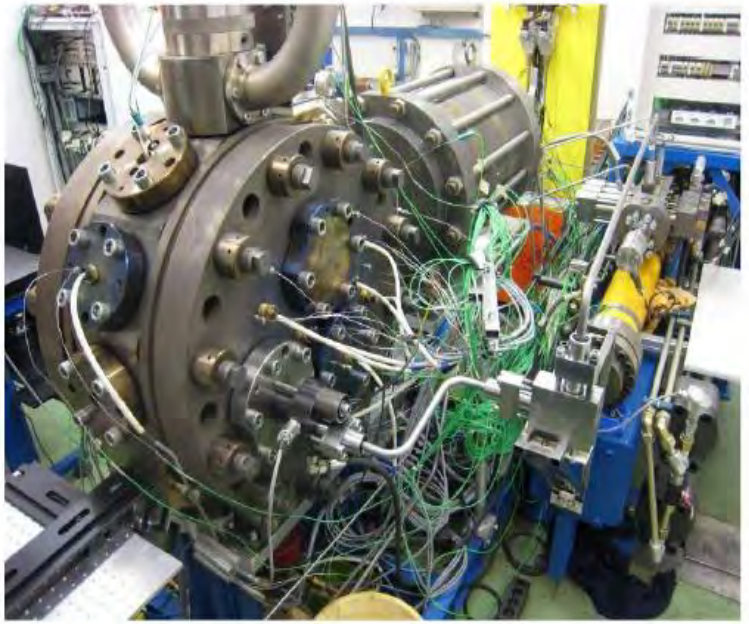
H·C

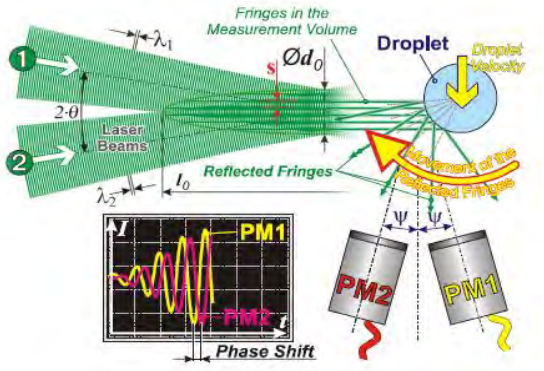
Nikolaos Kyritsis

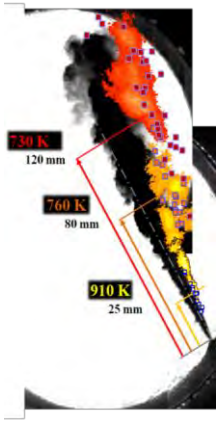
Objective # 1:Substantial reduction in fuel consumption (WPG1, WPG2, WPG4)



Optical cylinder head with optical access and viewing range







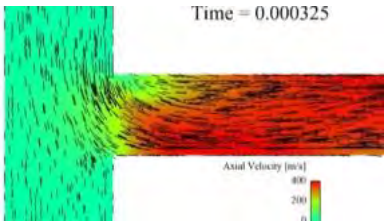
WP 3: Injection, Spray Formation and Combustion

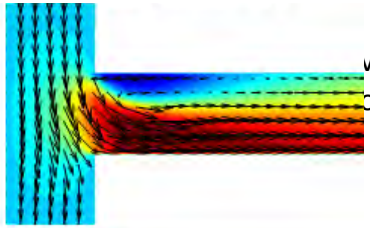
STAR-CD vs. IFP-C3D (incl. cavitatio

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

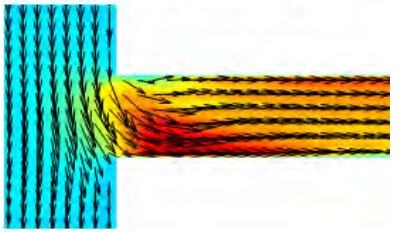
WORK PACKAGE GROUP	ITEM	
WPG2 Fuel Injection Models & Experiments	Models for flow and cavitation applicable to large engine injectors	M

