APPLICATION OF SYSML IN THE DEVELOPMENT OF AIRCRAFT CABIN HEALTH MANAGEMENT

Adrian Hechelmann[1], Thomas Mannchen[2]

Baden-Wuerttemberg Cooperative State University (DHBW) Ravensburg, Campus Friedrichshafen, Aerospace Engineering, Fallenbrunnen 2, 88045 Friedrichshafen,
[1]hechelmann.a@dhbw-ravensburg.de, [2]mannchen@dhbw-ravensburg.de

Abstract

Digitalization unlocks new prospects for aircraft cabin maintenance, which have to be developed under consideration of operational aspects and adherence to safety and security regulations. This paper presents the application of a customized model-based systems engineering (MBSE) approach advancing the development of health management for aircraft cabin systems.

Keywords: Model-based Systems Engineering, Aircraft Health Management, Aircraft Cabin Systems

1. Introduction

Aircraft availability, reliable operation and efficient maintenance without compromising safety or security are essential objectives for airlines. By leveraging services such as health monitoring and prognostics provided by the aircraft manufacturer and suppliers, airlines are enabled to meet these essential objectives [1]. Status information from avionics systems is already being transmitted from the aircraft to the airline as of now; however, the integration of the aircraft cabin into these services remains limited. As a benefit of increased digitalization, the cabin is becoming a widely connected and digitally integrated environment. Such a “smart” cabin will interconnect cabin systems via a cabin network and generate, collect and transfer status information from sensors and cabin systems to generate an “overall picture” of the cabin’s condition [2]. The overall picture of the cabin will then be provided by a health indication function, which is defined as reporting, indicating and visualizing a set of status information of the entire cabin as well as of individual cabin systems or components. The health indication function uses sensor data, network information and usage information and performs aggregations by applying algorithms on status information. Health indication may include both qualitative and quantitative data, as well as graphical representations of the cabin and its systems or components. It transmits failure messages with different levels of dispatch criticality and the related fault codes. The on-board system, when accessed by the crew, displays only the faults that impact service delivery. On the other hand, maintenance personnel, whether using on-board terminals or ground-based systems, have access to fault codes for troubleshooting.

Integrating aircraft cabin health indication into the aircraft health management is a further step to optimize maintenance scheduling of aircraft. Deriving maintenance actions for the cabin, by using cabin health indication, becomes a conceivable and desirable scenario for the future. The implementation of prognostics, based on cabin health indication, will enable aircraft operators to anticipate failures before they occur [1].

The research project “i+sCabin2.0” is the follow-on project of the original “intelligent and smart cabin” research project, again conducted by an industry-wide collaboration of aerospace suppliers, aircraft manufactures, airline and academia. To enhance cabin reliability and improve passenger comfort, i+sCabin2.0 pursues several strategies, including linking the smart aircraft cabin to the ground [2]. To advance the development in the research project, the Baden-Wuerttemberg Cooperative State University (DHBW) designs and applies model-based systems engineering (MBSE) methods. The application of MBSE on cabin systems provides model-based documentation of the development and supports the design of the research project’s MBSE framework, which will be the starting point

of a methodology exploration of model-based support for the certification process of aircraft cabin systems with special focus on airworthiness security [3]. In this paper, the application of the systems modelling language (SysML) to support the development towards health management for digitalized aircraft cabin systems is presented. This is conducted by applying a customized, structured model-based systems engineering approach on the state of the aircraft cabin before digitalization and interconnection and comparing the results with results of the application of the approach on the development of digital aircraft cabin health management. The main results include the advantages of an unambiguous, clear documentation and a usable SysML model as basis for further research on model-based support for the certification process, underlining the potential and applicability of MBSE in the context of digital aircraft cabin systems.

2. Technical Foundation

2.1 Aircraft Health Management

Towards the definition and development of a technical implementation of the cabin's condition in aircraft health management systems, the understanding of the customer's perspective (airline) and the consideration of aviation regulations with regard to regulatory approval are fundamental.

Airlines use aircraft health management (AHM) to consolidate all fault messages and all aircraft in the fleet, to receive real-time faults, to learn about fleet performance and to control and schedule needed maintenance actions [4]. To provide an overall picture of the aircraft condition, derive appropriate work orders and improve maintenance planning from an airlines perspective, AHM should include all relevant aircraft health information. Advances in aircraft cabin system digitization and interconnection could lead to an increased integration of cabin faults, cabin system status information and cabin health indication into AHM, promising improved availability and reliability of the aircraft cabin. It is expected that the airline's maintenance control will benefit from this integration for base and line maintenance purposes. According to [4], the future goal is an integrated aircraft health management (IAHM), where maintenance is condition-based and maintenance action is guided by reliable remaining useful life (RLU) estimates, in contrary of today's scheduled approach. This contains system-level health indication (e.g. cabin health indication) and aircraft level health indication. It should be noted, though, that only some maintenance tasks can be condition-based, as visual inspection for condition and functional checks for items without sensors will still require daily checks to confirm serviceability of the cabin.

2.2 Regulations

For operation, an aircraft must be in an airworthy condition. The aircraft's operations manual specifies the way of operating an aircraft to comply with aviation regulations [5]. To prove that the aircraft is in a condition for safe use, inspections are performed. These inspections are following a standardized manner, with areas of inspection being defined as flight deck, cabin safety, aircraft condition and cargo [6]. Aircraft maintenance manuals, minimum equipment lists (MELs) and operators' maintenance policies define the requirements for cabin serviceability [7]. Innovations discussed in this paper, such as interconnection of cabin systems via a cabin network to provide an updated overall picture of the cabin's condition, may have an impact on operations and hence will have to be developed sensibly, since operations are subject to regulatory approval.

2.3 Airworthiness Security

Information which is processed in the cabin and transferred to AHM must be treated with respect to cyber threats, as aviation cybersecurity is a critical consideration for airlines [8]. The increasing threat of cyberattacks has been identified by the regulatory authority: Equipment, system and network information must be protected from intentional unauthorized electronic interactions (IUEI) [9]. Unlike traditional airworthiness, which primarily focuses on the physical and functional integrity of aircraft, airworthiness security is the protection of the airworthiness of an aircraft from IUEI [10]. To address the demands of the regulatory authority regarding IUEI, a regulatory framework has been published by the European Organization for Civil Aviation Equipment (EUROCAE). These regulations are recognized as acceptable means of compliance [11] and are considered within the research project.

2.4 Model-Based Systems Engineering

Systems engineering is an approach and means to develop multidisciplinary systems, spanning all phases of the development cycle [12]. Model-based systems engineering allows to cope with increasing system complexity and can be applied to improve the efficiency of the development of new, complex systems such as systems and networks of the aircraft's cabin. Fundamental for MBSE is the system model, which serves as a repository of design decisions, and a set of standardized system diagrams is used as an effective means for communication between stakeholders [13]. SysML is the chosen language here and enables to practice MBSE.

3. Research Approach

This paper demonstrates the application of a structured model-based systems engineering approach on aircraft cabin systems in order to use the potentials of digitalization for integrating cabin systems into AHM framework. Potential architectures could include a self-contained cabin network, analogous to the AHM system, or a complete integration of cabin systems into the existing AHM framework. Guided by a comprehensive review of the literature and building upon established research, two approaches that apply SysML on aviation maintenance systems [14, 15] have been selected as foundational framework. These have been subsequently customized for use in the development of digital health management for aircraft cabin systems. Details and rationale of the customized model-based approach will be presented in a following section. By applying the steps of the customized approach, the following two contributions will be realized:

1. Modelling and use of SysML diagrams to demonstrate prospects and new use-cases that cabin system status information and health indication will deliver
2. Show applicability of MBSE in the cyber-physical system of a digitalized aircraft cabin and the benefits of model-based development by modelling structural and behavioral diagrams

To visualize structural and behavioral changes and improvements of implementing cabin health indication, this paper recommends a model-based comparison with the aircraft cabin before digitalization. Through the application of the customized approach on both scenarios, two more contributions will be achieved:

3. Generate the basis for the suggested model-based comparison
4. Verify that the customized approach fulfills the expectation of providing a comprehensive model-based documentation

4. Status Quo

Currently, defects in the aircraft cabin are frequently recorded manually in paper-based cabin logbooks only. This means that the airline receives information about cabin defects not until after the flight. These limitations can be addressed through digitalization and interconnection, albeit to varying degrees across different components. Firstly, certain cabin systems, currently non-digital, can be enhanced by integrating sensors, thereby facilitating real-time data capture. Secondly, there are cabin components that are already equipped with digital sensors but remain isolated from any networked environment, in part for lack of established communication standard for aircraft cabin systems [16]. This isolation limits the potential for systems integration, hindering the possibility of leveraging collected data for predictive maintenance and operational optimization. Lastly, some cabin components or aspects are inherently unable to be captured by digital sensors due to technical or practical limitations. Although these components will continue to require manual checks, their integration into a digital logbook system could still offer improvements in data consistency and accessibility, reducing the risk of human error and improving maintenance tracking. This state of the aircraft cabin, before digitalization and interconnection, is referred to as "status quo" in the context of this paper. On the other hand, some airlines are already using digital logbooks [17]. According to [17] it was found that significant cost savings by elimination of mistakes and by automation can be achieved. Cabin defects are recorded by the crew in a digital cabin logbook, which transfers the information directly to the aircraft maintenance and engineering system[1]. Despite the advantages of

[1] The phrase "aircraft maintenance and engineering system" broadly refers to a maintenance information system, examples of which include AMOS [18] and TRAX [19]

a digital logbook as described in [17], there is still a limitation: no status information of cabin and systems and networks is integrated into AHM and a direct connection between the digital cabin logbook and the aircraft manufacturer's AHM is missing. Because of that limitation the airline's maintenance control can only react to existing cabin defects, precluding the prospect of maintenance prognostics to forecast defects [1].

