Objectives / Expected Results

WP Leader: Dr. M. Moser, T. Moeller

Cut operating, maintenance and deployment costs

- Develop systems, methods an processes for improved engine lifetime performance

Reduction of emission & increased efficiency at part load

- Cylinder cut-out
- NOx: expanding operation range emission reduction technologies
- Particle: novel lubrication injection system

Enhance dynamic performance

- Model-based control

Partners:

University of Bremen

Vienna University of Technology

Karlsruher Institute of Technology

Linköping University

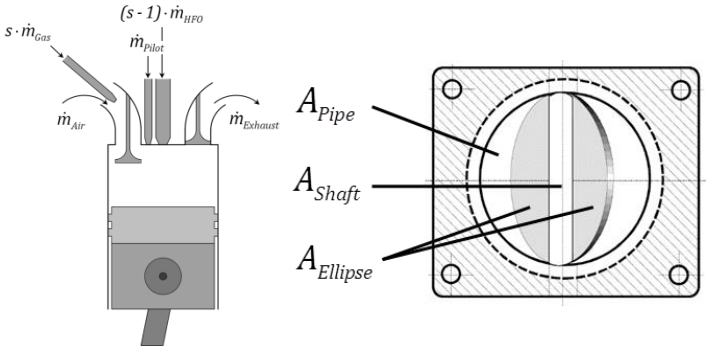
Aventics GmbH

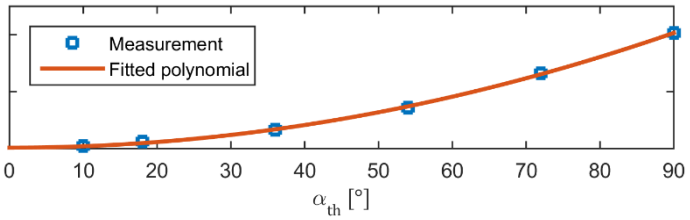
Technical University of Denmark

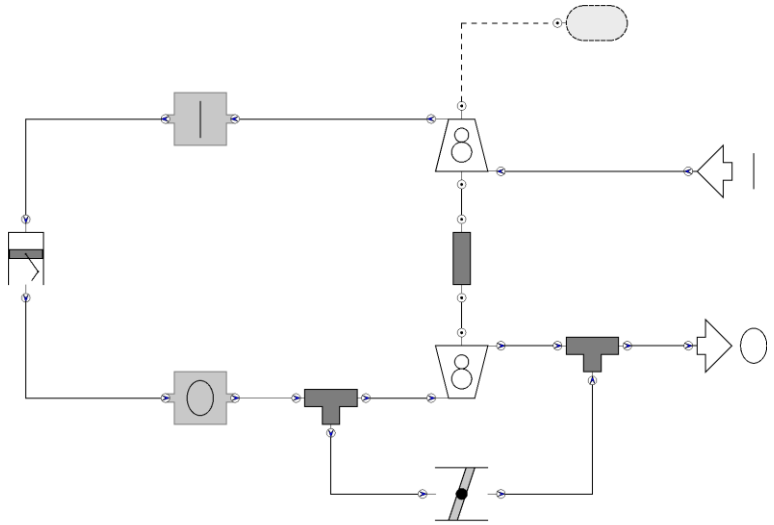
National Technical University of Athens

Engine control and optimization

- Development of physical-based models for Model-based engine control
- More engine parts and features (e.g. Jet Assist) were included in the model
- Rework of models for WG and TC towards more model stability
- Dynamics for temperature & pressure in receivers
- Dynamics for TC speed
- Interpolation along turbocharger-maps
- Development in C++ and validation in Modelica and Matlab/Simulink
- Test bed measurements for identification of parameters ware performed

