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SHIPYARD 1737

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OPC UA-based simulation-aided automation testing environment of a cruise ship LNG system

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Semantum

Background

- Established in 2007
- Located in Espoo, Finland
- VTT Technical Research Centre of Finland background
- Apros partners since 2021

Expertise

- Highly skilled, multidisciplinary team of software developers, automation engineers and modelling & simulation specialists

Focus areas

- Development and maintenance of system simulation tools for process industry such as Apros
- Industrial Simulation-Based Digital Twins
- Engineering automation solutions
- Life Cycle Assessment solutions

Trusted by:

ABB, Autodesk, fortum, Granlund, High Metal, Meyer Turku Shipyard 1737, Siemens, Sumitomo SHI FW

Meyer Turku

- Founded in 1737, Meyer Turku Oy is a leading European shipyard
- Specialized in building cruise ships, car-passenger ferries, and technically demanding special vessels
- Turku shipyard employs 1,350 people
- Meyer Turku is constantly developing innovative conceptual solutions in close co-operation with their customers

Motivation and project introduction

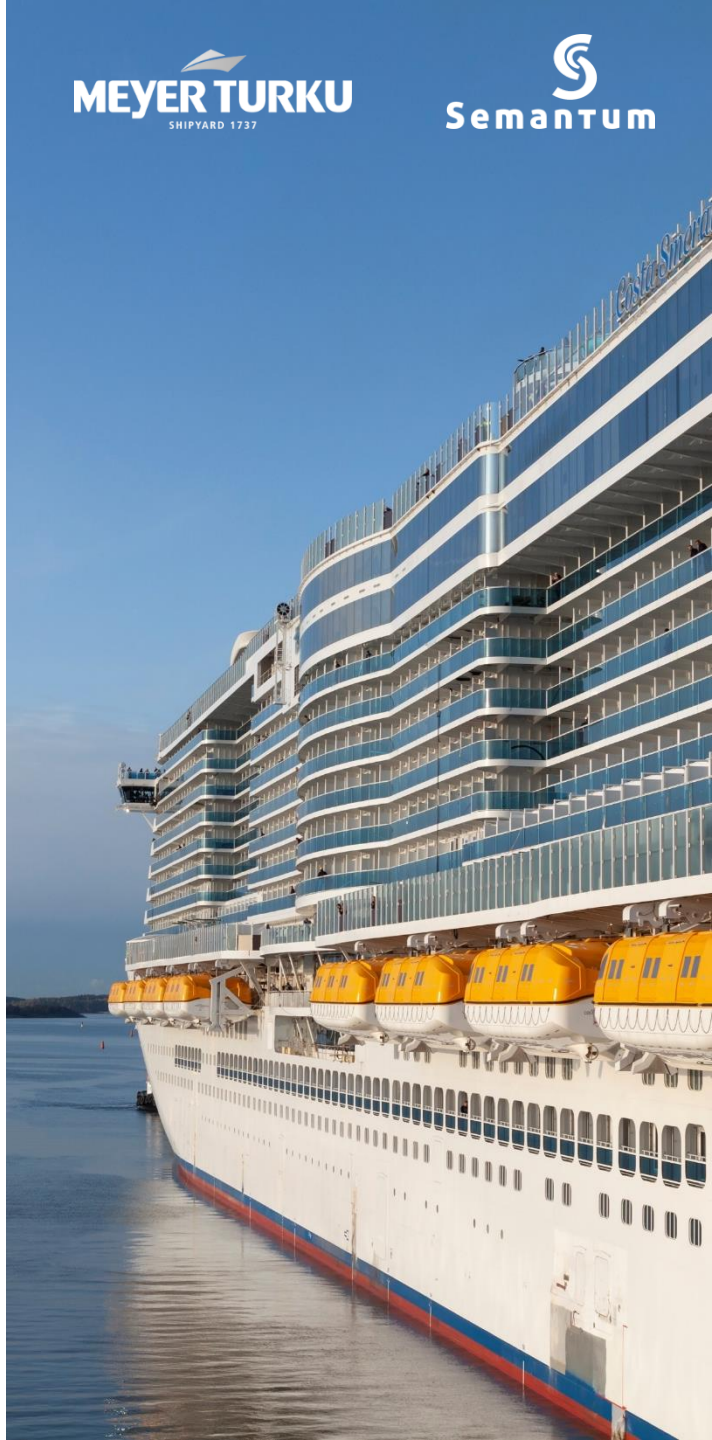
LNG as a marine fuel

LNG is becoming more popular as marine fuel

- LNG is a more environmentally friendly energy source. LNG-fueled engines promote decarbonization development
- Natural gas is cooled to -162°C and turned into liquid to reduce its volume to 1/600
  - This makes it easier to store and transport
- LNG has been recently used as an alternative to heavy oil as a marine fuel
  - The shift from heavy oil to LNG will be further accelerated as a result of the strengthening of SOx regulations
- **Meyer Turku is currently building several LNG-fueled cruise ships**