Due to the fact that the entries in the digital cabin logbook are recorded by humans, the qualitative reliability of this information may potentially be questionable. An implementation of prognostics and the derivation of measures to optimize maintenance scheduling should be based on the most reliable information available. Potentially limited reliability of the human-generated logbook information can be optimized by combining human-generated cabin logbook information with cabin system status information, which this paper proposes in support of providing cabin health indication.

5. Model-Based Approach

This section describes the customized model-based approach. To generate the basis for the suggested model-based comparison and to verify that the customized model-based approach fulfills the expectations on the system documentation, the customized approach is also applied to the status quo of the aircraft cabin before digitalization.

Like the model-based approach proposed in [14] and [15], the customized approach also uses structural and behavioral SysML diagrams. The customized approach is divided into static and dynamic analyses as demonstrated in [15]. Static analysis and dynamic analysis are each consisting of different steps, representing structured modelling activities. The customization proposed in this paper is an extension of modelling allocations. SysML allocation matrices are used to allocate requirements to the identified stakeholders and to the identified components and artifacts. The advantages of the customized approach are immediately evident: The allocation of modeled elements is directly displayed, enabling instant visual recognition. This facilitates rapid and efficient visualization of changes as well as enables the process of verifying consistency and completeness. This significantly enhances the stakeholder's ability to assess and refine the model. Figure 1 shows an overview of the customized approach.

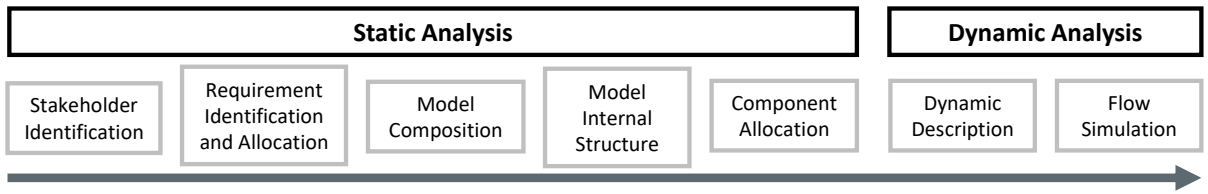

Figure 1 - Overview customized modelling approach

The static analysis is the first section of the approach. It will be the foundation for the second section (dynamic analysis) and aims to generate a structured documentation of the system. Consistent modelling of the relevant systems allows their intersections and detailed intricacies to be identified and documented. Before setting up a model and identifying the requirements, it is a best practice to identify stakeholders and stakeholder concerns first. It is also a recommended practice to continuously involve stakeholders and their needs into the development process [20]. By following the customized approach, these practices are applied and in addition to that a coherence of interest is captured by allocating the identified stakeholders and requirements in a matrix. While the composition is a depiction of all relevant components and functions, the definition of the internal structure portraits the system's inner architecture including information about interfaces, data and functionality. The last step of the static part of the approach is the allocation of the components, systems and sub-systems towards the defined requirements. This generated assignment between the requirements and the modelled elements is supporting the check of consistency: for every requirement there must be at least one allocated system, sub-system, component or function.

The dynamic analysis aims to visualize and understand the behavior. It consists of the dynamic description and an optional flow simulation. The optional simulation allows model-based testing and an animation of the behavior.

6. Application of the Approach to the Status Quo

In this chapter, the contribution of the generated basis for the suggested model-based comparison is demonstrated. A total of 7 SysML diagrams were developed by following the customized model-based approach. Figure 2 shows a package diagram containing all top-level diagrams which were modeled by applying the approach, providing an overview of the complete model structure.

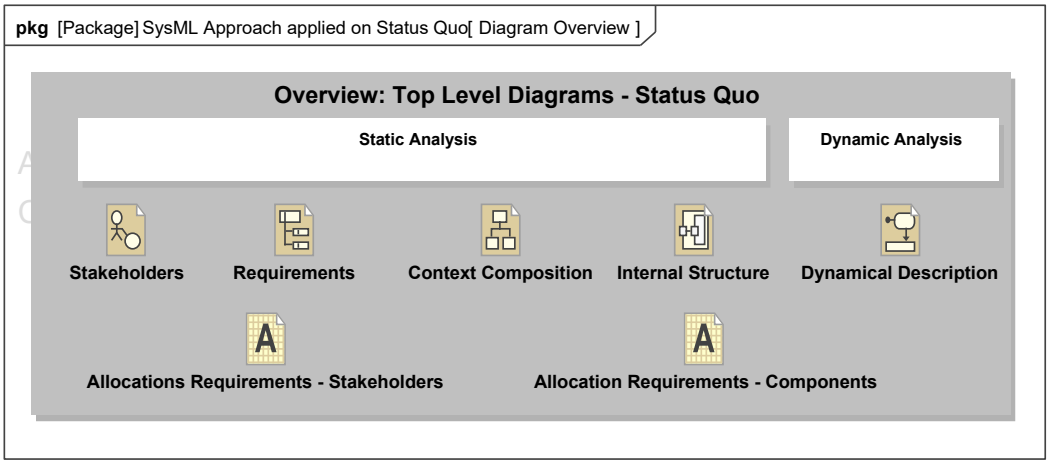

Figure 2 - SysML package diagram showing an overview of top level diagrams of the modelled status quo of the aircraft cabin before digitalization and interconnection

By following the model-based approach the first structured modelling activity is to identify the stakeholders. The top-level SysML use-case diagram in Figure 3 illustrates all relevant stakeholders: “Supplier”, “MRO”, “Airline Maintenance Control” and “Cabin Crew” which are associated to the primary use-case “Ensure availability, accessibility and serviceability of aircraft cabin”. For safe operation, the airline has to implement processes to ensure the availability, accessibility and serviceability of the aircraft cabin.

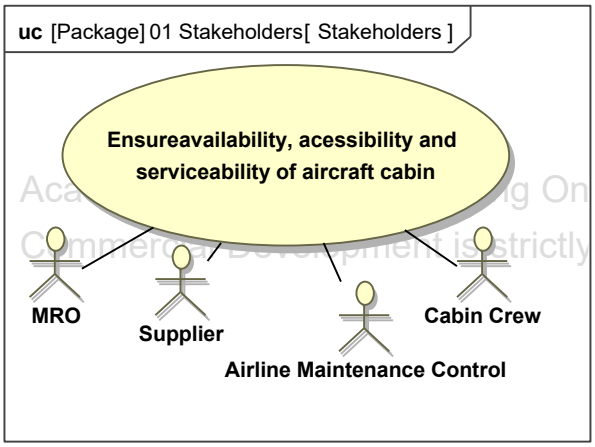

Figure 3 - SysML use-case diagram visualizing stakeholders and primary use-case

As part of the next modelling activity, the requirement identification and allocation, a SysML requirement diagram is generated. In Figure 4 the primary use-case of the previously modelled use-case diagram has been placed in the top right corner. This paper focuses on the “Record and control cabin defects” aspect, which is one of the aspects required to fulfill the top-level use-case “Ensure availability, accessibility and serviceability of aircraft cabin”.

