

INTERDISCIPLINARY DOCTORAL SCHOOL

Faculty of Electrical Engineering and Computer Science

Cristian VIZITIU

**System-level approaches to the life-cycle stages of
integrated and/or connected solutions in the field of
human performance**

SUMMARY

Scientific supervisor

Prof.Dr. Sorin Aurel MORARU

BRAȘOV, 2026

Topic of the thesis and the field(s) / discipline(s) in which it integrates

In the context of increasingly complex socio-technical environments, from space exploration to healthcare, disaster management and industrial automation, the ability to design, develop and implement efficient systems is closely linked to our ability to understand, model and manage complexity itself. The rapid evolution of technological ecosystems, coupled with the growing interdependence between human operators and intelligent systems, has fundamentally reshaped engineering challenges. Addressing these challenges requires more than the development of individual technologies, i.e. it requires the establishment of systemic approaches that integrate interdisciplinary knowledge, ensure functional interoperability and place human performance at the heart of system design.

The motivation behind this research is rooted in the pressing need to create architectures that support decision-making, adaptability, and resilience in environments where human performance is critical to mission success. Whether it's spaceflight operations, the provision of healthcare, or emergency response, human capabilities increasingly need to interact with advanced digital systems, including artificial intelligence (AI), the Internet of Things (IoT), digital twins (DTs), and automation processes, so that technology assists and enables the optimize human decision-making, without replacing it. These complex environments require engineering methodologies that can anticipate emerging behaviors, support continuous adaptation, and guarantee safety and reliability under uncertain conditions. Traditional design approaches are often insufficient when faced with such multifaceted requirements, highlighting the need to embrace Model-Based Engineering (MBE) and concurrent engineering as central paradigms for managing complexity in the 21st century.

From the point of view of the connection between the approached scientific pillars, the thesis proposes a coherent integration between the perspectives offered by complexity theory, the principles of concurrent engineering and the MBE paradigm, in the context of complex socio-technical systems. The studies and systems of interest analyzed in this paper integrate components from fields such as IoT, artificial intelligence, telemedicine and human factors, requiring an extensive interdisciplinary approach. In this framework, architectural modeling is used as a tool for structuring, correlating and integrating system components and interactions, facilitating the definition, development and evolution of complex systems, as well as the management of their complexity. While MBE aims at the integrated approach of digital and human ecosystems, Model-Based Systems Engineering (MBSE), as an integral part of this paradigm, offers specific methodologies and tools, used in a complementary way in particular for the description and architectural analysis of systems.

This perspective is deeply influenced by the professional experience of the author of this doctoral work, who built his career at the intersection of research and development, engineering and design of complex systems based on space technologies. As head of the

laboratory/research team for space applications dedicated to health and security, belonging to the Institute of Space Science, Magurele, his concerns focused on the application of space technologies in practical applications for both space and ground use cases. His contributions include the design of telemedicine platforms, the development of Human Spaceflight Countermeasures (HSCs), the creation of assistive technologies, and participation in terrestrial analogues that simulate the physiological and psychological adversities of short- and long-duration space missions. In parallel, its involvement in AI-based Unmanned Aerial Systems (UAS) for search and rescue, as well as nuclear preparedness and response tools, underlines an ongoing commitment to promoting human safety and performance in high-risk, data-intensive environments and machine learning algorithms. This specific blend of research and practical expertise provides a solid foundation for understanding how complex systems can be designed to support human-centered goals.

The motivation to define systemic approaches is also determined by the evolving nature of the challenges faced by these areas. The convergence of space technologies, health systems and digital engineering tools requires frameworks capable of uniting traditionally isolated disciplines. By integrating MBE, concurrent engineering, and emerging technologies such as Digital Twins, along with generative AI and adaptive automation, it becomes possible to design systems that not only reflect the complexity and dynamics of their operational environments, but continuously adapt and improve in response to conditions changing. This continuous adaptation ensures that solutions evolve in parallel with mission requirements, technological progress and human factors. As a result, such systems can support the continuous improvement of human performance, from physiological monitoring and cognitive assessment to mission planning and real-time decision-making, while remaining consistently aligned with human needs throughout their entire lifecycle.

