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RESONANCE – a Satellite Construction Kit to support design and verification of Functional Satellite Modules

[1]*Plasberg, C., [1]Schulze, M., [1]Graaf, F., [2]Neacsu, T., [3]Gancet, J., [3]Letier, P., [1]Timmermann, D., Heppner, G., Schnell, T., Dillmann, R.

*lead presenter

[1] plasberg@fzi.de, FZI Research Center for Information Technology, Germany

[2] ReOrbit, Finland

[3] Space Applications Services N.V./S.A., Belgium

Abstract

Designing a satellite or a satellite module is a costly and time-consuming process. Starting with Specification design over component selection to compatibility tests, a lot of effort is needed to come up with a new design fulfilling the customer's needs. This sets a high entry barrier to the market of space modules, especially for newcomers. To enable the full potential of future space economy, the entry barrier needs to be lowered. This also allows to use new approaches, encourages innovations and more competition.

The project SCHUMANN and the within this project developed toolkit RESONANCE aim to simplify the process of designing functional satellite modules (FSM). The toolkit closes a gap between providers of components and space equipment designers. Similar to a shopping cart or app store FSM manufacturers get access to a database of verified space grade components. Based on an initially set specification of the newly to develop FSM, those components can be compared, selected and checked for compliance with the given specification. Providing an UI to connect the selected components interfaces to each other also allows to check compatibility on interface level.

A generated report provides the final overview about the given constraints, selected components, and set interconnections. This is accompanied by the results of the compliance check as well as the compatibility check for connected components.

To support trustworthiness, high quality data and up-to-date parts, components get certified when a quality check is passed. Modeling FSMs and components in an ontology allows for multi-level compatibility and compliance checks.

Introduction

NewSpace describes a fundamental change in space industry. With private investors heavily investing approaches for Systems become more agile and business oriented [1]. Some of the ideas of this market are about life extension by Orbital Replacement Units (ORU), refueling or

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in-space assembly and recycling. SCHUMANN [2] [3] is an activity, funded by the European Unions Horizon 2020 Research and Innovation Programme, aiming to improve the foundation for future space ecosystems and modular spacecrafts. The SCHUMANN activity is working on two critical issues to get closer to this NewSpace vision: On the one hand improving technical maturation of functional satellite modules (FSM) with a refuellable Tank and on the other hand developing a Satellite Construction Kit (SCK) to streamline the design of new FSMs.

When designing a new FSM, a lot of effort goes into component selection. Tools like satsearch [4] already helps to give an overview of available components. Nevertheless, finding the right ones for your design, checking their capabilities and compatibility with other components still require lots of manual effort. Concurrent Approaches are DLRs Virtual Satellite [5] [6] or ideas from the project ORU-BOAS [7].