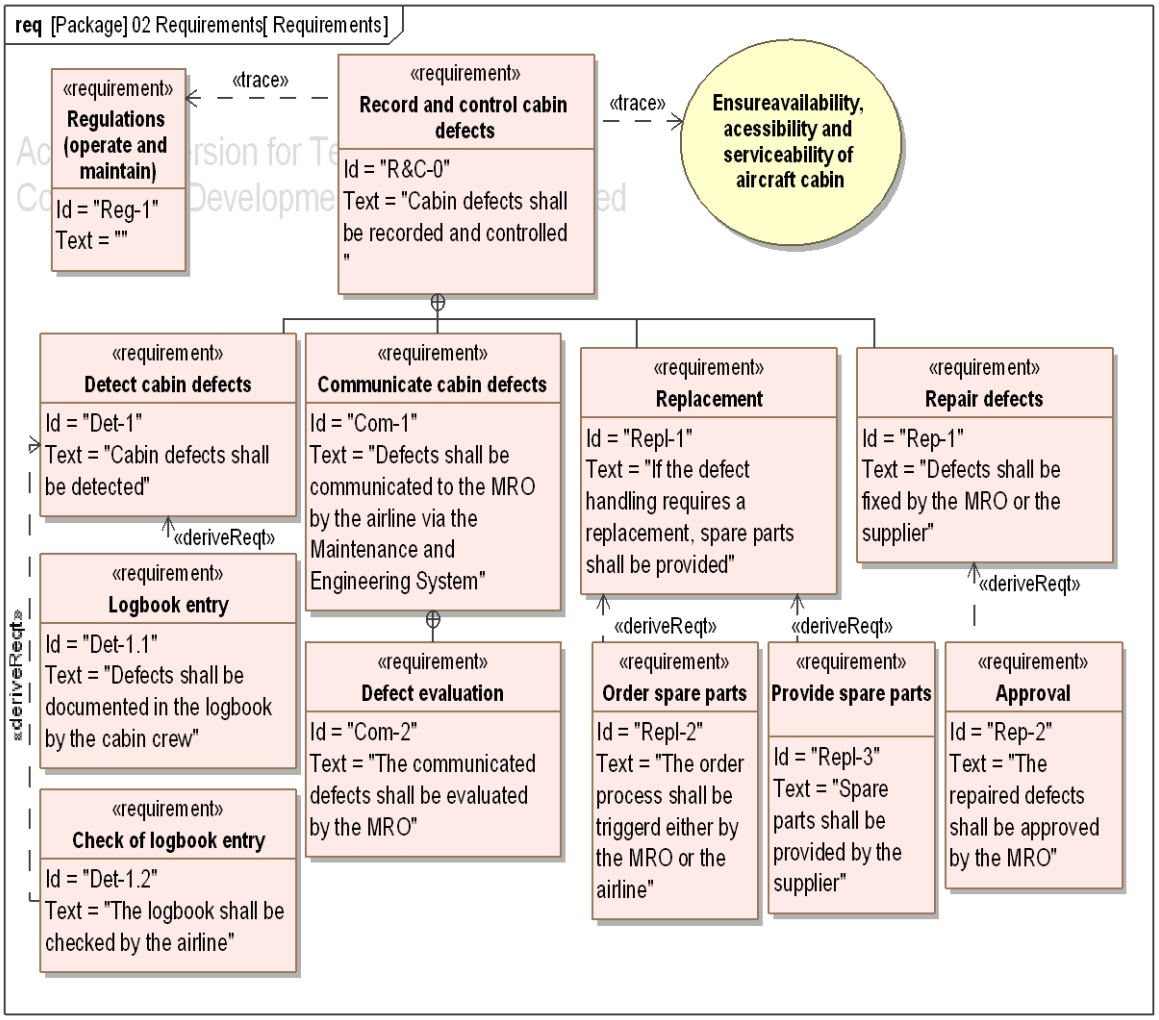

Figure 4 - SysML requirements diagram showing the requirements of the status quo of the aircraft cabin before digitalization and interconnection

Within the airline's management for maintenance operations, compliance with applicable regulations is ensured [21]. The regulations are organized in a dedicated requirement diagram und are represented in the shown SysML diagram by a single requirements element. The relationship between the superior requirement ("Record and control cabin defects") and the regulations, located in the upper left, is expressed in the SysML diagram by a trace relationship. Subordinated requirements are modelled under the superior requirement and are assigned to it through a containment dependency. These requirements regard "Detect cabin defects", "Communicate cabin defects", "Replacement" and "Repair defects". As further step the requirements are allocated to the stakeholders by generating a matrix. Through this modelling activity the allocations of the requirements and stakeholders are directly displayed, enabling instant visual recognition. Figure 5 displays the allocation matrix.

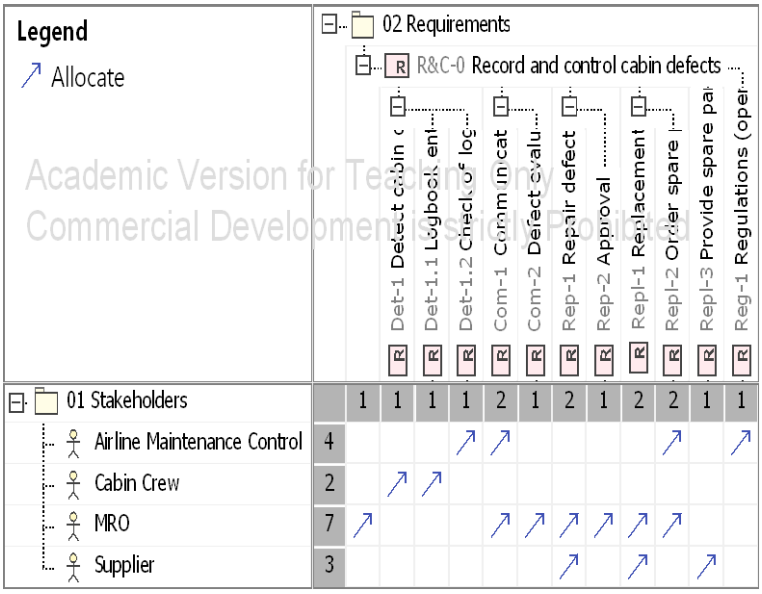

Figure 5 - Matrix showing the stakeholders, allocated to the requirements

Following the model based approach, the next activity is to collect relevant elements and visualize the context composition by modelling a SysML block definition diagram. Figure 6 displays the context composition of the status quo's systems elements. In the diagram, a system context element for the status quo is modelled in the upper left corner, containing different parts and properties. Relevant elements are assigned to the system context by an aggregation dependency and broader specified by part properties and classifier behaviors. Further, these elements are the basis for the internal structure, while the properties of the block "Information and Data Status Quo" are later being utilized to specify connections of the internal structure.

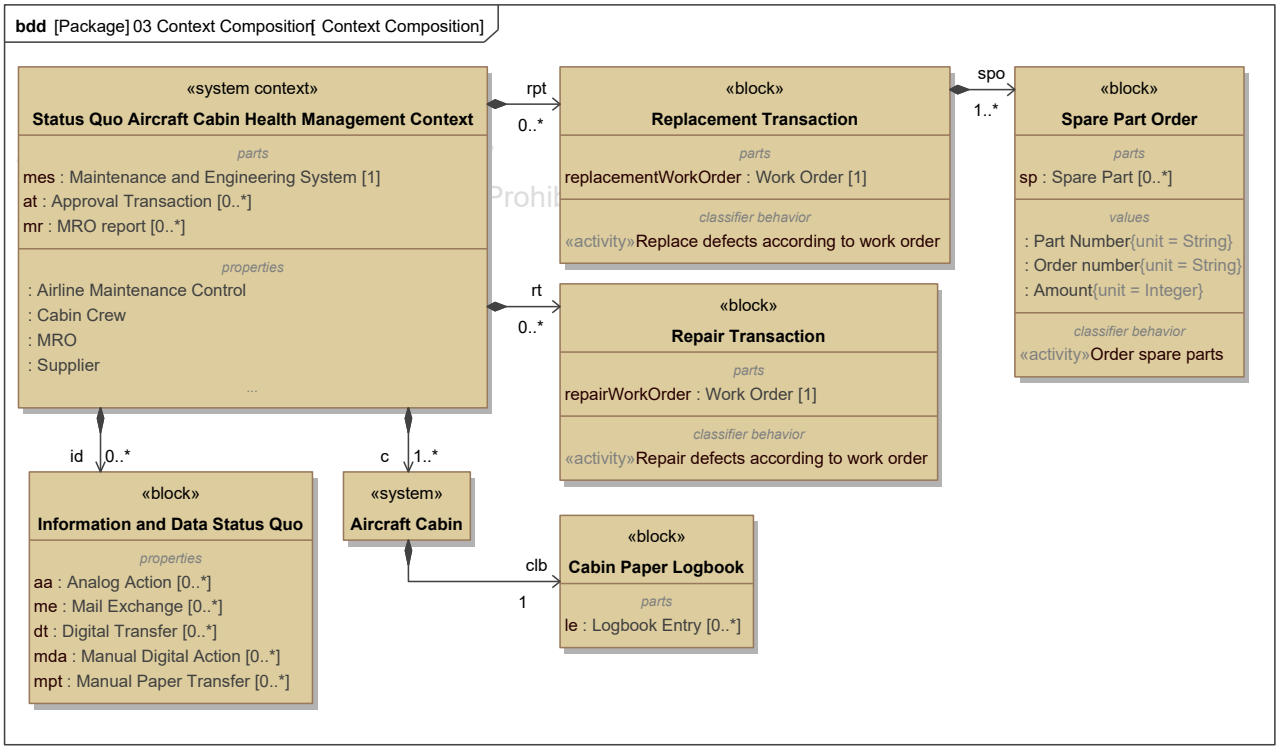

Figure 6 - SysML block definition diagram showing the system context composition of the status quo

The next step of the modelling approach is to define the internal structure. This is accomplished by defining a SysML internal block diagram shown in Figure 7, containing the relevant elements from the context composition. This diagram was developed in collaboration with the project partners and features the "Maintenance and Engineering System" as a central element. It specifically delineates the non-digitalized front end, characterized by the use of cabin paper logbooks as the current status quo outlined in this paper, as well as the digitalized back end. In the aircraft cabin, the "Cabin Paper

Logbook" is modeled as a part property, where defects are recorded by the "Cabin Crew" through a "Manual Paper Transfer". These entries are then manually integrated into the "Maintenance and Engineering System" by scanning the logbook, a process facilitated by the "Analog Action" connector depicted in the diagram. While the manual and personnel-dependent structure of the front end is susceptible to errors, the back end, on the other hand, demonstrates a higher degree of reliability because work orders and spare part requests are digitally transmitted to the "MRO" and "Supplier". However, issues persist at the back end; findings from this research indicate that despite the digital capabilities, opaque "Mail Exchange" among stakeholders compromises the reliability, primarily due to non-uniform event formats and limited access to data from cabin systems and components, such as component-specific fault codes.