In addition, the growing reliance on data-driven insights and real-time adaptability means that systems must be designed not as static solutions, but as dynamic ecosystems capable of learning, predicting, and responding to changing conditions. A systems approach ensures that the development of technology does not take place in isolation, but is guided by a holistic understanding of human-system-environment interaction. This mindset is essential not only for advancing the frontiers of space exploration, but also for addressing complex terrestrial challenges such as healthcare resilience, disaster response, and critical infrastructure protection.

Ultimately, the motivation for this doctoral work lies in the recognition that human performance is the central pillar of success in complex missions and systems. Enabling this performance, whether by improving cognitive ability, improving physiological resilience, or increasing decision-making, requires seamless integration of engineering principles, human factors science, and emerging digital technologies.

The systemic approaches proposed and explored during this research represent a step towards this integration. They provide a structured, scalable and adaptable foundation for

engineering solutions that not only support human beings in complex environments, but actively optimize them to excel.

Purpose of the thesis

The thesis is built on a coherent logical thread, which progressively integrates the theoretical foundations with the original scientific contributions. Thus, the research approach starts from the definition of complexity and perspectives associated with complex systems, addressing both general concepts from complexity theory and particularizations in the fields of interest of the thesis.

In the first part of the paper, the theoretical and methodological foundations of complex systems theory are analyzed, adding detailed descriptions of statistical and machine learning algorithms and methods, as well as the complexity:

1. IoT assistive technologies used in working with users with cognitive impairments; astronaut applications and protection systems;
2. emerging technologies, including digital twin ecosystems with human factors, as well as engineering facilities competing with adaptive automation

In the second part of the thesis, in continuation of the theoretical framework, the original scientific contributions are developed, following a pyramidal structure, presented in Figure 1. These include conducting a systematic review of the literature, which highlights the benefits of concurrent engineering and MBE approaches, defining an advanced hybrid methodology, Design SynMeth, and validating it through a case study applied to the rapid development of prototypes for complex systems and IoT assistive technologies.

Contributions are continued by defining, developing and validating a proof-of-concept system for evaluating reaction time in a pilot, as well as by applying model-based engineering principles in defining architectures for emerging technologies in digital and human ecosystems. These are concretely illustrated by the development of a complex digital twin for sweat physiology and by defining a concurrent engineering facility with adaptive automation.

Thus, a direct correlation between the theoretical foundations and the original contributions is highlighted, the doctoral student having specific contributions throughout the research, through the analysis of the literature and the subsequent development of the methodological and applicative components.

The scientific contributions in systemic approaches to the life cycle stages of integrated and/or connected solutions in the field of human performance concern 5 (five) studies on five levels of pyramidal development according to Figure 1.

This paper explores the pyramid approach, the development of complex systems in the early stages of the life cycle and up to advanced phases of technology integration and validation, based on the use of architectural modeling in the design process. The paper presents five studies, each with a strategic role in building an integrated vision on the use of

these methodologies in areas from mobile health (mHealth) to Digital Twins and adaptive automation.

Study 1 according to level 1 of the pyramid view is presented in Figure 1: The foundation characterized by the in-depth systematic analysis of the literature on modeling in the early development of the life cycle of complex systems. At the basis of this approach is a systematic review (SR) study on the use of modelling in the early stages of the life cycle of complex systems. This study reviews the literature to identify optimal methods and practices, highlighting emerging challenges and trends. The theoretical foundation offered by this level supports further studies by consolidating a solid methodological basis. The process of searching and selecting scientific articles was extremely rigorous using a number of methods and databases, such as IEEE Xplore, NLM, Scopus and WoS, resulting in 81 relevant scientific articles to investigate, including a bibliometric analysis.

Study 1 proposes Objective 1, namely:

Objective 1: To develop a comprehensive systematic investigation with a bibliometric review to examine the usability and effectiveness of Model-Based Systems Engineering (MBSE) and concurrent engineering in managing and improving system design factors in complex systems in various fields, including space, healthcare, as well as Active Assisted Living (AAL) and smart environments. Study 1 aims to explore how MBSE and concurrent engineering can address the challenges inherent in defining and developing complex systems, focusing in particular on their impact on critical system design factors such as mission analysis, system architecture, cost, schedule, and risk contingencies.