IFP-C3D

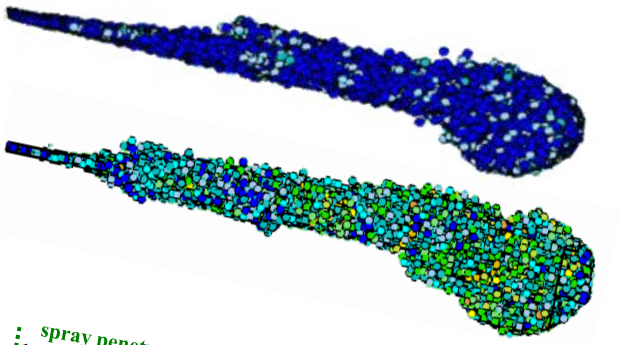


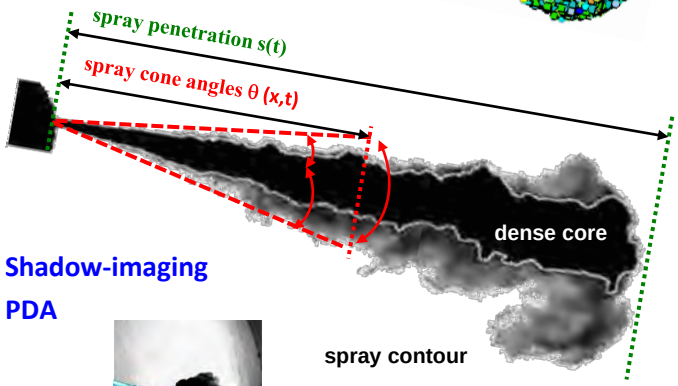


vestigations of
ozzle internal
flow



StarCD





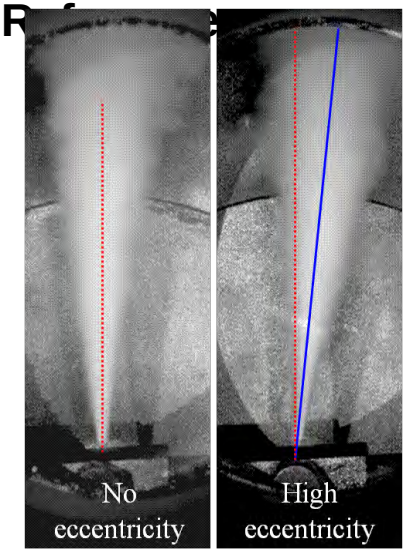
Shadow-imaging

PDA

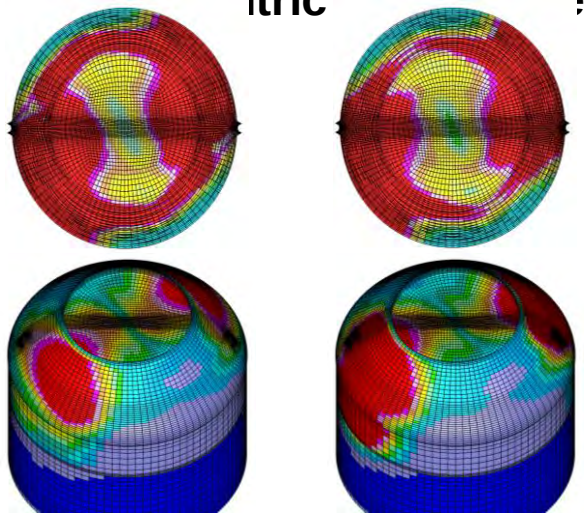
spray contour

droplet size and velocity

R



Eccentric nozzle case

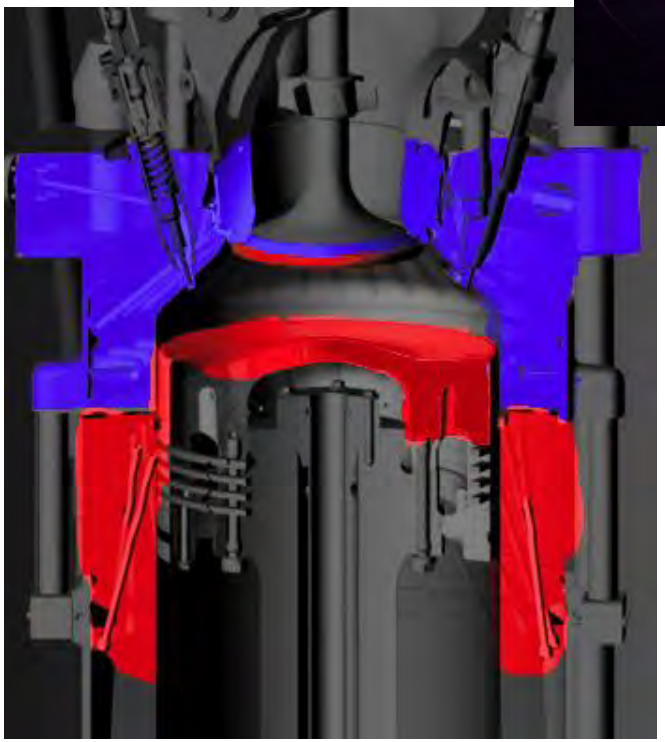