Using LNG brings challenges

- Purchasing and installing LNG fuel tanks, vaporization systems and engines increases the capital investment
- Current cost of new construction is 15 ~ 30% higher compared to conventional fueled vessels
- For cruise industry, tighter regulations require additional safety measures for designing, commissioning and operating LNG-marine systems and their automation
  - E.g., operation, bunkering and ESD procedures must be considered
- Ship's crew requires additional training for safe and efficient ship operation



Project introduction and motivation

- Project type: Big cruise ship. Delivered with new type of LNG system.
- Ship specification: HIL testing was requested.
- Agreement: Decision that some kind of testing will be done for LNG system which was new system to Owner.
- Testing method: MIL/SIL were agreed instead of HIL. Reason was that HIL testing was too extensive.
- Testing platform: Apros was agreed to be used. MT already had some simulations done for LNG system via MT energy team.

- Customer need → Avoid issues during commissioning and operation, new system to customer
- System evaluation in design phase → Detect failures in process and automation. System tuning.
- Reduce commissioning time → More mature system than in normal situation.
- Cost savings → Less failures more savings and work.

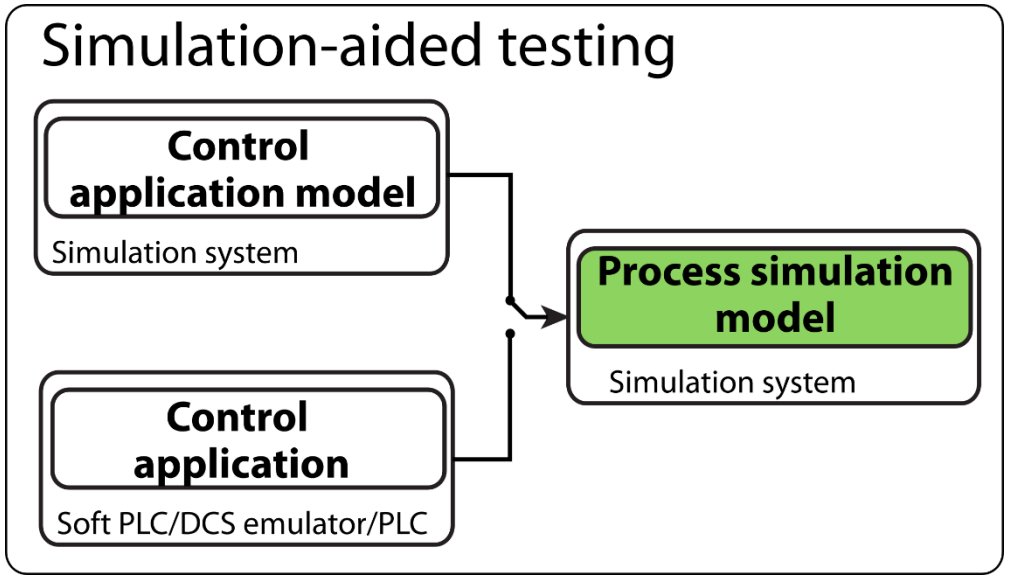
Simulation-aided automation testing of marine LNG fuel systems

Simulation-aided testing refers to the use of a dynamic process simulation model to test and verify the process control application

- It can be carried out either using a control application model or the actual control application

This approach can help addressing different challenges of marine LNG systems. E,g., It can be used to:

- Verify the process design before commissioning
- Integrated testing of the process and the control application using a realistic process model
  - Before the real system is available
- Test and verify safety and correctness of the different parts of the control application, including:
  - Control loops, operation sequences, interlockings and, high level automation functions
- Develop crew training systems

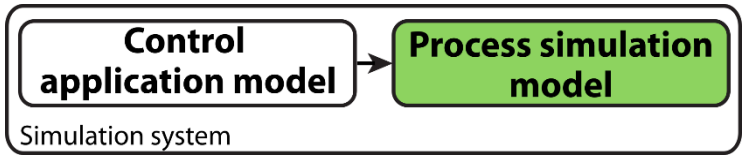


Simulation-aided testing at Meyer Turku

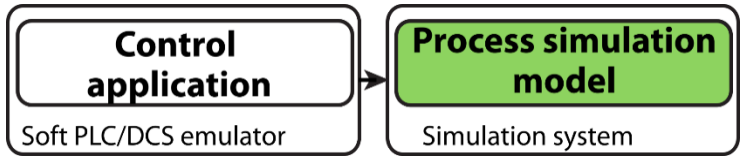
Process simulation is used at Meyer Turku for different applications, including automation testing and energy systems optimization