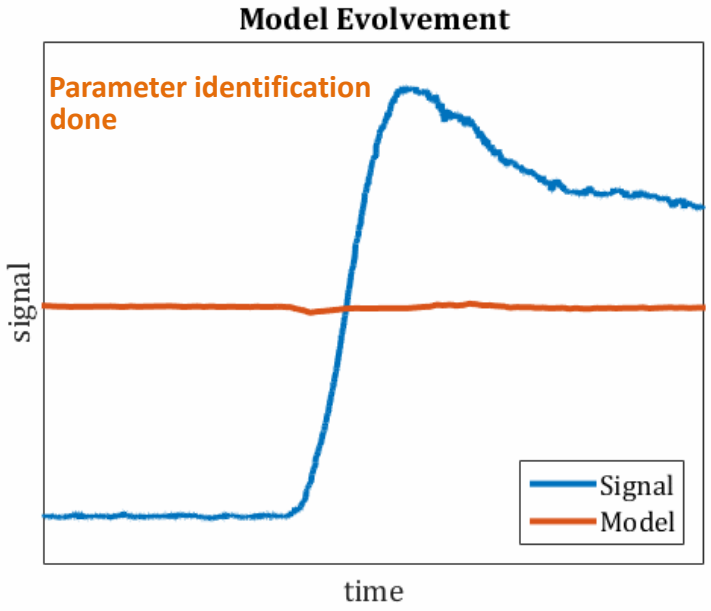


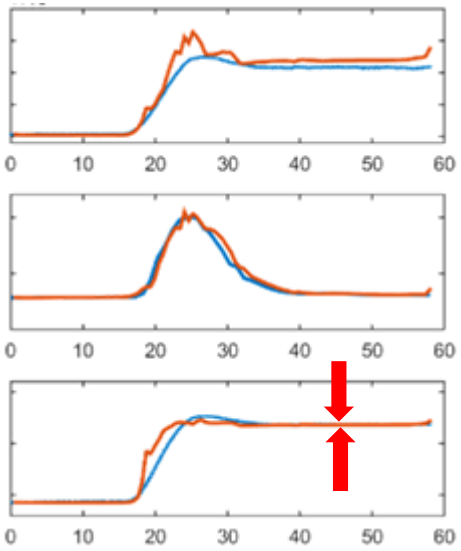




Engine control and optimization

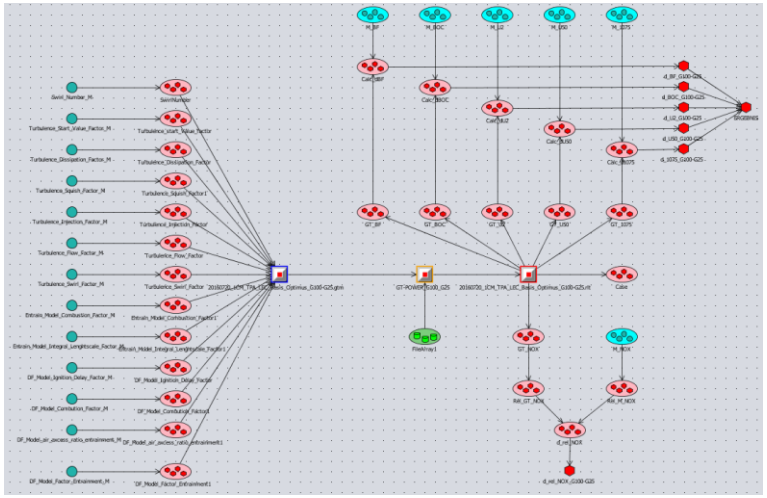
- Parameter identification to identify not covered effects (like friction, real gas behavior, ...) has been done
- Model has ~100 free coefficients
- Numerical problems could be solved by implementing a new solver for the differential equations
- Parameter identification in terms of minimize differences between measurements and simulation
- Parameter identification successful for gas- and liquid fuel mode at certain data sets
- To achieve good model accuracy parameter identification for more/all datasets ongoing