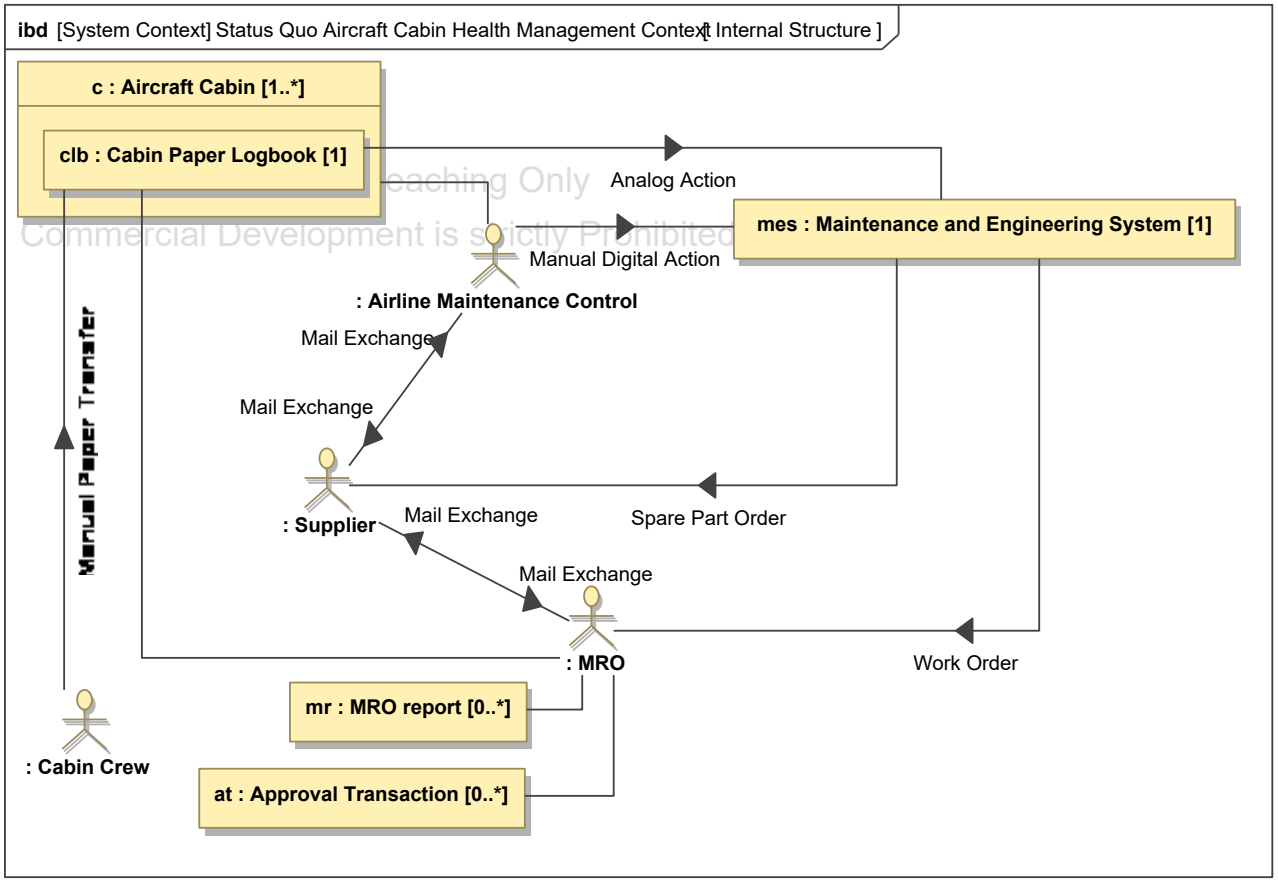

Figure 7 - SysML internal block diagram showing the internal structure of the status quo

Due to the potentially error-prone structure, it can be deduced that digitalization-enabled measures will lead to improvements. Further validation of this claim can be obtained through behavior modeling. Prior to modeling behavior, a consistency check of the static approach section is conducted: elements of the structure are aligned with previously defined requirements. This consistency check is facilitated by generating a matrix and mapping the systems, components, and requirements. As Figure 8 shows, all requirements are allocated to at least one system or component. When new requirements are added to the model, the matrix must be updated.

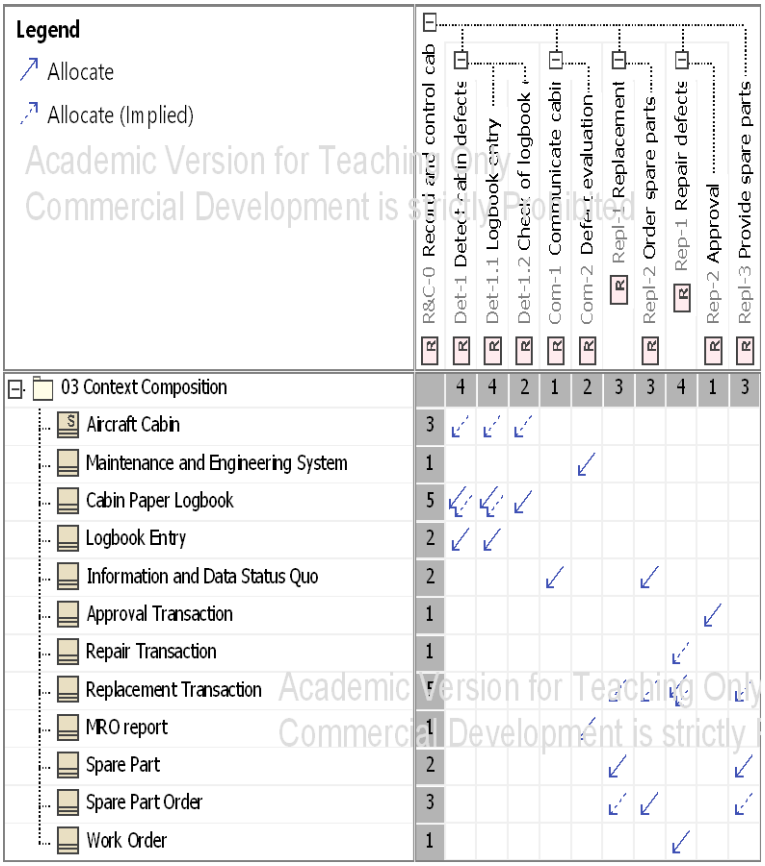

Figure 8 - Matrix showing requirements allocated to components and systems

After the consistency check has been conducted, the second section of the approach and next modelling activity follows. Figure 9 illustrates the behavior of the status quo using a SysML activity diagram. Different activities are modelled and displayed in lanes allocated to the actors introduced in the use-case diagram shown in Figure 3. The internal block diagram presented in Figure 7 illustrates that the actors involved are stakeholders rather than systems. This distinction is critical as it contributes to the problem previously discussed: the reliance on error-prone, paper-based work processes. The traditional paper-based logbook lacks data consistency as it exclusively contains manually entered data, which is inherently unstructured from a data analytics perspective. Such unstructured data significantly complicates accessibility for subsequent use, as well as analysis, thereby impeding opportunities for predictive maintenance. Further, no effective aircraft cabin health management can be implemented. By leveraging the potential of digitalization and interconnection, these problems can be addressed. A solution which will allow to achieve digital aircraft cabin health management is provided in the next section.

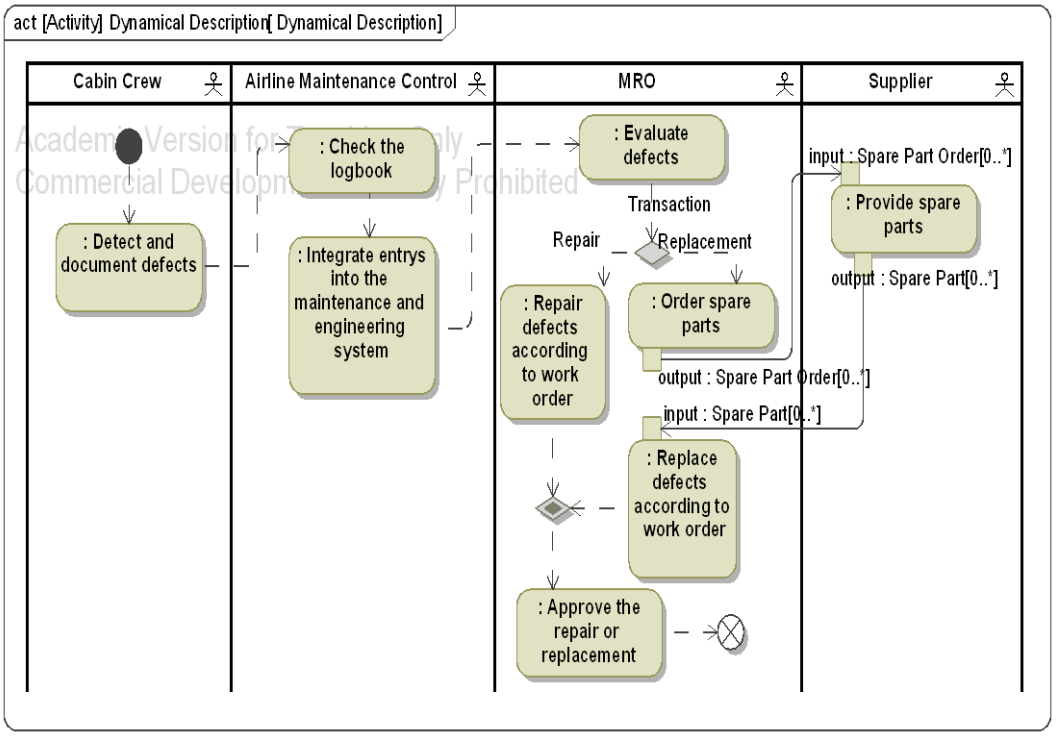

Figure 9 - SysML activity diagram showing the dynamical description of the status quo

7. Application of the Approach in the Development of Aircraft Cabin Health Management

The structured model-based approach is now applied to the digitized aircraft cabin, demonstrating prospects: a cabin system status information will enhance tools for aircraft scheduling and maintenance control and thereby improve reliability. A total of 10 SysML diagrams were developed by following the customized model-based approach. Additionally, the applicability and benefits of model-based development for aircraft cabin system are demonstrated. This section also presents the resulting diagrams from applying the model-based approach in the context of aircraft cabin health management. As a first step, the stakeholder analysis of the status quo, as depicted in Figure 3, was expanded. Therefore, higher level groups are defined and the use-case name was augmented by “digitalization” to reflect the new focus and purpose. Figure 10 shows the groups “Airline”, “Maintenance Organisation”, “Supplier Actors” and “Supporting Actors” which are associated to the use-case. Further subordinated stakeholders are modelled in more detail in a block definition diagram, shown in Figure 11. To represent actors belonging to a group, directed composition relationships were employed.