- Current simulation-aided testing projects focus on testing the control application of LNG fuel systems for cruise ships
- Model in the loop (MIL) and Software in the loop (SIL) configurations are used to:
  - Verify LNG fuel system (process) design
  - Analyze fuel system behavior under different operation conditions
  - Assess transient impact on fuel and auxiliary systems of common operating conditions
  - Test behavior of stabilizing control loops
  - Test operation sequences required e.g., for bunkering
  - Verify safety functions of the control application

MIL configuration



SIL configuration



MIL/SIL testing of the LNG fuel system control application

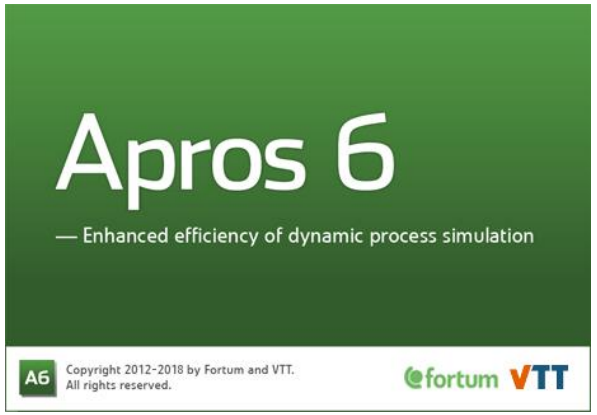
APROS

Dynamic process simulation software

- Apros is a dynamic thermal-hydraulic simulation software developed by VTT and Fortum
- It has been used to simulate:
  - Thermal and nuclear power plants
  - Pulp and paper mills
  - District heating and cooling networks
  - **Gas systems (LNG)**
  - Cooling systems (data centers)
  - Ship energy systems
  - Desalination plants, solid oxide fuel cell systems (SOFCs)
  - Concentrating solar power plants (CSPs)
  - Heat storage and transfer with molten salt
  - Hydrogen production systems (H2O electrolysis)

Applications and benefits

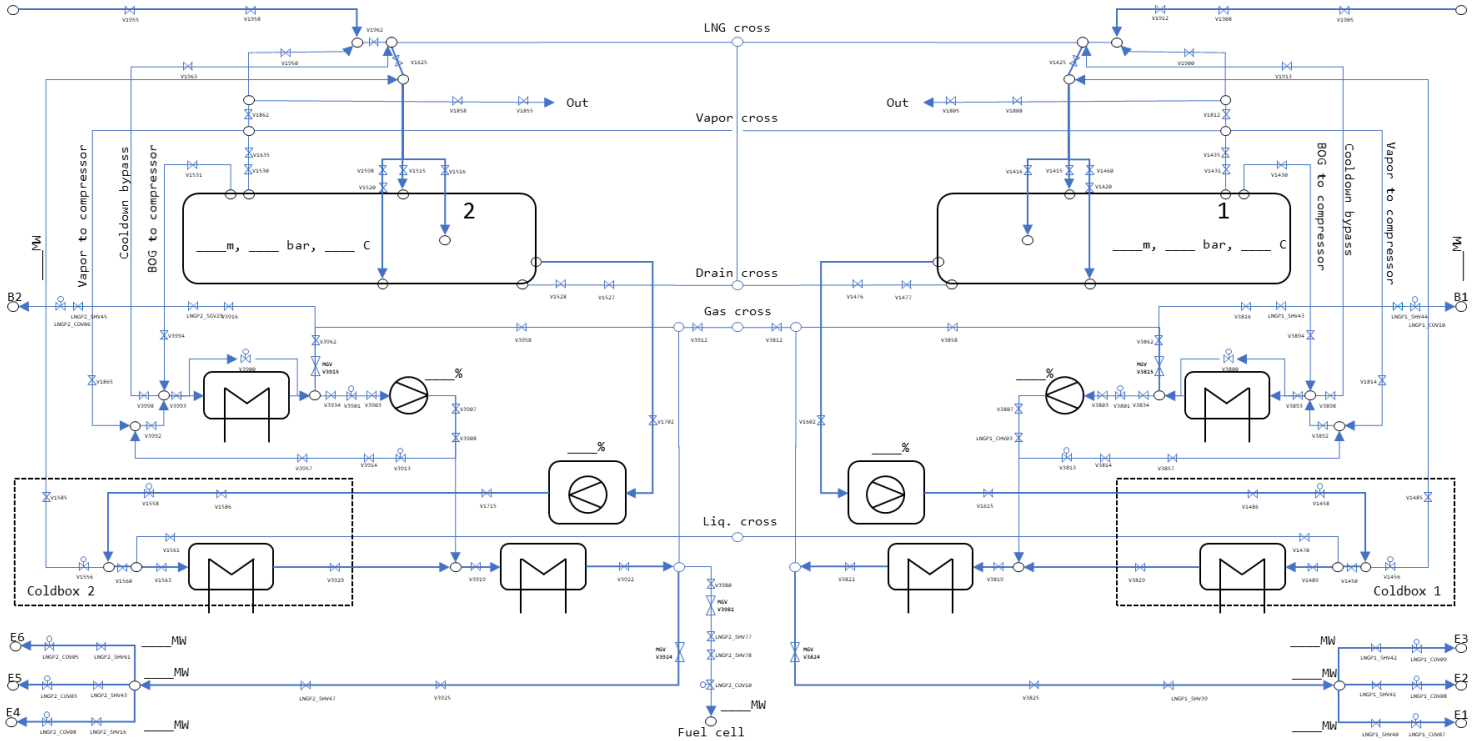
- **Security Analysis** - reduce risks and assure security authorities
- **Design support** - evaluate the process and control system design in advance
- **Automation testing** - shorten commissioning time
- **Operator training** - knowledge transfer through participation