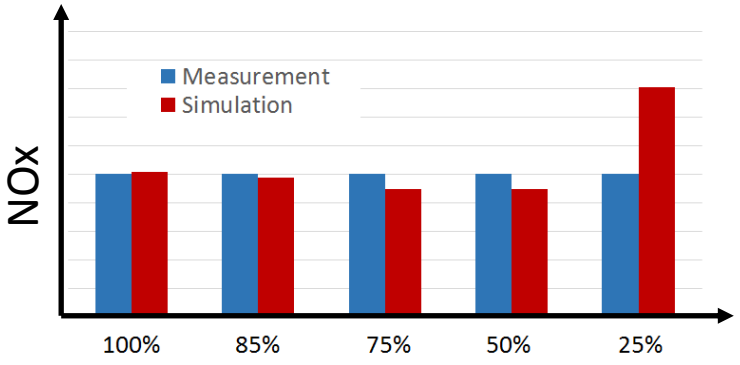


Learned on **three** datasets

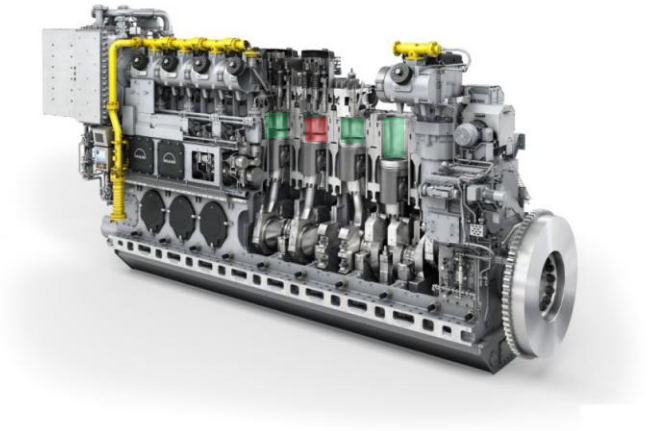
Engine control and optimization



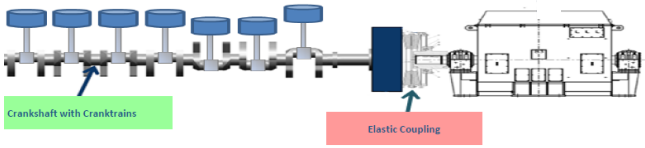
- First step was modeling of Single-Cylinder model for TPA and adjustment of combustion model
- Calibration of the combustion model (which was developed during Hercules C) with the help of optimization tool
  - Optimization of 11 Input variables
  - *Differential Evolution Algorithm* for middle term optimization (~500 iterations)
  - *Covariance Matrix Adaptation - Evolution Strategy* for long term optimization (>1500 iterations)
- Good overall agreement of simulation and measurement from G100 down to G50
- Further investigations of G25 slated