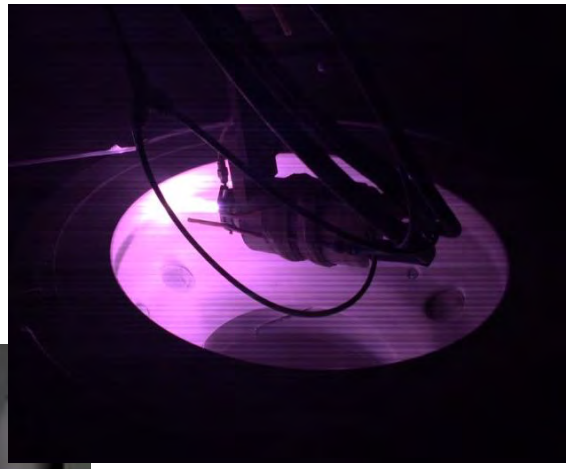
Nozzle bore eccentricity investigation

(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





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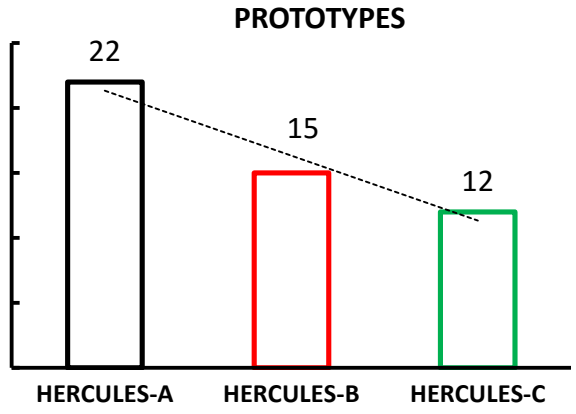
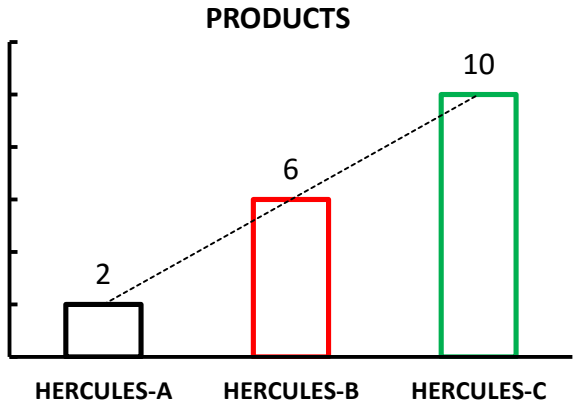
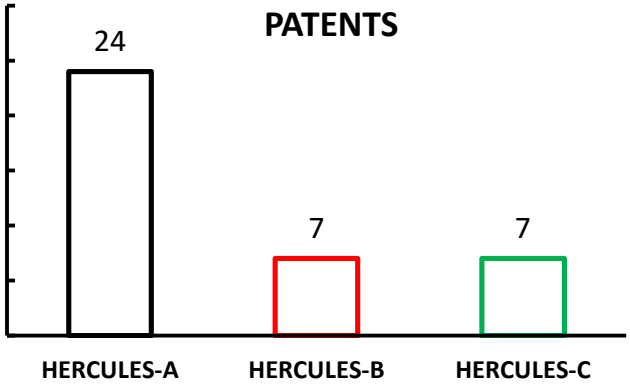
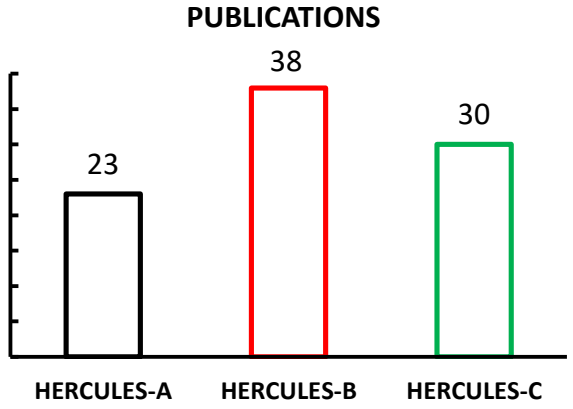
Productivity , HERCULES-A to HERCULES-C