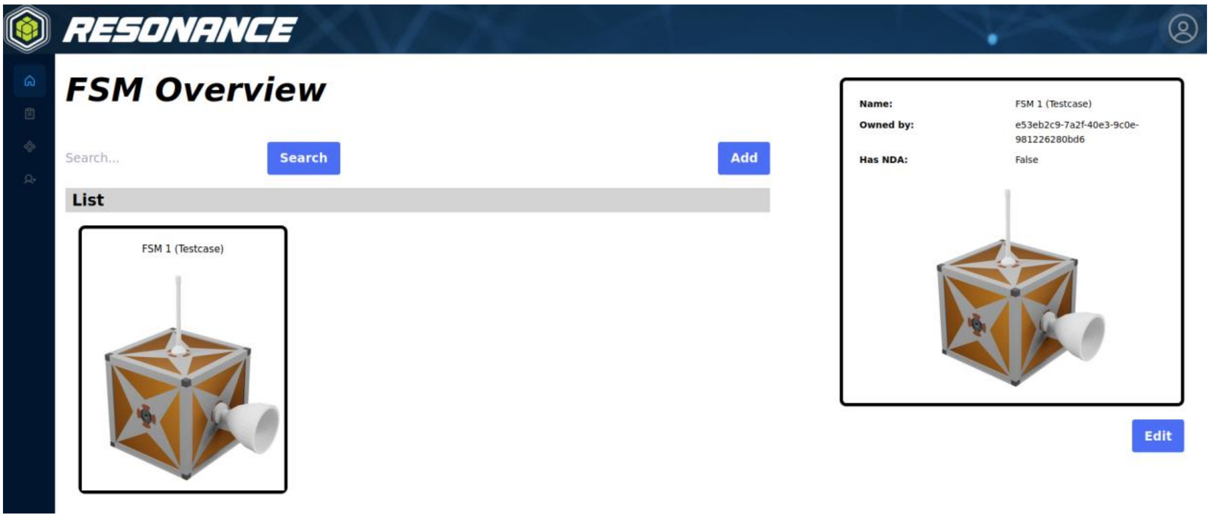

Figure 1: Overview of last FSMs that the user has interacted with.

RESONANCE Overview

Effective handling of modularity for future spacecrafts requires feasible support for validation and verification. Support should start as early as possible to prevent expensive late design changes. Therefor tools need to be available already at the design phase, to check the compliance of required submodules and the overall consistency of their designs. A SCK self-certification process is proposed to help module builders increasing the ease of integration of their products into systems while ensuring reliability and system integrity at the same time. The initiative therefore includes the development of a set of specifications, referred to as "Design and Development Specifications for a Satellite Construction Kit" (DSSCK), to provide a structured approach to the design of the platform's modules

Main objective of the Design and Development Specifications for a Satellite Construction Kit is to develop specifications and to create designs that can be checked against these specifications. By applying a specification, FSM developers are guided to create compatible designs with future space ecosystems. This ensures easy integration by satellite developers, saving time and money. The DSSCK Software has been named RESONANCE – in favor of the famous composer Schumann, that is named the same as the project. Figure 1 gives a small insight to the RESONANCE tool.

Design Support by RESONANCE

Main target as a user for RESONANCE is an FSM developer. The developer is asked to design a new module to match certain specifications to result in a compliant, interfaceable module. While a specification normally is relatively stable and unchanged, developers while have several iterations of designing the FSM.

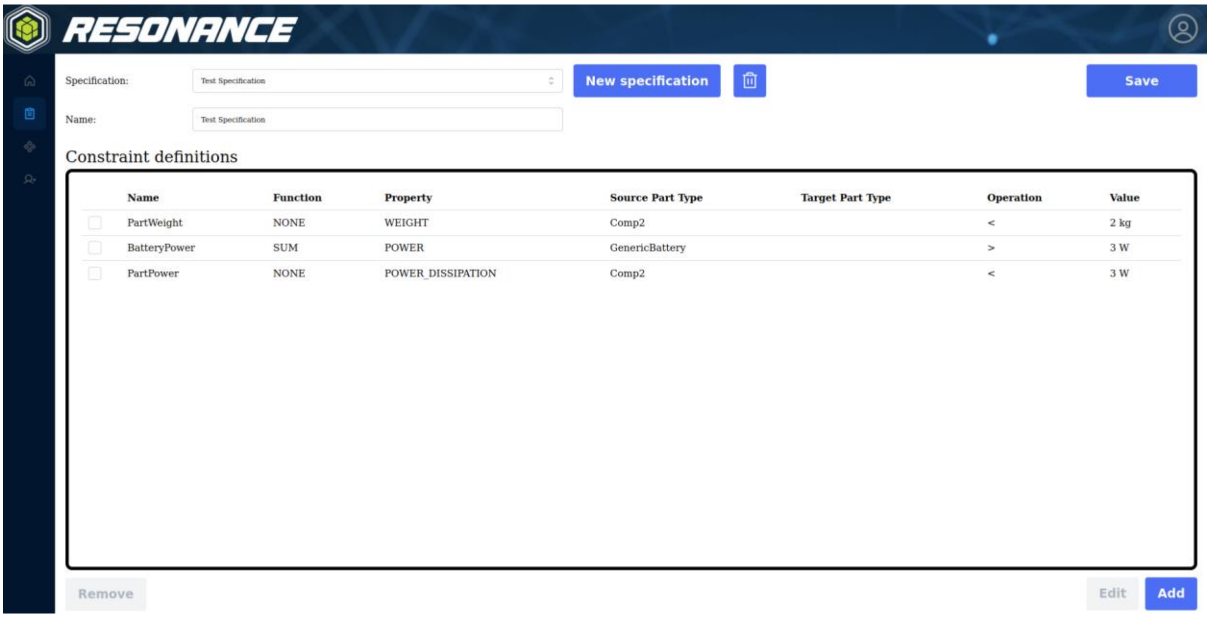

Figure 2: A specification is a set of constraints that shall be matched either by individual Components or the overall FSM.