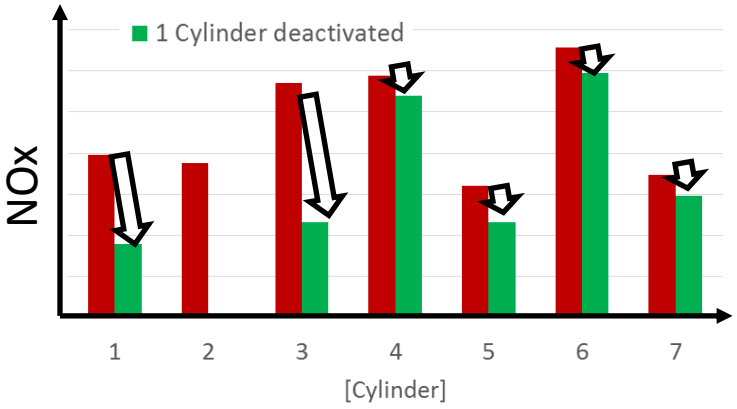


Engine control and optimization



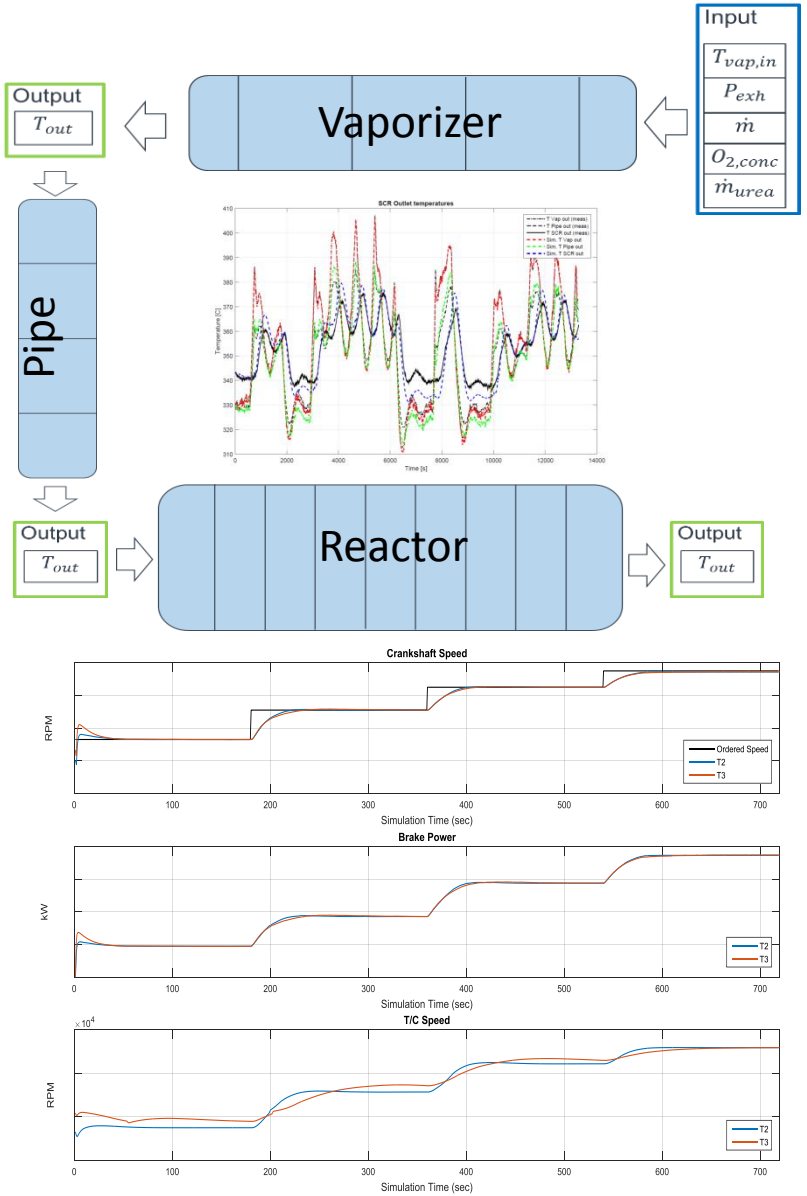
- Low load operation with cylinder cut out was investigated
- 350 different cut out sequences are calculated and analyzed in terms of torsional vibrations and resonances
- Investigation concerning restrictions of engine operation area for different cut out scenarios in terms of combustion behavior
- Calculation of the effects on emissions and fuel oil consumption due cylinder deactivation (global and cycle average) shoed promising results
- First control strategies derived
- FRM model was already successful coupled with Simulink in order to develop the control for the engine test run





