UDT 2019 – System engineering for complex system design

Abstract — The evolution of technology during the last decades has been extremely fast. The consequences for underwater systems are deep in terms of capabilities, performances and automation. Naval Group is involved in a number of R&D actions aiming at developing the methods for designing tomorrow's submarines. System architecture is one of the main challenges in the design of complex systems, and many different tools are being used today for system architecting. In most cases, connecting system architecture and functional analysis with the conventional naval architecture process is an issue. Naval Group is investigating an alternative approach to system architecting that is based on the analysis of the interactions between the physical components of the ship (taken from the Product Breakdown Structure). This approach will improve the overall development process and life cycle cost control, and provide a framework for risk mitigation based on architecture analysis coupled with a detailed physical description of the product.

1 Complex systems digitalisation at early design stage

1.1 Objectives and challenges

Submarines and warship supplied by Naval Group are complex system to design, manufacture and operate. In particular, at early design stage, the following challenges shall be addressed by architects:

- Large amount of multi-physical subsystems involving heterogeneous technical domains.
- Connectivity
- Iterative design (design loop)

This paper describes an approach inspired form civilian shipbuilding industry works in order to address those challenges. Tools and methods are developed and tested in order to tune the early stage design of warship and submarines on 3 aspects:

- Stakeholders needs elicitation based on scenario oriented approach.
- System architecture modelling.
- Automatic physical simulation.

The main objective of the approach described in this paper is to reach a high level of definition and performance assessment as early as possible in the design. Increasing design knowledge induce a better control on life cycle cost and project risks :

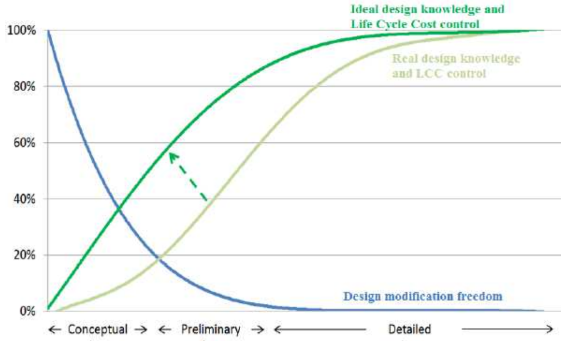

Fig. 1. Life cycle cost control with respect to design phases.

The main focus here is performed on complex system architecture modelling tools and methods.

2 Complex system architecture modelling

2.1 Objectives of System Modelling at early stage design.

- Offer relevant views of system architecture to handle complexity.
- Explore numerous possibilities of systems architecture solutions.
- Organize the collaborative design workflow.
- Ensure that system definition meet stakeholders needs.
- Identify emerging behaviours as opportunities or failures.

2.2 Tools developed for system architecture handling.

Two main tools have been tested in this approach for system architecture handling and definition. The first tool (1.) describes design requirements facing operational scenarios and one second tool (2.) is a representation of system architecture, mapping systems components and their physical interactions:

1. Requirement and operational scenarios management tool :

- Describe stake-holders requirements for the whole Life Cycle.
- Contextualize requirements within operational scenarios to ease discussion and trade off.
- Link between requirements and performance are performed directly via users responsible of systems and/or operational scenarios.

In this tool, stakeholders' needs description is based on operational scenario concept. Those scenarios describe textually the whole context involving requirements and systems. Operational scenarios are independent and discriminant. It is justifying the existence of the system and it will be the basis of discussion to find a trade-off between technical specification and performance assessment.

2. System architecture diagram tool :
- Map and navigate among system components and physical interactions.
- Document all components and interface properties.
- Identify functional chains and networks.
- Perform global qualitative analysis such as dysfunctional analysis.

This tool supports the system architect to navigate into system architecture among components via physical interfaces. This model is a multi-physical and multiscale representation of the complex system architecture. In the following chapter, a modelling example is given.

3 Propulsion system modelling and dysfunctional analysis example

3.1. Multi-physic and multiscale modelling of a propulsion system

Here is an example of a propulsion system model. In this Figure 2, the fuel circuit is highlighted but other functional chains can be defined such as mechanical transmission or electrical network for instance.