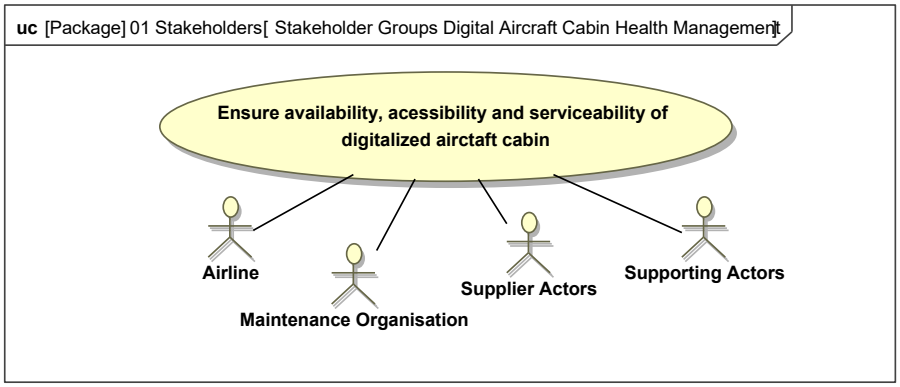

Figure 10 – SysML use-case diagram showing the primary use-case and the stakeholder groups

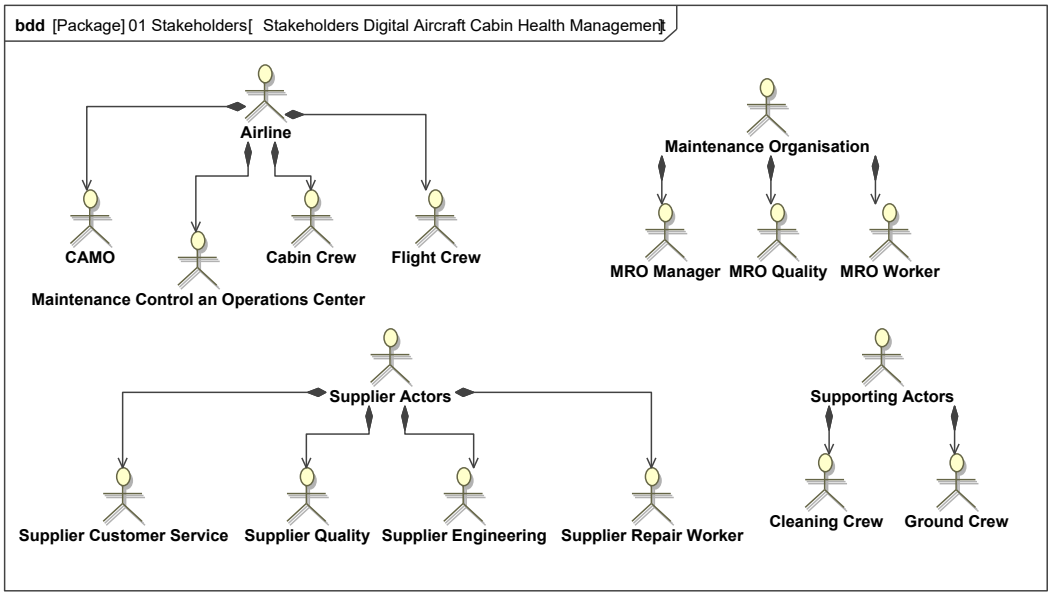

Figure 11 – SysML block definition diagram showing the stakeholders and the stakeholder groups

The model also contains subordinated use-cases as “Generate system health status“, “Visualize cabin system and component health status in cabin”, “Integrate cabin system and component health status on ground” and “Interconnect cabin systems and components”. The use-cases are modelled in a separate diagram and are presented in Figure 12.

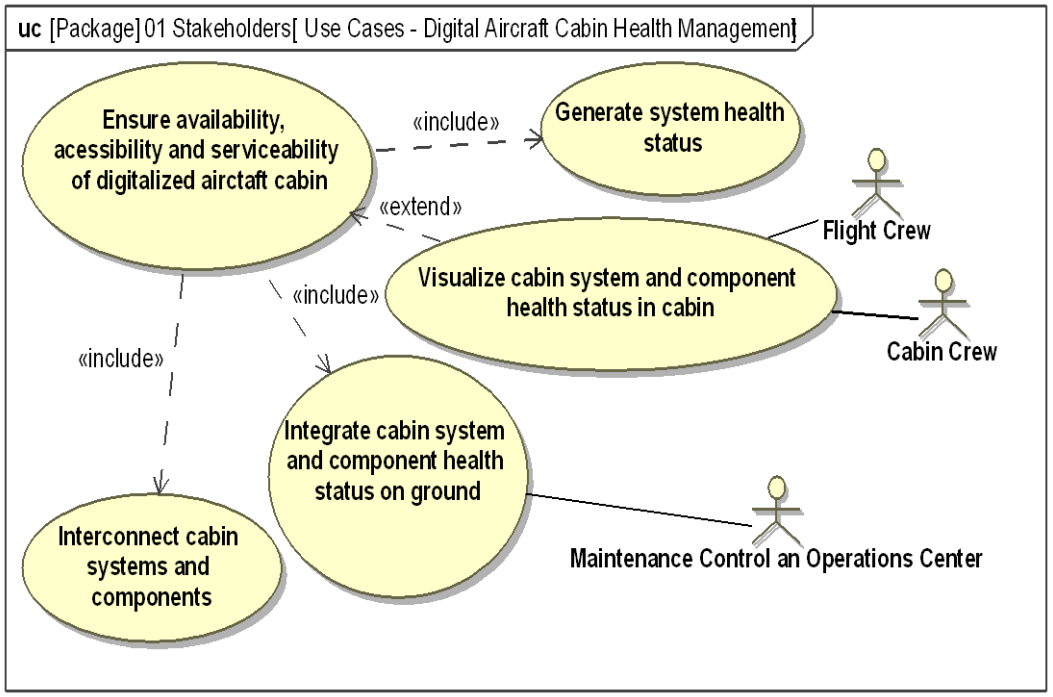

Figure 12 – SysML use-case diagram: subordinated use-cases

After revising the stakeholder analysis, the requirement identification and allocation is carried out. The requirements of the status quo have been reviewed and adapted in the context of digitalization and are presented in Figure 13. The requirements containing the top-level requirement “Record and control cabin defects digitally” and different subordinated requirements, including ”Detect cabin defects”, “Communicate cabin defects, events and failures”, “Replacement”, “Repair defects” and “Regulations”.

In addition to the adaption of the requirement diagram of the status quo a second SysML requirement was modelled, addressing subordinated requirements of the digital end-to-end process to the top-level requirement. The digital end-to-end process addresses how information is transmitted from the cabin systems and components to the ground via the cabins network. The requirement diagram in

Figure 14 presents these subordinated requirements, containing “Basic requirements digital end-to-end process”, “Extended requirements digital end to end process” and “Format related requirements digital end-to-end process”.

In addressing the limitations of traditional paper-based logbooks highlighted previously, the transition to digital logbooks marks a significant improvement in data handling and analytics. Digital logbooks offer to inherently ensure data consistency and structure. Providing structured data is crucial from a data analytics perspective, as it enhances accessibility and simplifies subsequent use, including opportunities for predictive maintenance.

In both modelled requirement diagrams the defined use-case “Ensure availability, accessibility and serviceability of digitalized aircraft cabin from Figure 10 is placed in the top right corner and traced to the top-level requirement. In order to specify the subordinated requirements from both diagrams in more detail, further requirements are derived. Detailed requirements are derived for all subordinated requirements. Derived requirements for “Extended requirements digital end-to-end process” are not essential and therefore modelled in a separate diagram. Further the “Regulations” Requirements expanded to include security aspects.