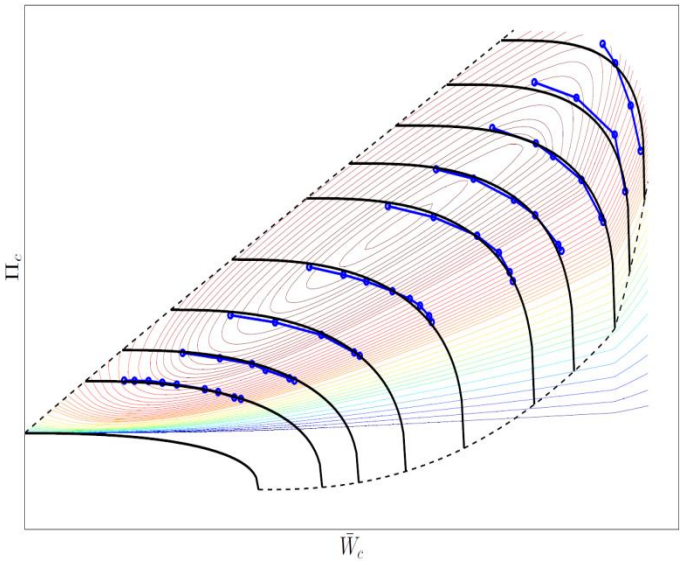
Engine control and optimization

- Full SCR model developed and validated on test data from 2013 – 2014. Each SCR subsystem modelled and validated individually
- Mass flow simulation with influence from valve positions
- Developed in order to simulate observed thermal oscillations at low load
- Implementation of the SCR model in the engine model
- Steady state simulations performed for Tier 2 and Tier 3 engine configurations
- Initial transient simulations performed
  - ➢ A real loading profile used from an engine of the same type
  - ➢ Engine response during transient simulations examined



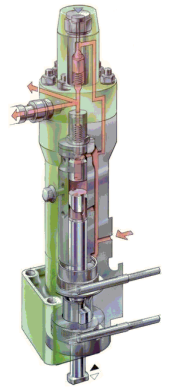
Engine control and optimization

- EGR model was designed to simulate low load operation
- Low load operation → investigation of vessel load profiles (e.g. approaching the harbor)
- The model is capable to extrapolate efficiency and mass flow for compressor speeds below the lowest measured speed line
- Complete compressor model parameterized with the manufacturer compressor performance map and is capable to operate at very low speeds
- The EGR engine model also includes a model for the auxiliary blower
- Paper* published with information about the parameterization and the model equations
- Developement of the control will be done on the model and testd on the vessel

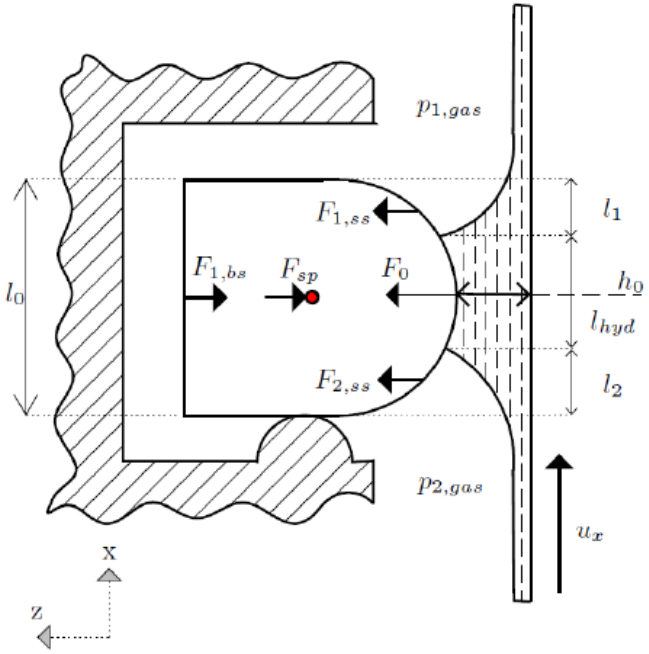


*) Llamas X, Eriksson L. A Model of a Marine Two-Stroke Diesel Engine with EGR for Low Load Simulation. 9th EUROSIM Congress on Modelling and Simulation. Oulu, Finland. 2016

Engine control and optimization



- Development of an retrofit solution for continuous engine performance optimization for mechanical controlled engines
- Electronically controlled actuator for fuel injection
- Prototype sample designed, produced and available
- Validation of porotype actuator on test rig