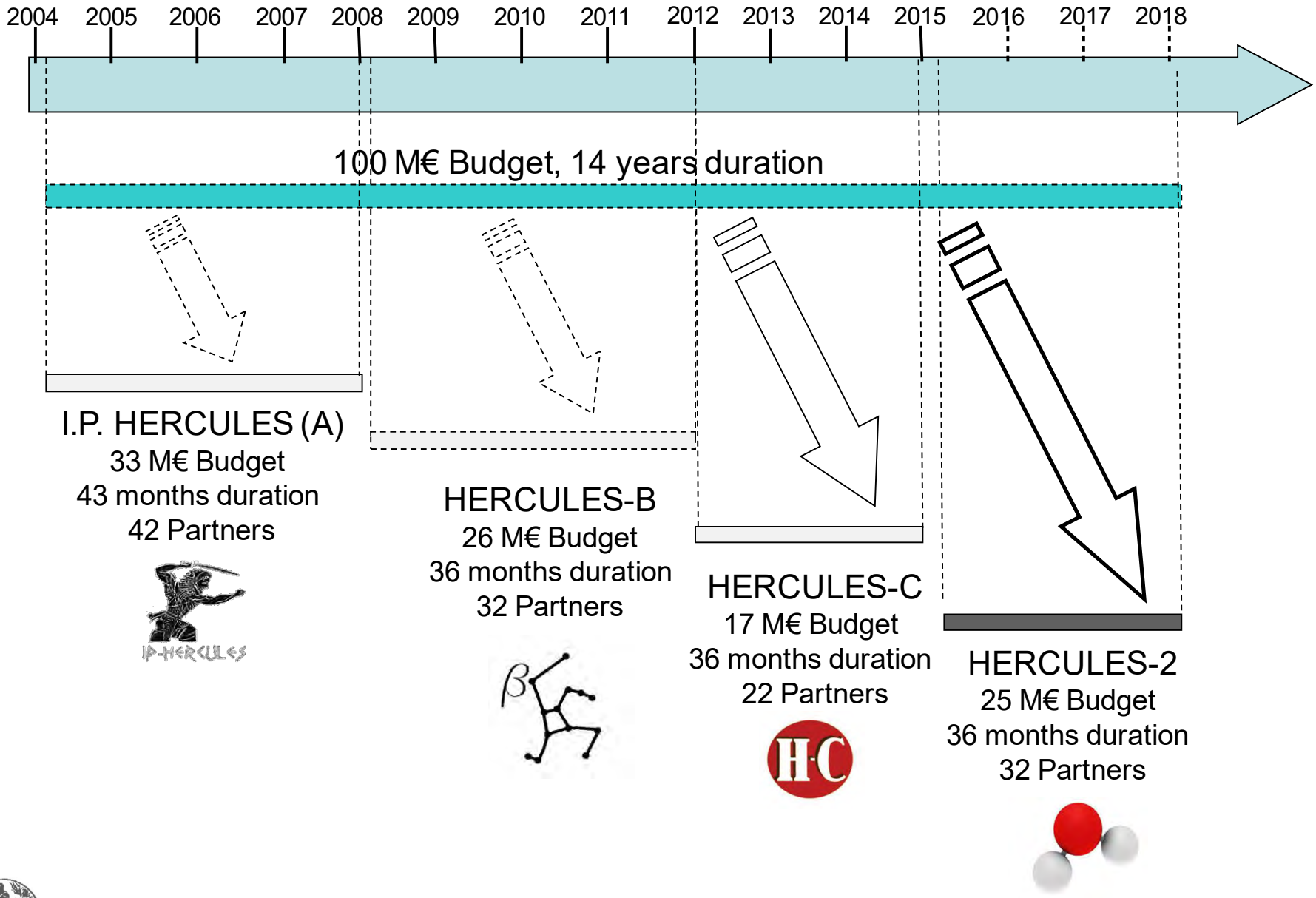


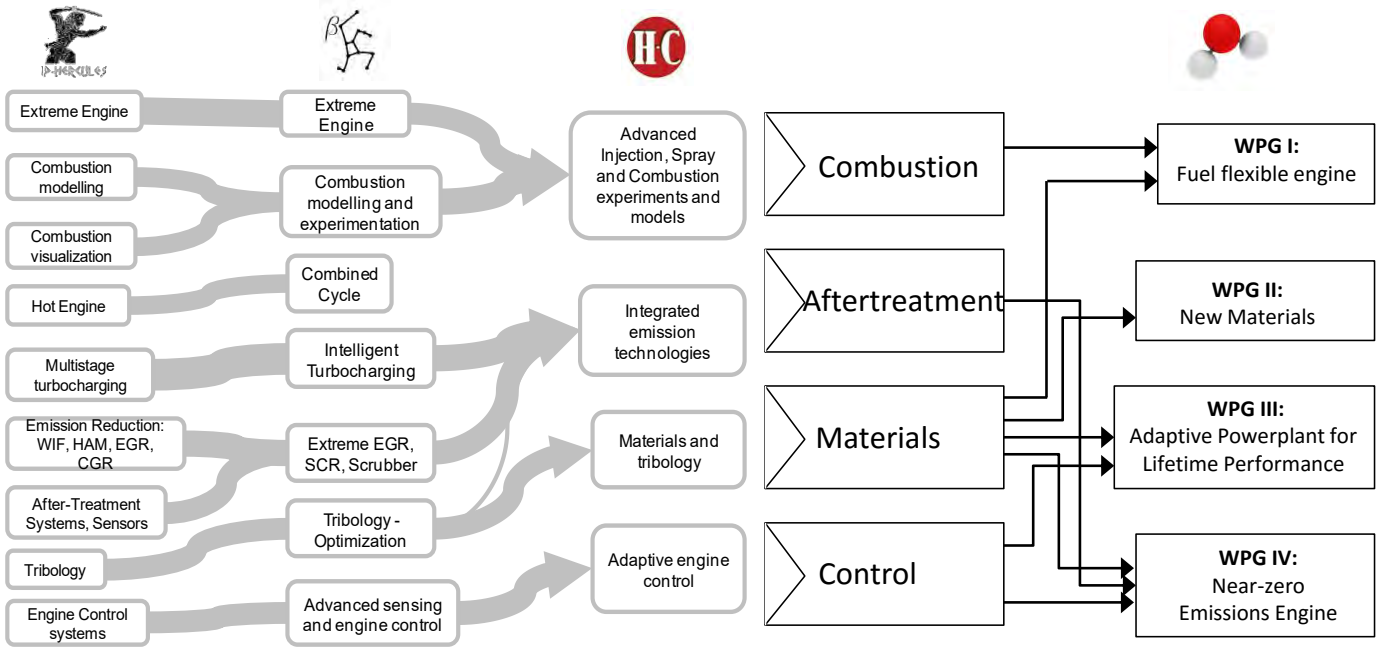


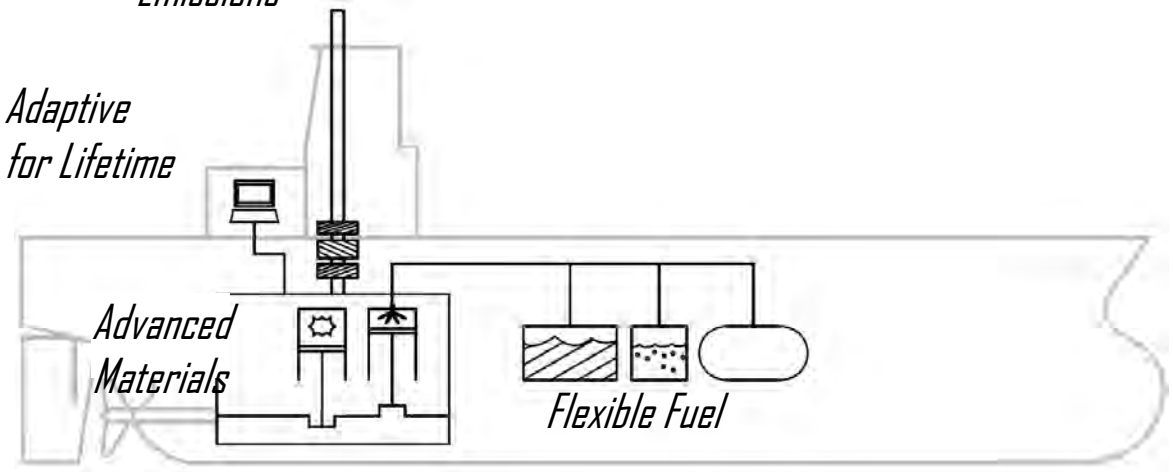




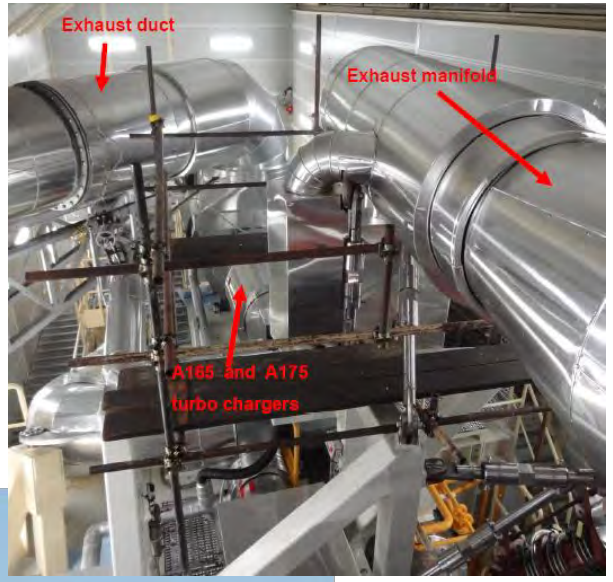
HERCULES TIMELINE

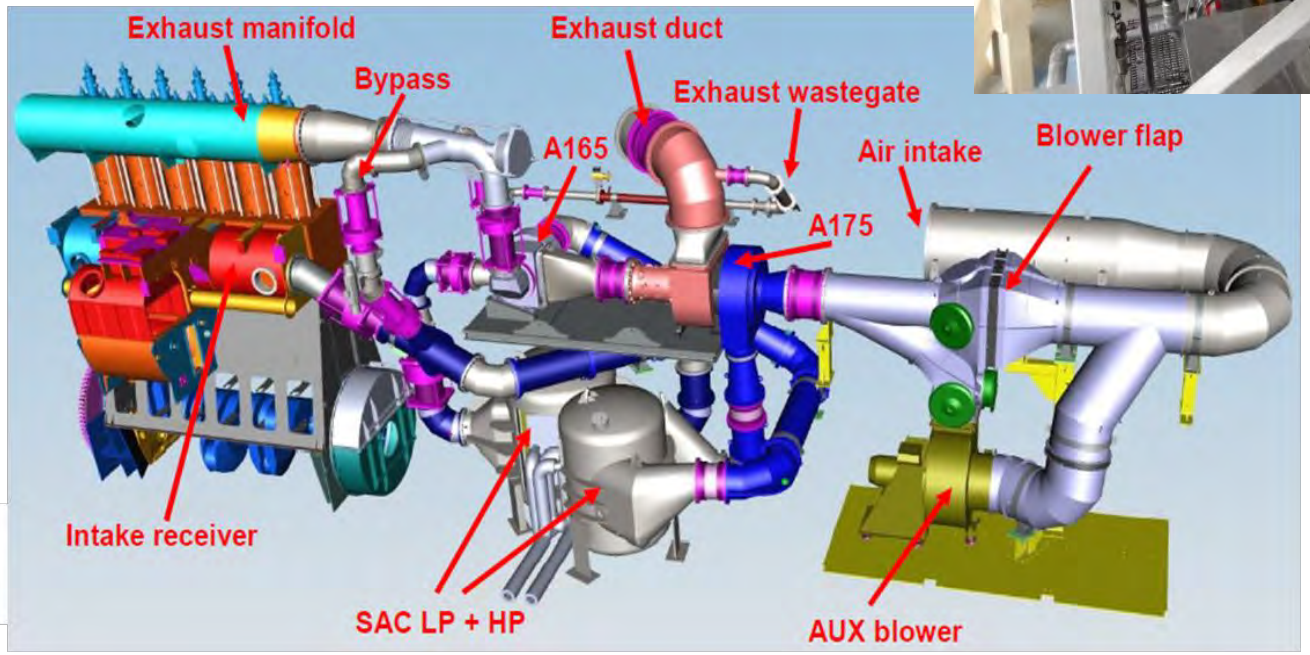



Extreme Engine
Combustion modelling
Combustion visualization
Hot Engine
Multistage turbocharging
Emission Reduction: WIF, HAM, EGR, CGR
After-Treatment Systems, Sensors
Tribology
Engine Control systems
Extreme Engine
Combustion modelling and experimentation
Combined Cycle
Intelligent Turbocharging
Extreme EGR, SCR, Scrubber
Tribology - Optimization
Advanced sensing and engine control
Advanced Injection, Spray and Combustion experiments and models
Integrated emission technologies
Materials and tribology
Adaptive engine control
Combustion
Aftertreatment
Materials
Control
WPG I: Fuel flexible engine
WPG II: New Materials
WPG III: Adaptive Powerplant for Lifetime Performance
WPG IV: Near-zero Emissions Engine