Marine LNG fuel system

Marine LNG fuel systems in a nutshell

- LNG-fueled ships must store LNG in low-pressure tanks and then vaporize it to cover fuel demand
- Natural LNG evaporation in the storage tanks, known as boil-off is unavoidable and must be removed from the tanks in order to maintain low tank pressure
    - This boil-off gas (BOG) is used as fuel
- Vaporization systems can be designed to recover cold from the LNG
    - This is particularly important in cruise ships, where cold recovery can reduce energy consumption of HVAC systems

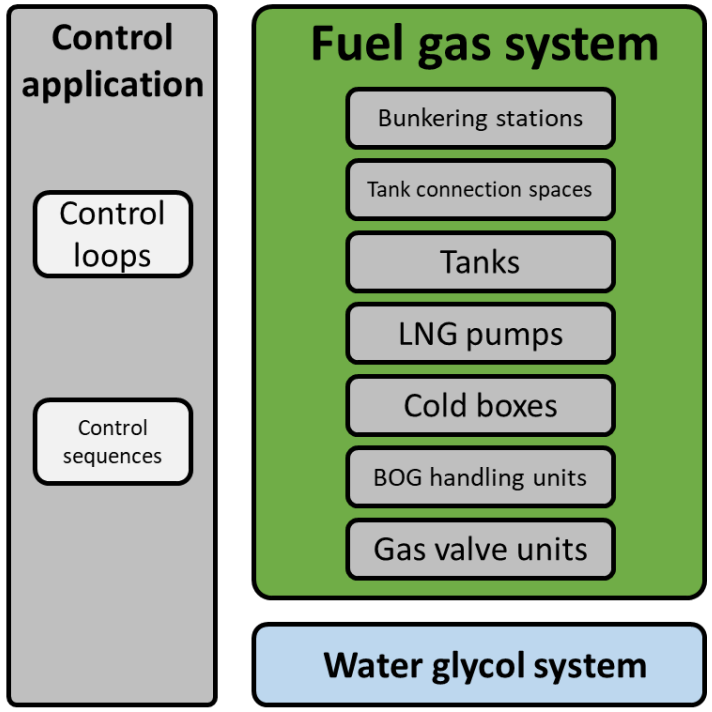


Dynamic simulation model

First-principles dynamic simulation of LNG systems

- Apros is used to model the LNG fuel system, including:
  - Main LNG fuel system: tanks, bunkering stations, pumps, BOG compressors, vaporizers, pipelines, inline equipment
  - Auxiliary systems: water-glycol system, gas-valve units (GVUs), cold recovery system (partially)
  - A comprehensive model of the control application
- Methane is used as fluid on the fuel gas system side
  - The simulation model has been configured using process diagrams, technical data sheet of the equipment, and nominal process variables values