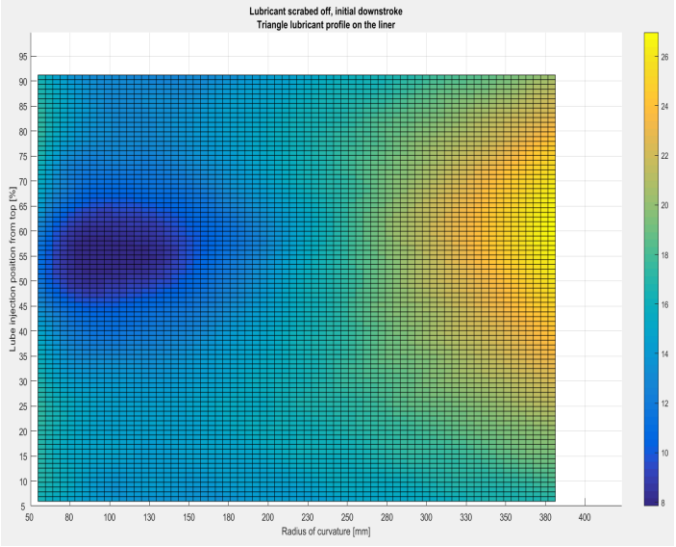
- Theoretical investigation of the hydrodynamic lubrication of the top compression piston ring was performed
- Modelling of hydrodynamic lubrication and free surface flow
- Inaccuracies of the existing model tracked down and solved

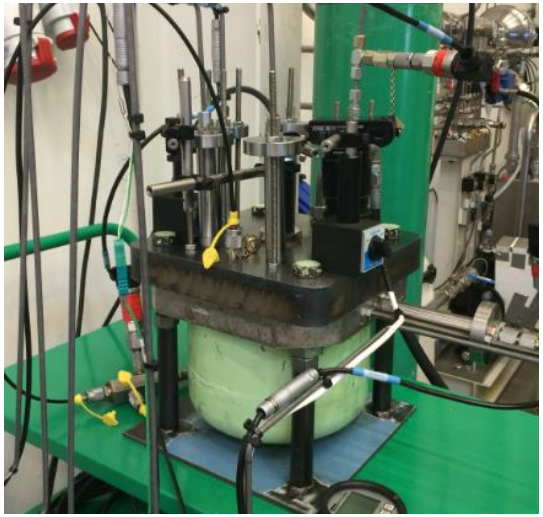
Engine control and optimization

- Experimental testing and validation of lube oil injection model
- Modelling of the axial and circumferential oil flow in front of the piston ring
- Different initial lubricant profiles are being investigated

- Model will be improved by implement multi-ring mass flow balance into system
- Parametric investigation of parameters affecting the oil transport (up-down / circumferential)
- Experimental investigation of oil usage in piston ring pack will be performed