Near Zero Emissions
Adaptive for Lifetime
Advanced Materials
Flexible Fuel

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





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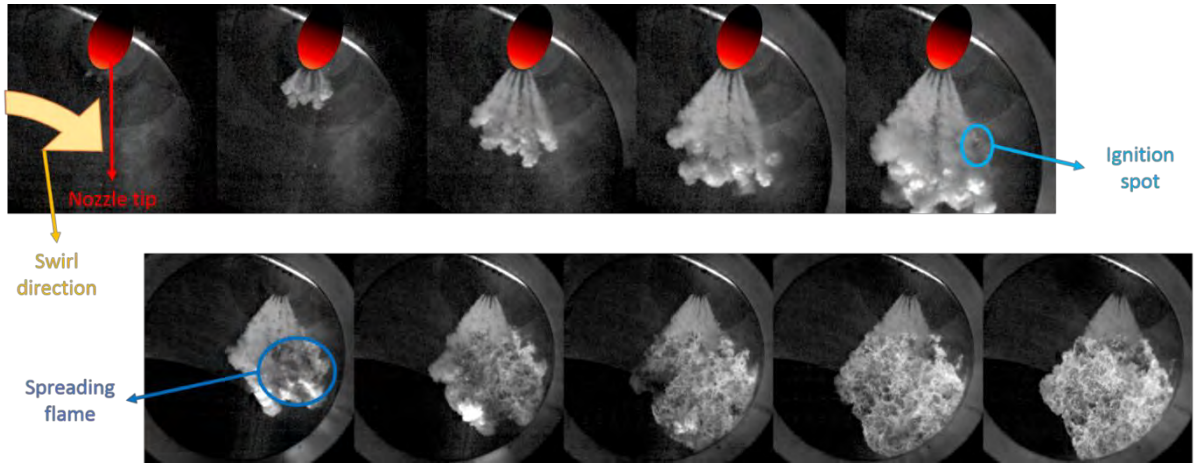
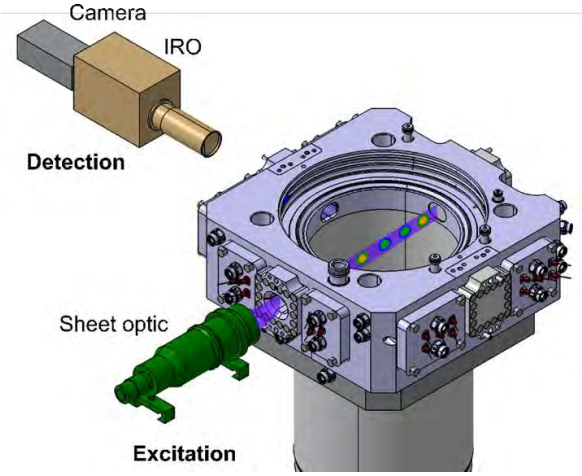
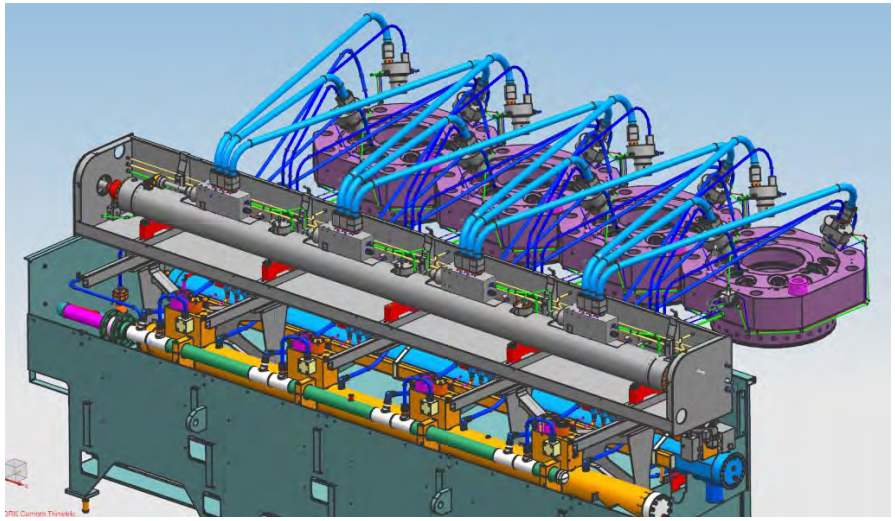
Nikolaos Kyritsis