Scope of the LNG fuel system simulation model

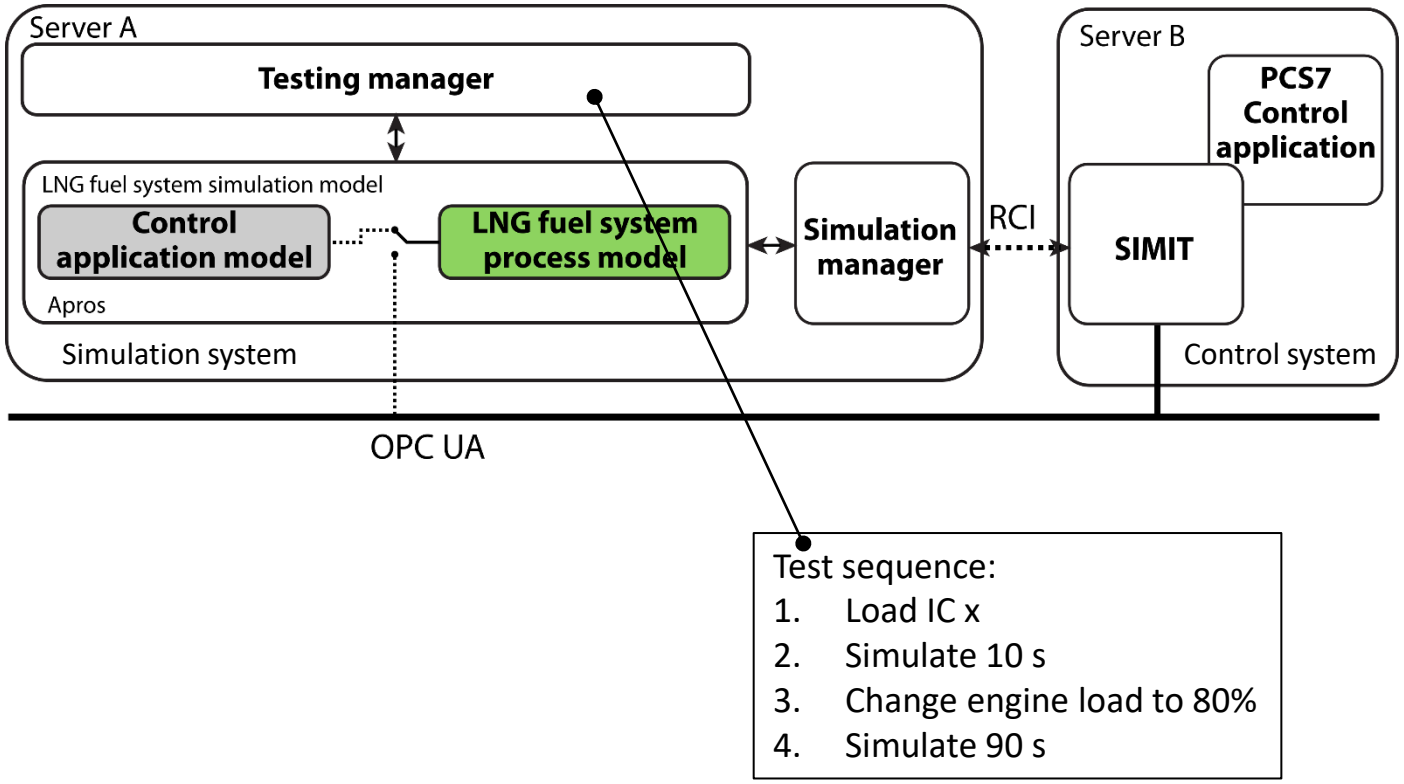


OPC-UA based environment for MIL/SIL testing

MIL/SIL testing is carried out using an OPC UA-based testing environment

- The simulation environment includes an OPC UA client. Additionally, It is comprised of:
  - LNG fuel system process simulation model: this model can be connected either to the control application model or directly to the real control application via OPC UA
  - Control application model
  - Testing manager: a separate Apros plugin required to systematically configure tests and manage its execution
  - Simulation manager: a separate Apros plugin required to manage synchronization between the simulation and the DCS systems. Synchronization is handled using a remote control interface (RCI)
- The real control application in current project is configured in Siemens PCS7
  - Siemens SIMIT OPC UA server is used to communicate with external systems during MIL/SIL testing
  - The SIMIT address space exposes all the tags available from the PCS7 control application