A specification for FSMs consists of a unique name for the specification and a set of constraints. Each constraint inside the specification has a unique name and an operation to work with the individual component's properties (see Figure 2). During specification checks and report generation for an FSM each of those constraints is individually checked and evaluated as pass or fail. For failed constraints the developer can get feedback to see why a constraint is not passed and to change the FSM accordingly.

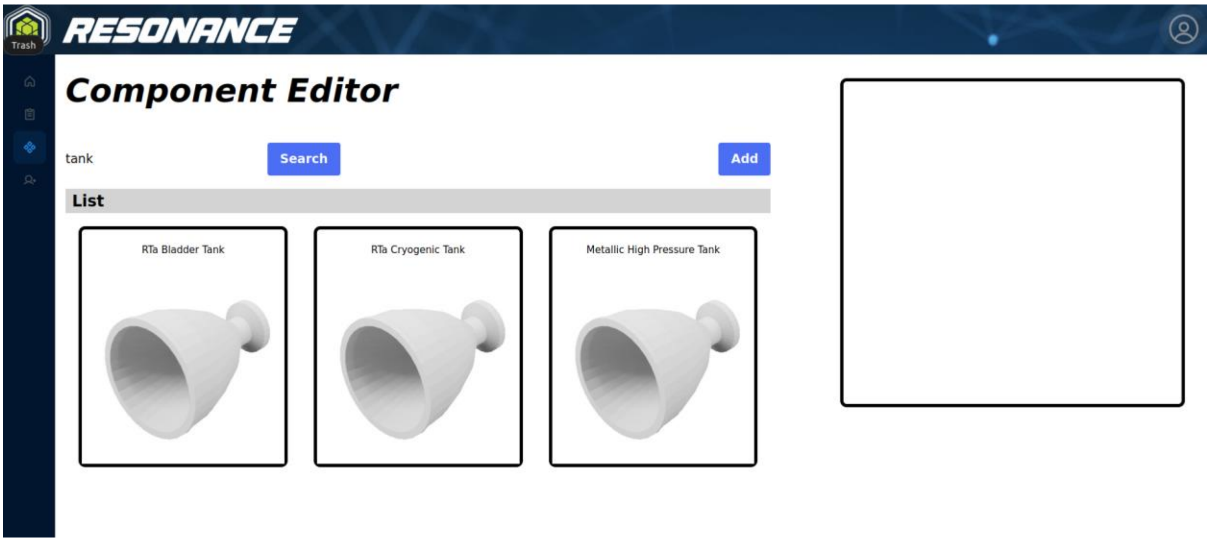

Figure 3: A searchable list of available components allows to get an overview and get a first glance at their details. Displayed components are for testing purposes only with fake thumbnails.

An FSM Development with RESONANCE aims to also make the developed FSM available to potential users, that want to build a satellite from the developed FSMs. Therefore, each FSM can also contain a verbose description and additional files like manuals or datasheets to inform potential users what the FSM is capable of (see Figure 4). Core feature of RESONANCE, next to compliance checks for specifications, is the possibility of virtually connecting several components interfaces to check compatibility (see Figure 5).