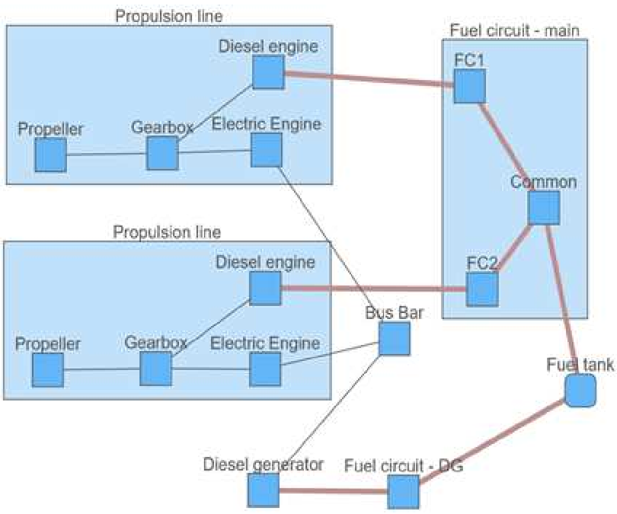

Fig. 2. System architecture model example: propulsion system CODLOD.

3.2. Dysfunctional analysis of propulsion system.

In functional chains model, users can identify for each physical network producer components and consumers component if any.

Then, the user can visualize multi-physical failures propagation and assess first qualitative implications. This is a way to identify some emerging behavior.

In this paper a dysfunctional analysis of a surface vessel propulsion system is given for example:

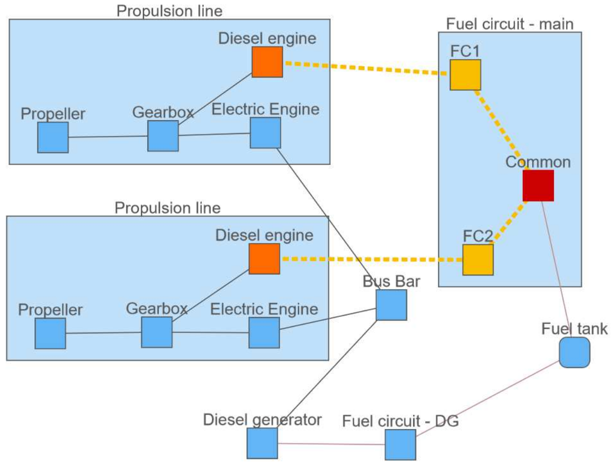

Fig. 3. Failure propagation from common fuel circuit component in propulsion system.

4. Conclusion

Methods to perform early design stage of complex systems using those tools are currently discussed, mainly on surface vessel designs application cases.

Modelling system architecture and stakeholder needs is a first step to capture the whole system complexity, to handle it and to select the “optimized” trade-off.

In addition to system modelling tools, some work is ongoing to explore the solution space using automated simulation management platforms. Simulation driven design will give to the designer a view of selected critical performances for a large range of different designs.

Author/Speaker Biographies

Romain LE NENA is R&D Project engineer at Naval Group Research in Complex System Modelling department. He was graduated from ENSTA Bretagne with a Master in naval architecture and offshore engineering.

Romain LE NENA has been working as naval architect in a design office for 6 years in civilian and defense shipbuilding industry as well as in offshore and maritime renewable energy field.

Benoit Rafine finished his doctorate in Aeronautics in 1978. He attended CHEAR (Center for Advanced Studies Armaments Paris) in 1994.

He had worked as Sonars Systems Manager in Le Brusc Laboratory (DCNS) in 1980-1997. From 1997 to 2002, he worked Technical Manager at Saint Tropez site of DCNS, which specializes in underwater weapons like Torpedoes. Between 2002 and 2006, he was working as Commercial Manager in Toulon Le Mourillon site of DCNS. He was Naval Systems Expert at DCNS during 2006-2012.

Since 2012 Complex Systems Modelling Manager in DCNS Research, which is now Naval Group Research as the company changed its name in 2017.

Alan GUEGAN is head of the Design & Engineering Methods department at Sirehna, a Naval Group company. His activities range from the development of software design tools to technical assessment and consulting in systems engineering. Alan's background is in system reliability (former head of RAM department, Bombardier Transportation), system architecting (technical lead in Marine Energy projects, Naval Group) and fundamental physics (PhD in Fluid Dynamics). He is currently investigating organizational and cognitive aspects of the engineering of large systems (see communications at IMDC 2018, CSD&M 2018).

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