measuring mixture distribution



engine with fuel flexible injection system

Combined SCR and DPF

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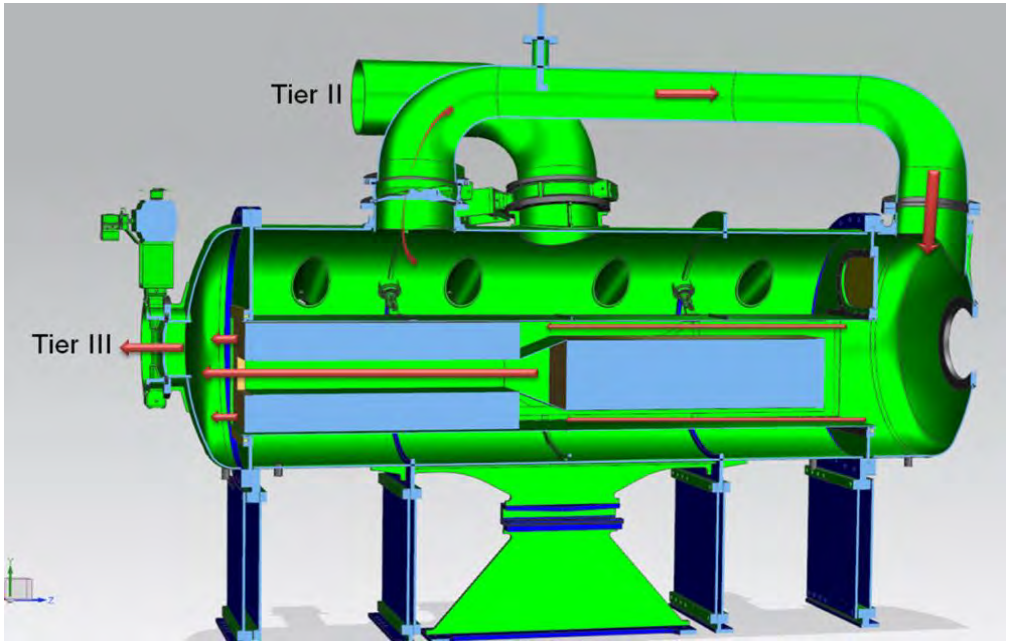
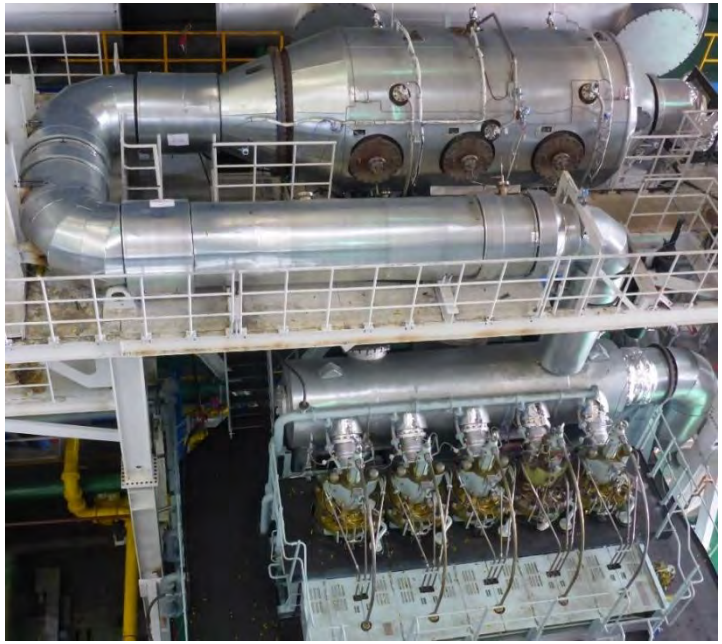
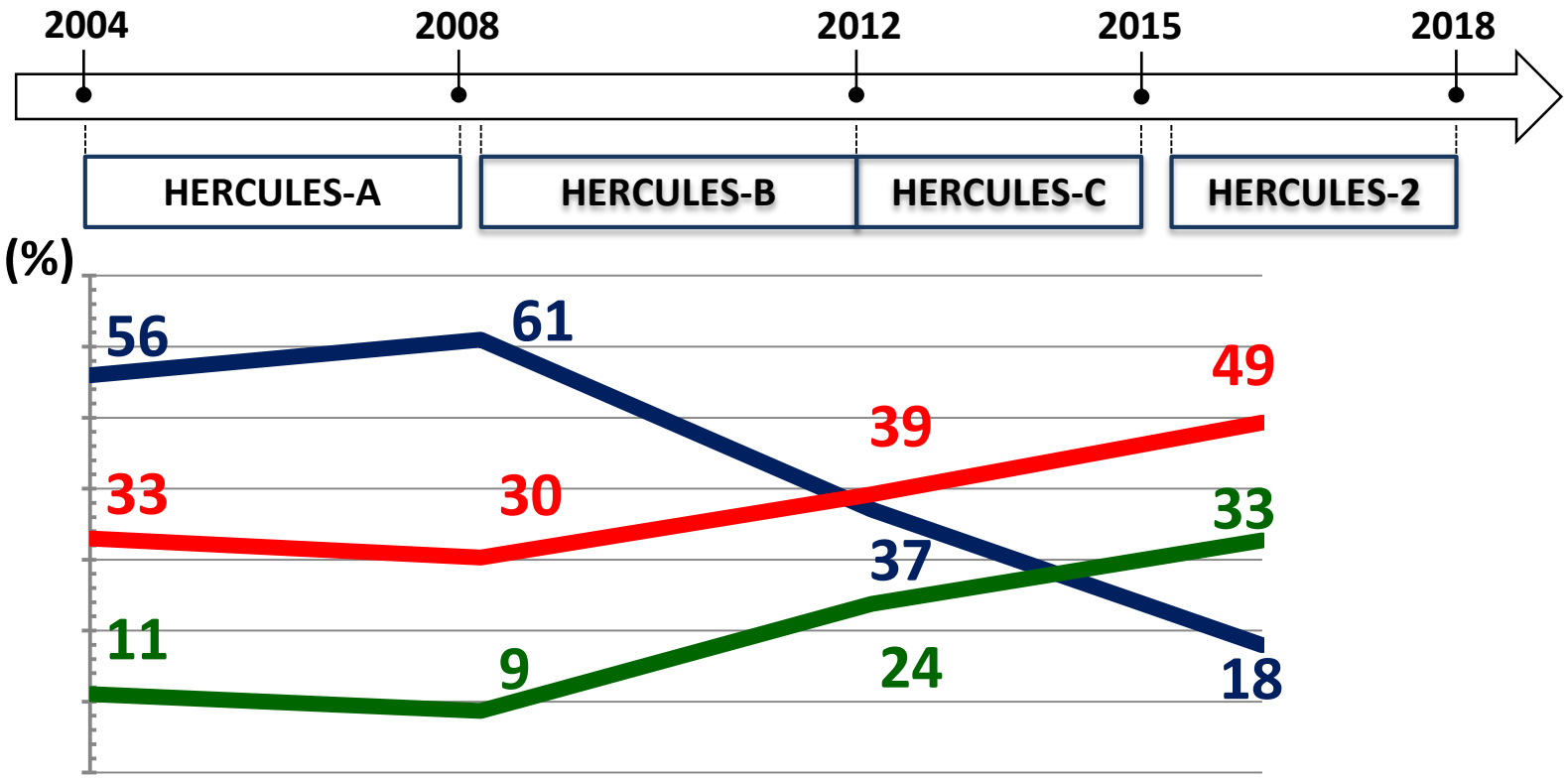