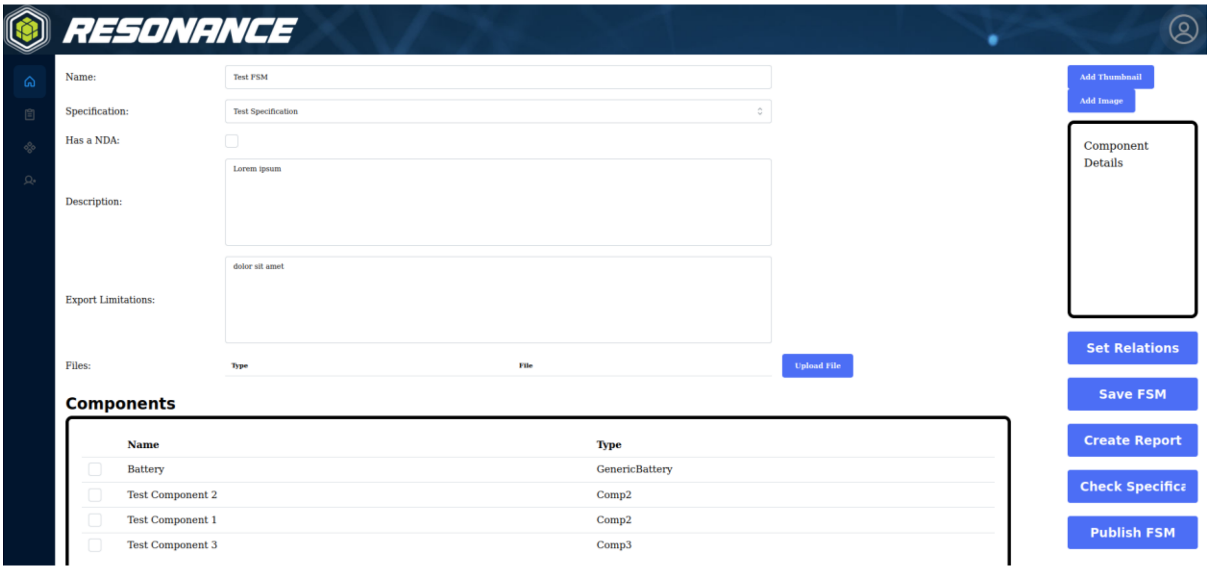

Figure 4: FSM editor to edit the selected FSM. Specifications can be selected, and Components be added or deleted. The result can also be exported as a pdf.

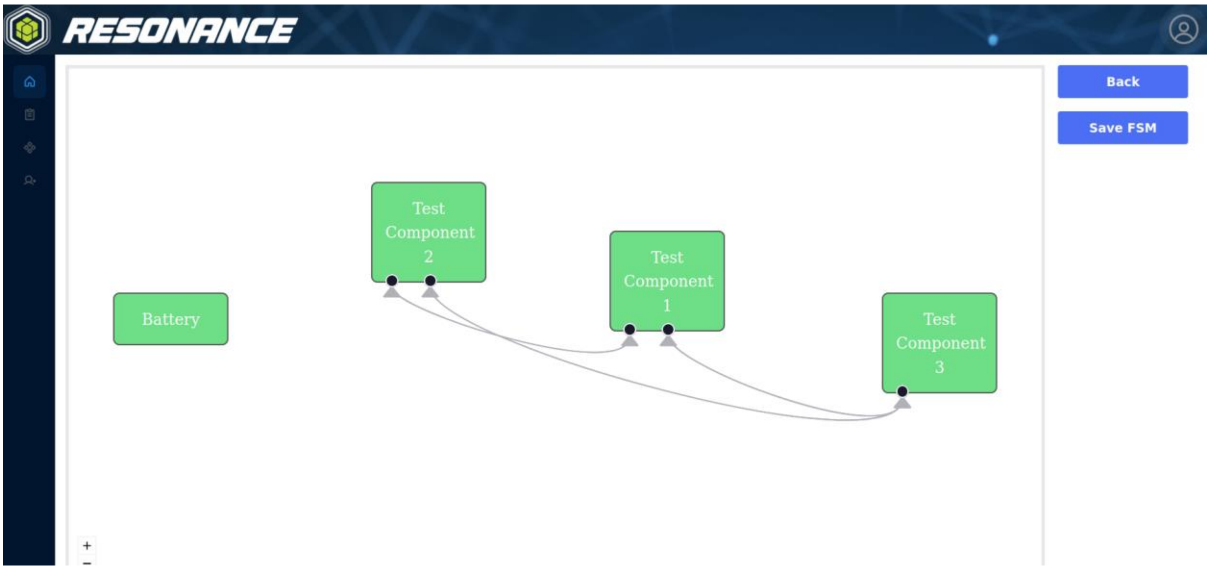

Figure 5: Relations Editor to connect components interfaces. Interfaces are modelled in the component's ontology representation and a brief summary can be viewed when hovering about an interface.