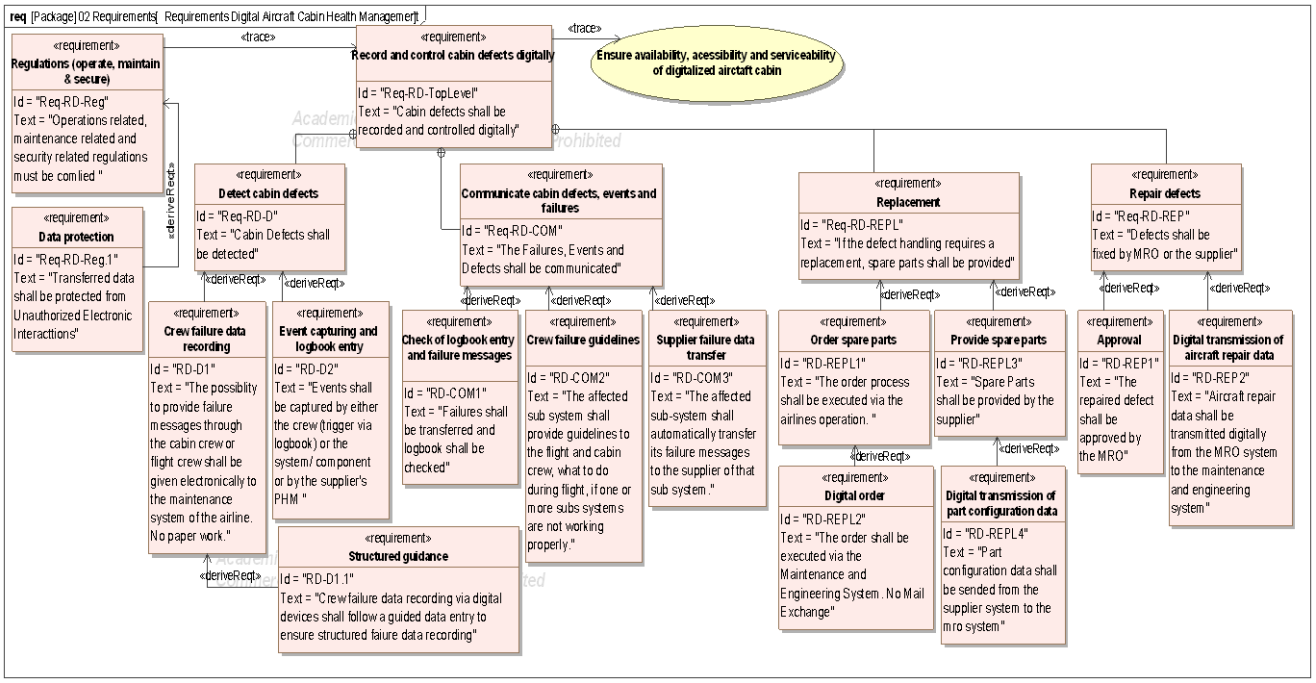

Figure 13 - SysML requirement diagram - requirements of aircraft cabin health management

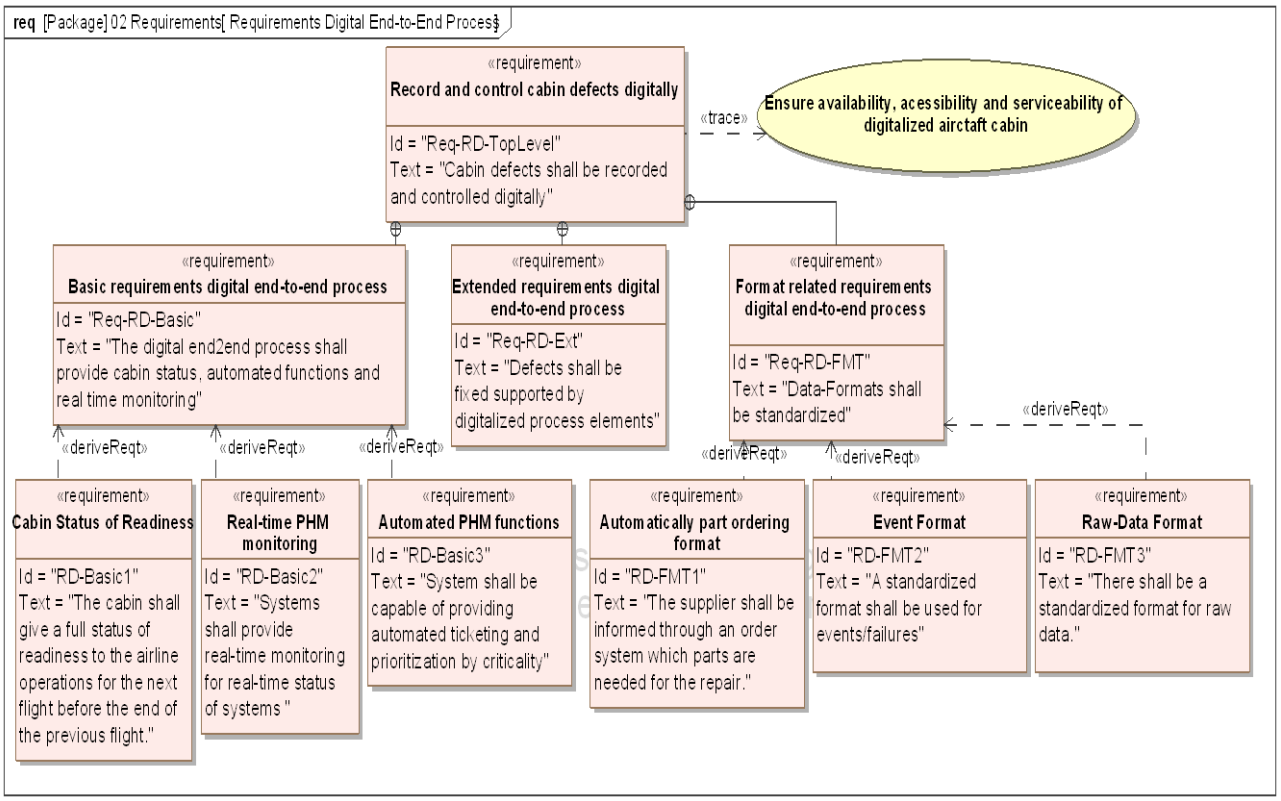

Figure 14 - SysML requirement diagram - requirements of the digital end-to-end process

The assignment of requirements to stakeholder groups and selected subordinated stakeholders is shown in Figure 15. Only stakeholders who have a connection to a requirement are shown in the matrix.

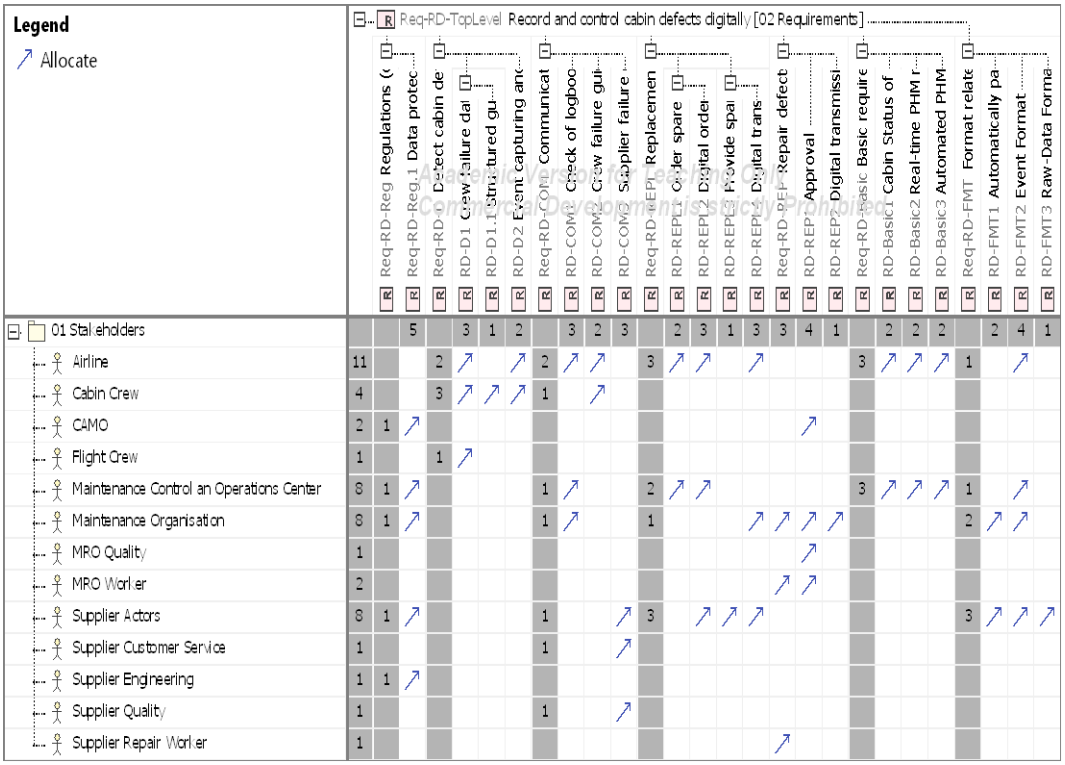

Figure 15 - Matrix allocating requirements and stakeholders

In Figure 16, the context composition for digital aircraft health management is modelled. In the block definition diagram, as already shown in the context composition of the status quo in Figure 6, a system context element is modelled as starting element for the context composition. Aggregated components to the system context are the “Digitalized Aircraft Cabin”, “Supplier System”, “MRO

System" and the "Airline Operation System, including "Aircraft Health Management" and the "Maintenance and Engineering System". These components are specified by modelled part properties and other subordinated blocks. Further there is the "Information and Data Digital Aircraft Health Management" block aggregated to the systems context, containing properties and values concerning data and information. The properties from this data and information element are later being used to specify connections between the part properties of the internal structure. In addition to the specification via part properties, constraints for the elements system status application and remaining useful life (RUL) calculation are modelled and applied value types are assigned to the block elements.