Engine integrated HP SCR inside exhaust receiver



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



% of individual project budget

- Efficiency
- Emissions
- Reliability & Lifetime

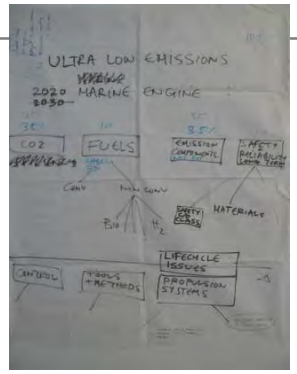
Total 102 M€

43%

38%

19%

HERCULES R&D 2002 Estimate and Spending TOTAL



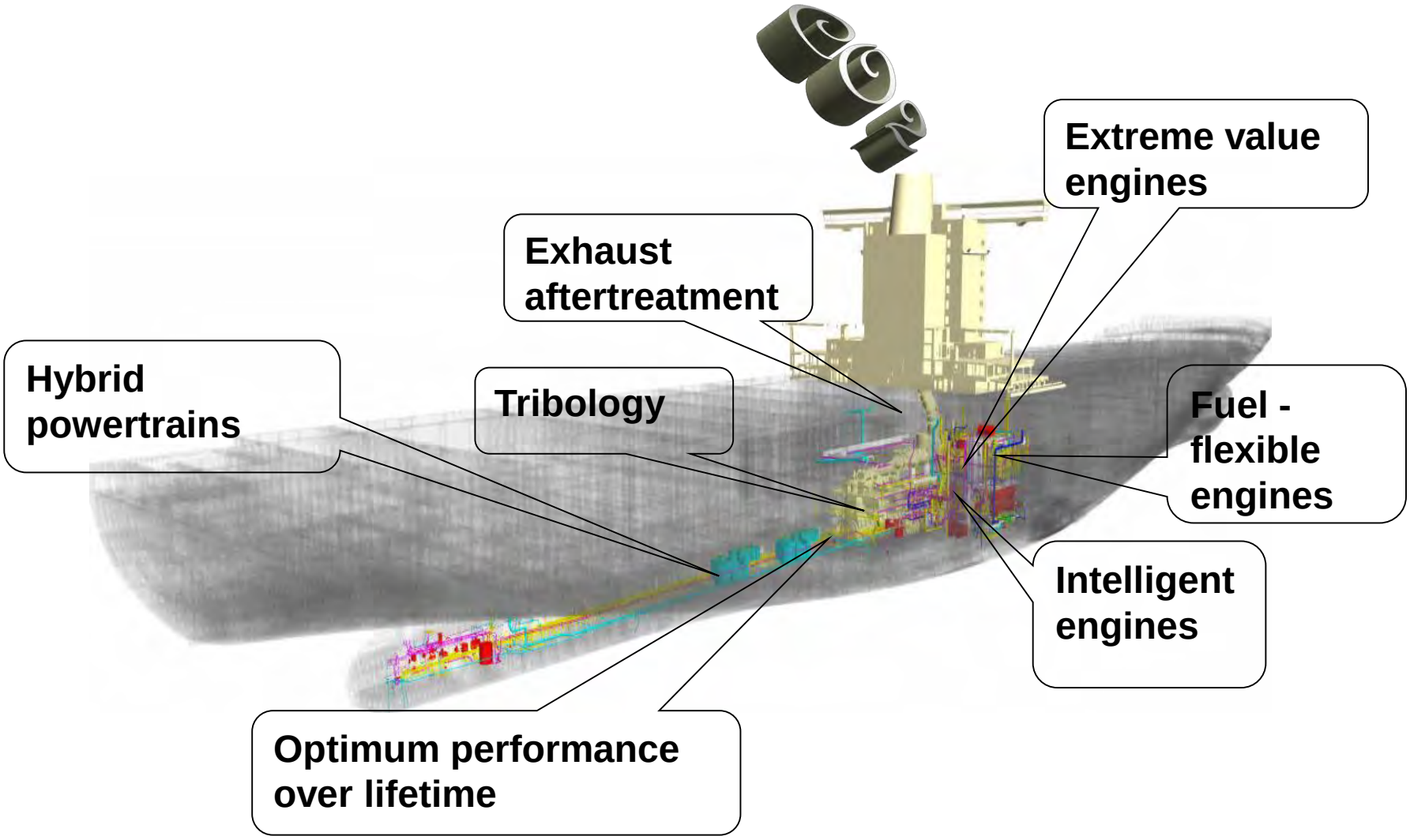
	2002 allocation estimates for 100 Meur	(merge)		H-A,B,C,2 Results **2016**
CO_2 (EFFICIENCY)	30%	37%	***EFFICIENCY***	**43%**
FUELS	10%			
EMISSIONS	35%	40%	***EMISSIONS***	**38%**
RELIABILITY LIFETIME CONTROL	10% 5% 5%	23%	***RELIABILITY LIFETIME***	**19%**
METHODS, TOOLS	5%			
	100%			

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.

TECHNOLOGY AREA / TECH ITEMS	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	✓				✓

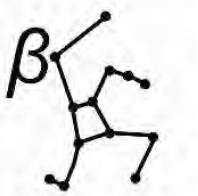
Nikolaos Kyrtatos

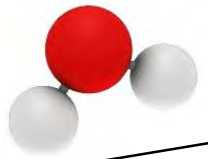


- The longevity of alliances is often used as proxy of their performance.
- The HERCULES alliance of 14 years has been demonstrably successful
- Many results of R&D already matured into products.
- Much of the 100M budget was spend towards **greening**.
- If efficiency increases achieved are applied,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

Compilation of the HERCULES Program 82 Partners

End of Presentation





SIXTH FRAMEWORK PROGRAMME

SEVENTH FRAMEWORK PROGRAMME

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