MIL/SIL OPC UA-based testing environment architecture



MIL testing

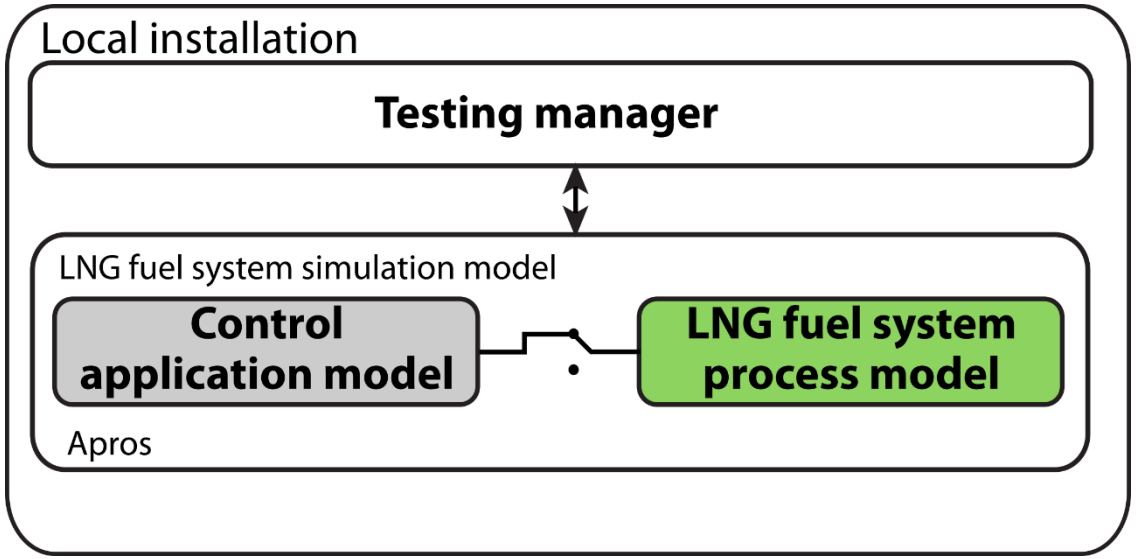
During MIL testing

- The entire testing is carried out in the Apros simulation environment
- The LNG fuel system process model is controlled by the control application model
- Tests are configured and their execution is managed by the Testing manager

MIL testing objectives:

- Verify LNG fuel system (process) design
- Analyze fuel system behavior under different operation conditions and malfunctions
- Assess transient impact on fuel and auxiliary systems of common operating conditions
- Test behavior of stabilizing control loops
  - And make changes if necessary
- MIL is a key preliminary step for SIL

MIL configuration



SIL testing

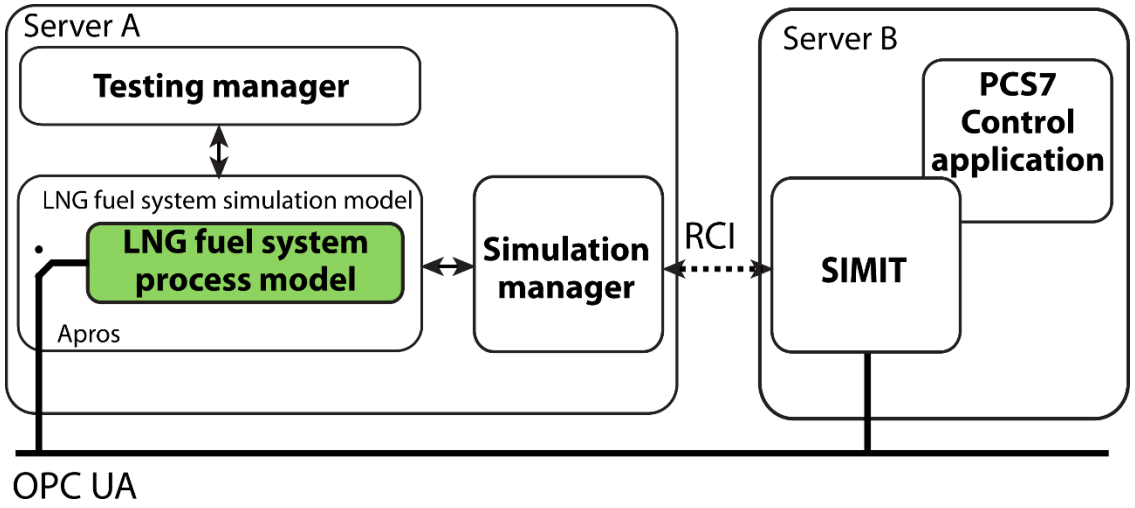
During SIL testing

- Testing requires connecting a server running the Apros simulation environment and a server running the control application in PCS7
- The LNG fuel system process model is controlled by real control application running in PCS7
- Same tests configured during MIL are executed by Testing manager during SIL
  - Only minor modifications to the tests are required during SIL. This saves time and work required for test configuration

SIL testing objectives

- Verify behavior of the real control application, its sequences and its interlocking under different operating conditions
  - Including transients and steady states.
  - Using a realistic simulation model that has been refined during MIL phase
- Further refine the process model for crew training applications

SIL configuration



OPC UA- related implementation facts

- SIMIT OPC UA server exposes the control application address space to the Apros client
- Communication between over 1200 tags
- OPC UA is used to exchange process and control variables information between the process model and the control application
  - While the Simulation manager handles system synchronization using RCI
  - Could this be implemented also with OPC UA?