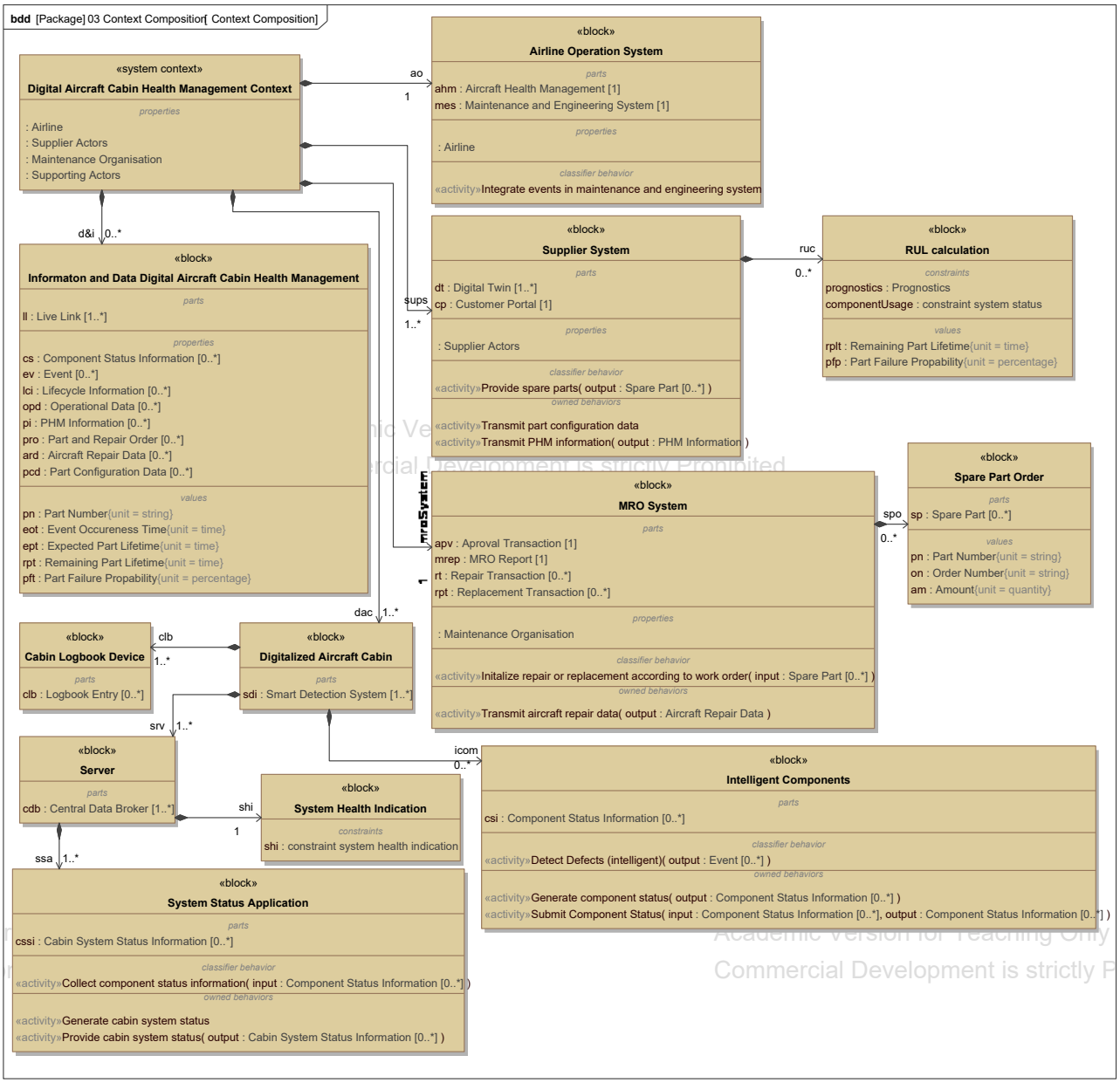

Figure 16 - SysML block definition diagram showing the system context and composition of digital aircraft cabin health management

The elements from the context composition in Figure 16 are being used in the next modelling activity of defining the internal structure and are shown in the internal block diagram in Figure 17. In the context of digitalizing cabin systems and components, and considering the requirements from Figure 13 and Figure 14, an architecture was derived together with the support of the project partners. While in the internal structure of the status quo, interfaces between various stakeholders are characterized by manual people-driven actions, the structure from Figure 17 is designed to reduce the susceptibility to errors by implementing direct connections between the different systems. The connections are further detailed through properties of the "Information and Data Digital Aircraft Health Management"

block in the context composition. For an optimized overview in the diagram, the top level groups of the stakeholders are connected to their respective system. The previously claimed health indication function is addressed in the cabin server and is connected to the “System Status Application”. Via a “Central Data Broker” information from different systems and components in the cabin is collected and transferred via a “Live Link” to the “Airline Operation System”. The airline as top-level stakeholder is connected to the “Airline Operation System” which includes the “Aircraft Health Management” and the “Maintenance and Engineering System”. Connections from the “Airline Operation System” to the supplier system enabling that “Operational Data” is transferred to the supplier to perform a “RUL calculation” and system or component “predictive health management (PHM) Information” from the supplier can be received and integrated. In addition to that, the structure provides a connection for transmitting the “Part and Repair Order” from “Airline Operation System” to the “Supplier System”. The “MRO System” is also connected to the “Supplier System” as well as to the “Airline Operation System” for receiving “Part Configuration Data” and addressing repair related data.

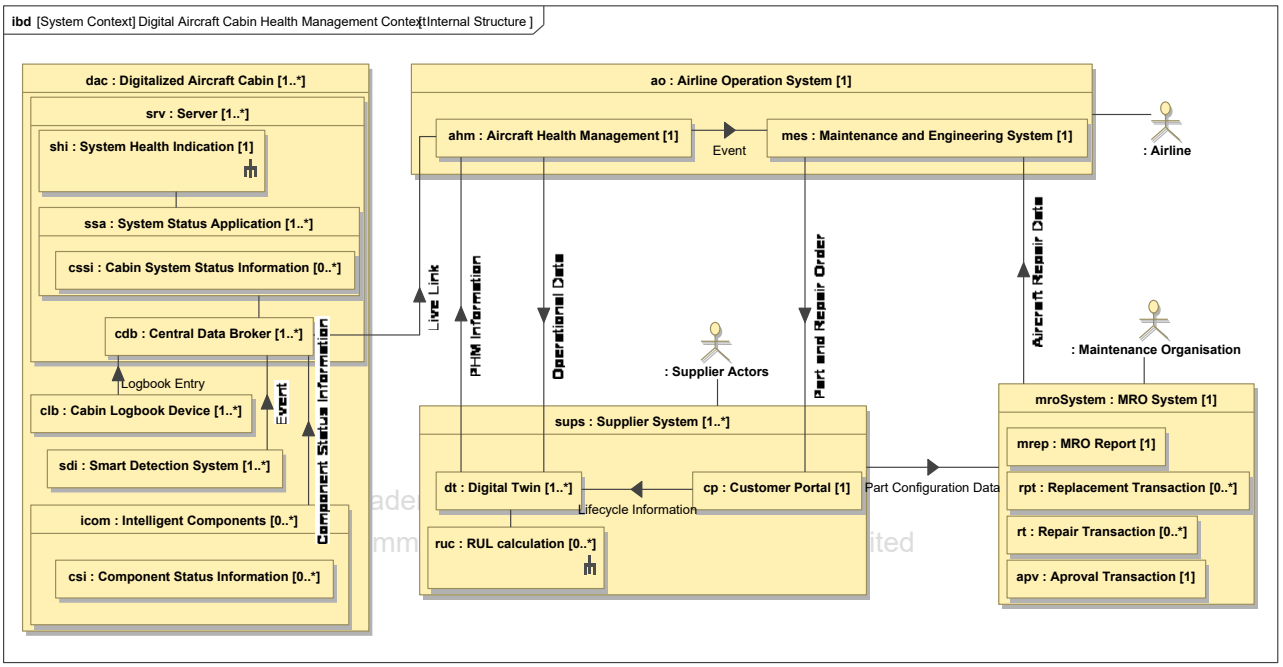

Figure 17 - SysML internal block diagram internal structure - digital aircraft cabin health management

The structured approach will deliver proof completeness between the defined requirements from Figure 13, Figure 14 and the structural elements, using an allocation matrix . The matrix allocating aircraft cabin health management requirements to components and systems, is shown in Figure 18. At least one system or component is assigned to each requirements, proving consistency.