Component Models in the Ontology

All available components to use within an FSM are modeled in an ontology. Using an ontology allows to model classes of things with properties and relation between them [8]. When modelled correctly it also allows consistency checks and reasoning [9]. To model a component for RESONANCE, main focus is on components properties and interfaces.

Interfaces follow the OSI model [10]. This concept allows to evaluate compatibility on different layers and to give appropriate feedback. Obviously, not all layers can be fully covered without an extreme modelling effort for each component. Therefore, compatibility checks are limited by the component models and the FSM developer has to check higher layers.

Properties are mainly compatibility properties like support for different software frameworks or physical properties. Physical properties use the Units of measurement ontology [11]. Sticking to SI-units and a unified approach f modelling helps to also aggregate or compare units with different exponents, e.g. cm and mm.

Conclusion

With RESONANCE a tool is developed, that supports the development of new FSMs. It supports the process quite early, during design phase and helps to determine matching and compatible components. The developed FSM can be checked for compliance with a predefined set of constraints from a specification. Also, the given design can be checked with an altered specification due to requirement changes. The user is informed about incompatibilities and specification violations to adjust the design accordingly. With this toolset RESONANCE can be trend-setting for new developments and compatibility standards in future space ecosystems.

References

[1] "What is New Space?," 22 07 2021. [Online]. Available: https://solar-mems.com/news/what-is-new-space/. [Accessed 26 09 2024].

[2] P. Letier, M. Debroise, A. M. Bario, J. Gancet, D. Silveira, C. Serra, H. Castaing, G. Mistritta, I. Chechile, M. Suomela, T. Neacsu, C. Plasberg and M. Schulze, "SCHUMANN - Fostering Satellite Modularity in the NewSpace Landscape," in *17th Symposium on Advanced Space Technologies in Robotics and Automation (ASTRA)*, Leiden, 2023.

[3] "Homepage - SCHUMANN," 09 09 2024. [Online]. Available: https://horizon-schumann.eu/. [Accessed 26 09 2024].

[4] "the global marketplace for the space industry | satsearch," 26 09 2024. [Online]. Available: https://satsearch.co/. [Accessed 26 09 2024].

[5] A. Martelo, S. S. Jahnke, A. Braukahne, D. Quantius, V. Maiwald and O. Romber, "Statistics and Evaluation of 60+ Concurrent Engineering Studies at DLR," in *68th International Astronautical Congress (IAC)*, Adelaide, 2017.

[6] H. Schumann, A. Berres, O. Maibaum and A. Röhnsch, "DLR's Virtual Satellite Approach," in *10th International Workshop on Simulation on European Space Programme*, Noordwijk, 2008.

[7] A. Ruiz, M. Diaz-Carrasco, J. Viñals, I. Prieto, A. Rozas, S. García, A. Lázaro, M. Ruiz, J. Gala, I. Soto, S. Behar-Lafenetre, G. Musso, F. Massobrio, S. Ferraris, M. De Stefano, H. Mishra and R. Lampariello, "ORU-BOAS: Developing Reusable Building Blocks For Satellite Modularisation," in *74th International Astronautical Congress (IAC)*, Baku, 2023.

[8] Z. Saigol, M. Wang, B. Ridder and D. M. Lane, “The Benefits of Explicit Ontological Knowledge-Bases for Robotic Systems,” in *Towards Autonomous Robotic Systems: 16th Annual Conference (TAROS)*, Liverpool, 2015.

[9] T. d. Boer, “Essence of Ontology Reasoning,” Medium, 19 10 2020. [Online]. Available: https://medium.com/introduction-to-knowlegde-representation/essence-of-ontology-reasoning-b38942ea5af5. [Accessed 26 09 2024].

[10] S. Kumar, S. Dalal and V. Dixit, “The OSI Model: Overview on the seven Layers of Computer Networks,” *International Journal of Computer Science and Information Technology Research,* vol. 2, no. 3, pp. 461-466, 2014.

[11] G. Gkoutos, “Ontbee - Units of measurement ontology,” University of Michigan Medical School, [Online]. Available: https://ontobee.org/ontology/UO. [Accessed 26 09 2024].