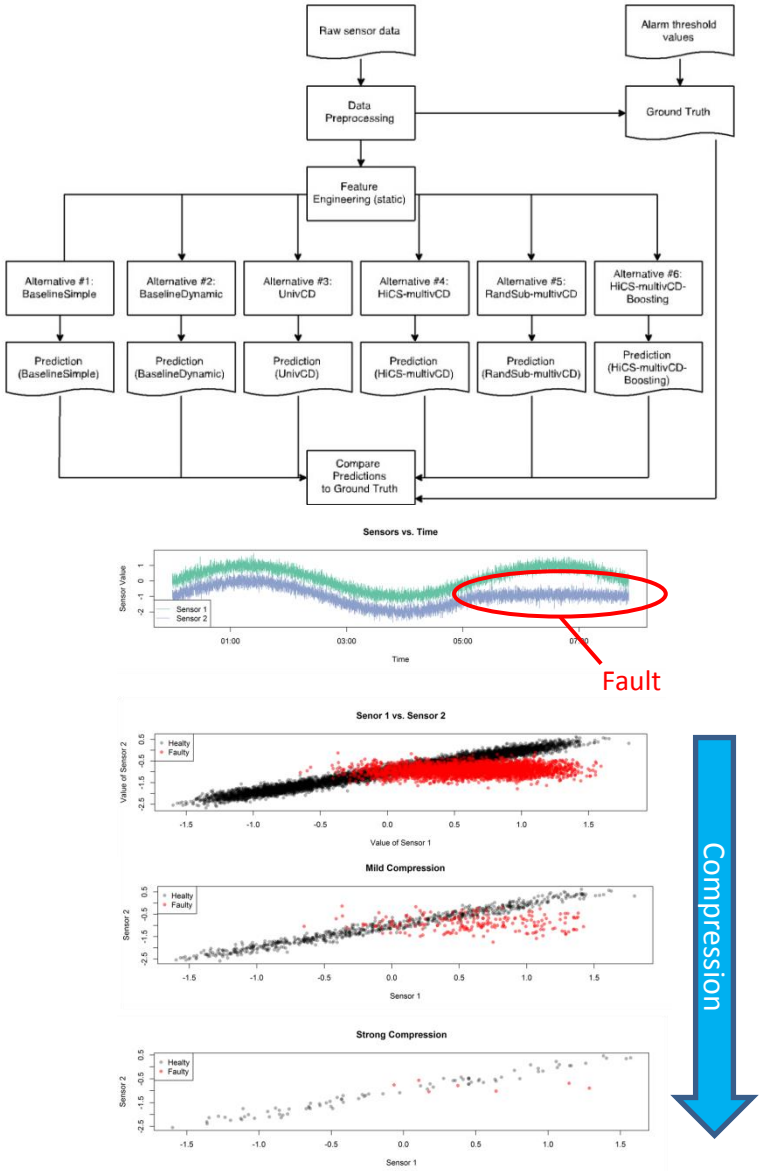
Lubricant scrubbed off in the initial down stroke



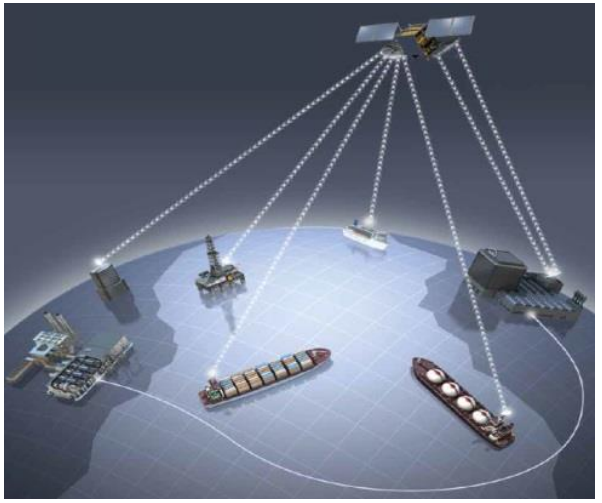


Remote monitoring & software distribution

- Different frameworks has ben validated (BaselineSimple/Dynamic, univCD, HiCS-mCD, RandSub-mCD, HiCS-mCD-Features, HiCS-mCD-Ensemble)
- Investigation of compression of measurement data in terms of sub space search quality was carried out
- Compression heavily reduces the quality
  - ➢ Making the search for subspaces difficult
  - ➢ Reducing the subspace effects dramatically
- Work on uncompressed data to investigate patterns and subspaces will be performed
- Investigations of alternative compression methods in terms of subspace search quality slated



Remote monitoring & software distribution



- Development of hardened secure onboard control system platform, designed for remote updating.
- Access management to applications and devices based on user access policy via federated thrust for collaboration between multiple partners
- Multifactor authentication and multilayer data encryption
- Zero-thrust, micro-segmented network as general IoT solution

- Prototype implementation done in laboratory
- Roll out of full system in progress