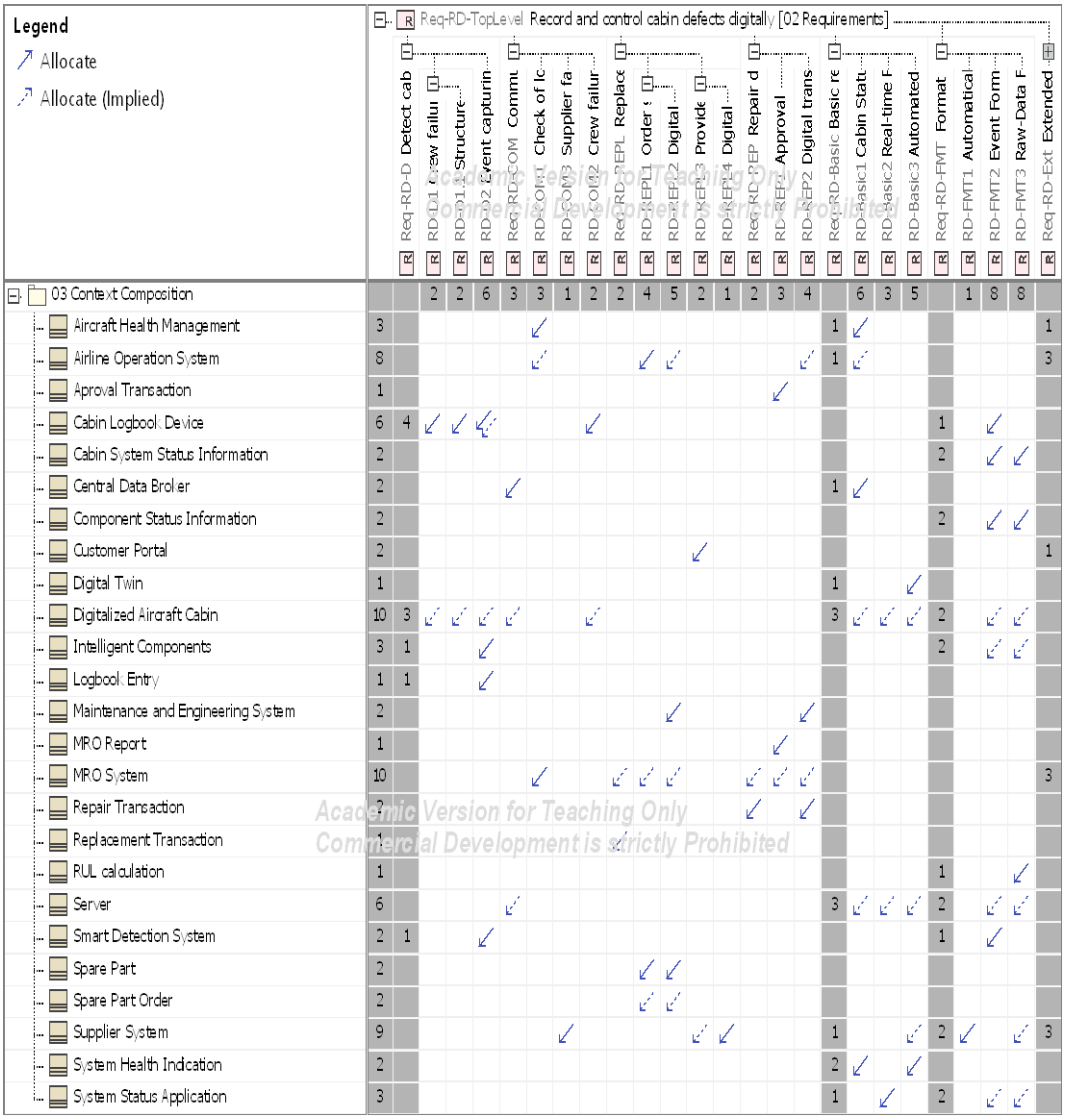

Figure 18 - Matrix allocating requirements, compontents and systems

Additionally, to the structural diagrams, the application of the dynamical section of the structured model-based approach on digital aircraft cabin health management visualizes the expansion and improvements. The SysML activity diagram in Figure 19 demonstrates the behavior. Since the actions are predominantly performed by systems or components, the people-driven actions are reduced, hence fulfilling the objective and envisioned goal of reducing potentially error-prone manual processes to enhance reliability and performance.

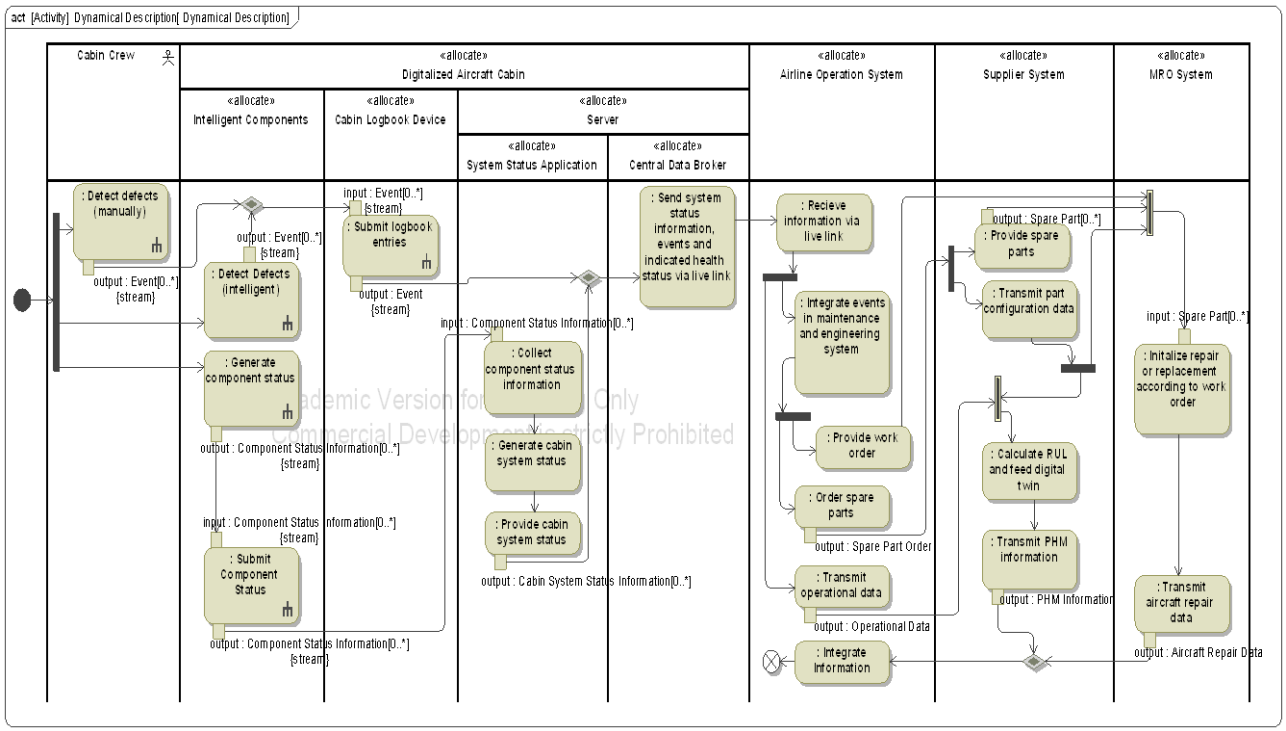

Figure 19: SysML activity diagram dynamical description of digital aircraft cabin health management

8. Comparison

When analyzing the status quo of the aircraft cabin on the basis of the SysML model created in the context of this paper, it becomes apparent that the non-digitalized structure and manual processes are potentially error-prone due to procedural, people-driven actions. This is in line with findings reported in [17]. Therefore, an effective implementation of digital aircraft cabin health management solely using existing systems is nearly unachievable. Comparing the system model of the status quo with the system model of the digital aircraft cabin health management, the following key differences can be summarized: The expansion by several stakeholders and a set of requirements for a wider, derived system context. Within this wider context, the examined use-case “Ensure availability, accessibility and serviceability of digitalized aircraft cabin” and new subordinated use-cases can be implemented and weaknesses of the status quo use-case can be effectively addressed. Technological innovations, such as data analytics and artificial intelligence, which are central to the i+sCabin2.0 research project, are enabled to be integrated into the aircraft cabin by the architecture of the digital aircraft cabin health management system.

9. Conclusion

By applying the proposed customized model-based systems engineering approach to the status quo of the aircraft cabin, a basis for the model-based comparison has been established. The application of SysML supports the i+sCabin2.0 project team to get a precise understanding of the current state of the aircraft cabin and the potentials enabled by digitalization and interconnection. The SysML model, developed as part of this work, enables visualization of the current processes for capturing cabin defects and identifies the stakeholders, systems, and components involved in the repair and replacement processes. Additionally, it illustrates how technological innovations and digital development methods – such as data analytics, artificial intelligence, and model-based development approaches – are applied within the project to capitalize on the opportunities presented by digitalization and interconnectivity. These prospects have been successfully verified in this paper by also applying the customized model-based approach to the new proposed architecture and processes of a digital aircraft cabin health management system. The benefits of model-based development include a unanimous understanding and uniform documentation across stakeholders, enhanced reusability of the model for different system variants, and a systematic approach to the development and comparison of digital aircraft cabin systems.

Adhering to the customized model-based systems engineering approach ensures the creation of comprehensive model-based documentation. The SysML model, which encompasses both structural and behavioral diagrams, plays a facilitating role in enhancing the collaborative efforts of the project partners to develop health management solutions for aircraft cabin systems. In summary, the results emphasize the efficacy of implementing MBSE within the cyber-physical systems context of a digitized aircraft cabin.

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Contact Author Email Address

hechelmann.a@dhbw-ravensburg.de

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