Conclusions

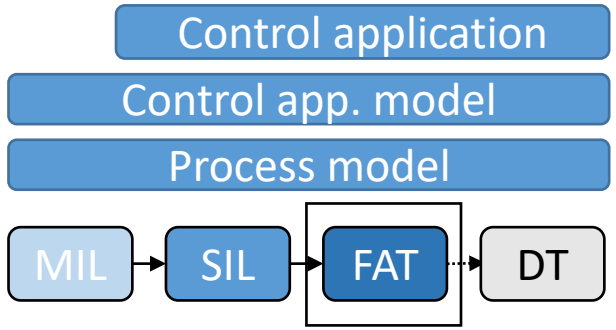
MIL/SIL testing: partial results

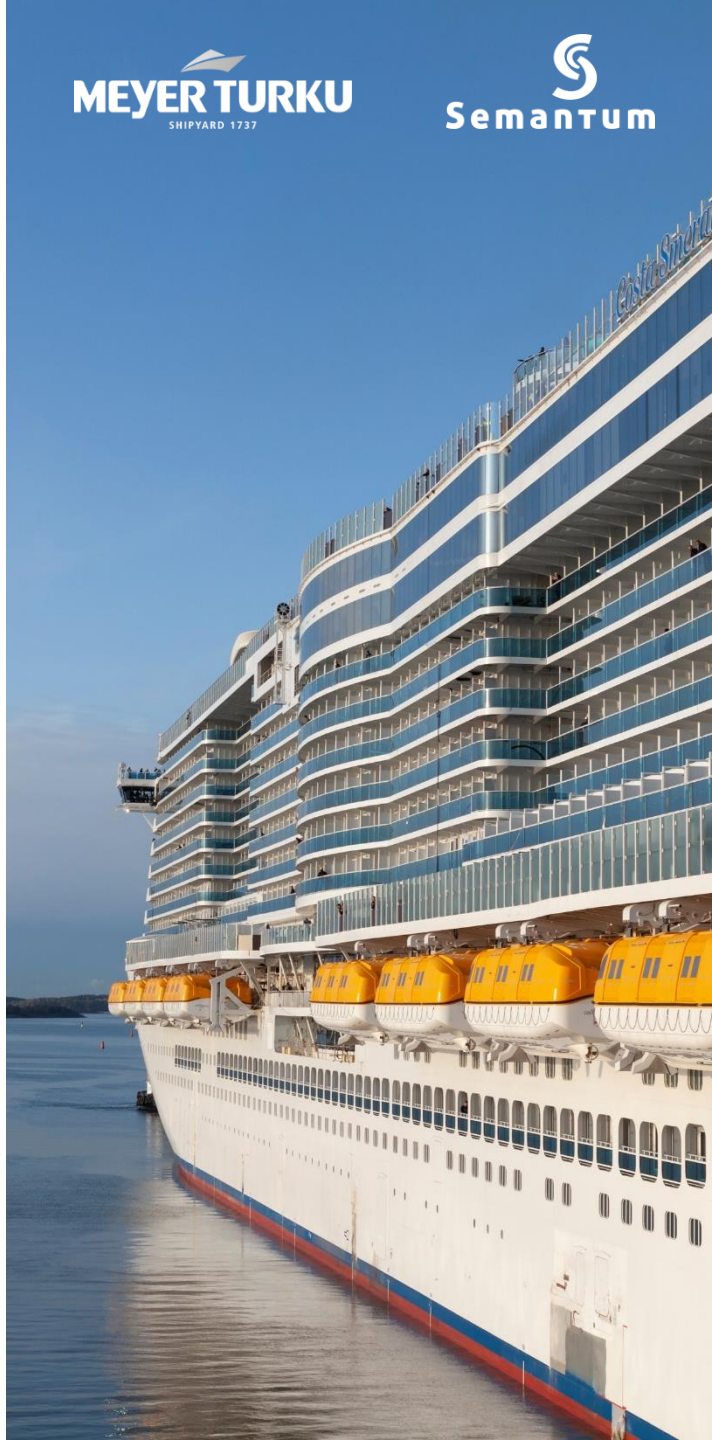
MIL testing results

- MIL phase has been completed and reviewed by all stakeholders
- Around 20 tests have been configured and run to test the system during Bunkering, normal operation and different malfunctions
- Increasing stakeholders understanding of the LNG fuel system and operations
- Over 10 different issues were raised and addressed during MIL phase
- Particularly useful to understand the inherent dynamics of different system operations, e.g., during bunkering
- During MIL testing, the simulation model has been refined to correspond to the process as built
  - At the same time, the process design and functional descriptions have been verified
  - This is important for SIL
- The behavior of the main control loops was verified
- System behavior during steady state, operational transients and malfunctions was analyzed

SIL testing partial results

- SIL phase is currently undergoing
- Same tests configured during MIL will be used for SIL
- SIL phase will put additional emphasis on testing safety functions of the real control application
- There has been additional tools developed for this purpose
  - Simulation manager: to synchronize execution of simulation and control systems



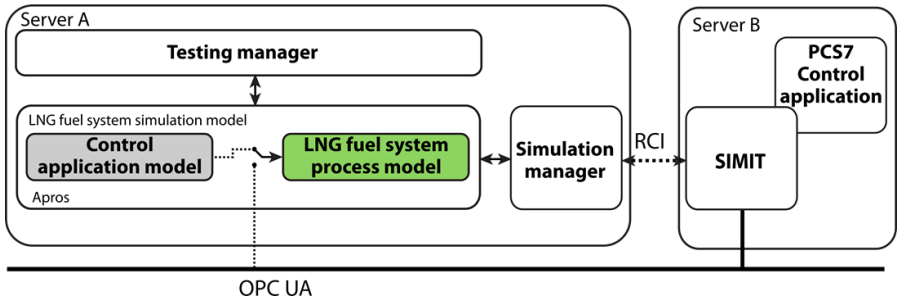


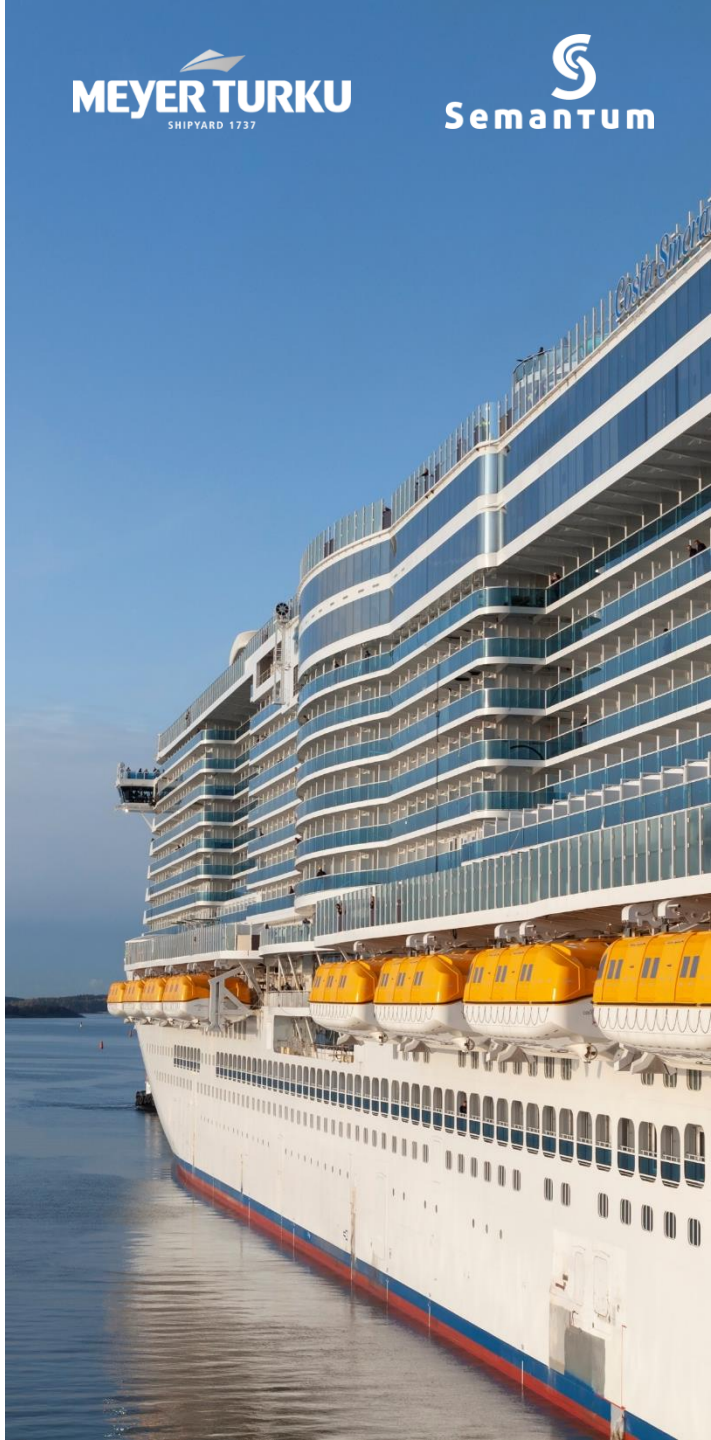
MIL/SIL testing: OPC UA

OPC UA-related results

- OPC UA-based testing architecture has been developed for this purpose
- OPC UA can successfully handle exchange of process & automation variables values
- There is still a need to handle simulation synchronization using a different communication mechanism. Thus, OPC UA could include options to also handle methods required for simulation control and synchronization with external systems:
  - Start/stop simulation
  - Save/Load initial conditions
- Required not only for MIL/SIL but for other applications where OPC UA is used to connect simulation and automation systems. E.g.,
  - Training systems
  - Digital Twins for operation support

MIL/SIL OPC UA-based testing environment architecture





Thank you!

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