Study 2 according to level 2 of the pyramid view is presented in Figure 1: Rapid Prototyping Methodology investigating the mapping of the Object-Process Methodology (OPM) and the Systems Modeling Language (SysML) with applicability in the field of IoT mHealth. In continuation of the theoretical foundation, this study proposes a rapid prototyping methodology, which includes a conceptual and operational combination between OPM and SysML. This methodology enables an efficient transition from concepts to formal systems engineering models, facilitating accelerated and adaptable development of complex architectures, especially for IoT systems. Study 2 proposes Objective 2, namely:

Objective 2: To define, structure and validate the Design SynMeth methodology as a new approach for modeling systems in complex socio-technical contexts. The aim is to develop a solution-neutral, model-driven methodology that unifies the strengths of existing approaches (SysML, OPM) into a coherent design framework. The research methodology is to integrate the principles of rapid prototyping with structural changes into the MagicGrid framework, allowing rapid iterations between the problem space and the solution space and allowing stakeholders to validate concepts early in the life cycle. To demonstrate its applicability, the methodology is applied in a case study on the definition and prototyping of

an IoT-based assistive technology for the elderly. In this way, the study combines methodological development with practical validation through a real-world domain.

Study 3 according to level 3 of the pyramid view is presented in Figure 1: Integration and validation of an IoT device for detecting cognitive impairments. This study explores the integration of a physical IoT system intended for detecting cognitive disorders within a modeled architecture. The IoT system has been physically developed and tested, demonstrating its ability to collect and analyze data relevant to monitoring the cognitive status of the elderly. The validation of the system was carried out through a data collection pilot, confirming the applicability of the system in the health field and providing a platform for further clinical trials. Study 3 proposes Objective 3, namely:

Objective 3: is to design, develop and validate an IoT-based Choice Reaction Time (CRT) device designed to improve the early detection and stratification of cognitive impairment in the elderly. Based on evidence of sensorimotor deceleration with age and the established diagnostic value of CRT in Mild Cognitive Impairment (MCI), the study addresses a major gap in the relevant literature by introducing a portable, connected and integrated system for cognitive assessment. The CRT device combines reaction time and accuracy measurements with demographic data and machine learning models to differentiate cognitive groups and predict preclinical dementia, providing a scalable solution for clinical practice and telemedicine contexts. The methodology consisted of data collection through specific questionnaires and CRT device used by human subjects, and data processing was carried out by statistical methods, and automatic learning classifiers (Machine Learning – ML).

Study 4 according to level 4 of the pyramid view is presented in Figure 1: Defining and modeling the architecture of a Digital Twin for the human sweating process. This study introduces the concept of the Digital Twin applied to the process of human sweating in specific contexts, such as pathological conditions or critical professions. A virtual model is being developed that allows the analysis of the physiological mechanisms involved in regulating sweating, optimizing cooling strategies and adapting to extreme environments, providing a useful framework for future research in the field of human health and performance.

Study 5 according to level 5 of the pyramid view is presented in Figure 1: Defining and modeling a competing design/engineering platform by integrating adaptive automation within complex systems. At the top of the proposed pyramid approach, the platform is designed to support the collaborative design process, reducing development times and improving the integration of complex systems, by using real-time modeling, simulation and optimization methodologies, with a focus on reuse and scalability. Studies 4 and 5 propose Objective 4, namely:

Objective 4: is to design and implement a comprehensive framework for emerging technologies in intelligent systems design and digital modelling, integrating two

complementary components (i.e., Studies 4 and 5). The first component (i.e., Study 4) focuses on the development and application of digital twins for the assessment and optimization of human performance through advanced simulation of physiological mechanisms, such as sweating dynamics and their role in performance and stress adaptation. This approach aims to define a robust Digital Twin architecture capable of supporting real-time data integration, predictive modeling, and adaptive decision-making. The second component (i.e., Study 5) focuses on Concurrent Design Facility (CDF) and adaptive automation, exploring their ability to enable parallel, multidisciplinary engineering workflows and improve the design of complex intelligent systems. Together, these components sought to establish a scalable and intelligent design paradigm that combines physical simulation, human performance modeling, and automation in a collaborative manner to address current and future space, health, and industrial challenges. The common methodology used in the achievement of objective 4 was model-based architectural modeling in close correlation with the integration of advanced ML and physiology concepts for study 4 and adaptive automation for study 5.

Throughout the thesis, the author's contributions are progressively integrated, starting from the literature analysis and leading to methodological developments and concrete applications, thus ensuring the coherence between the theoretical foundations and the original results.

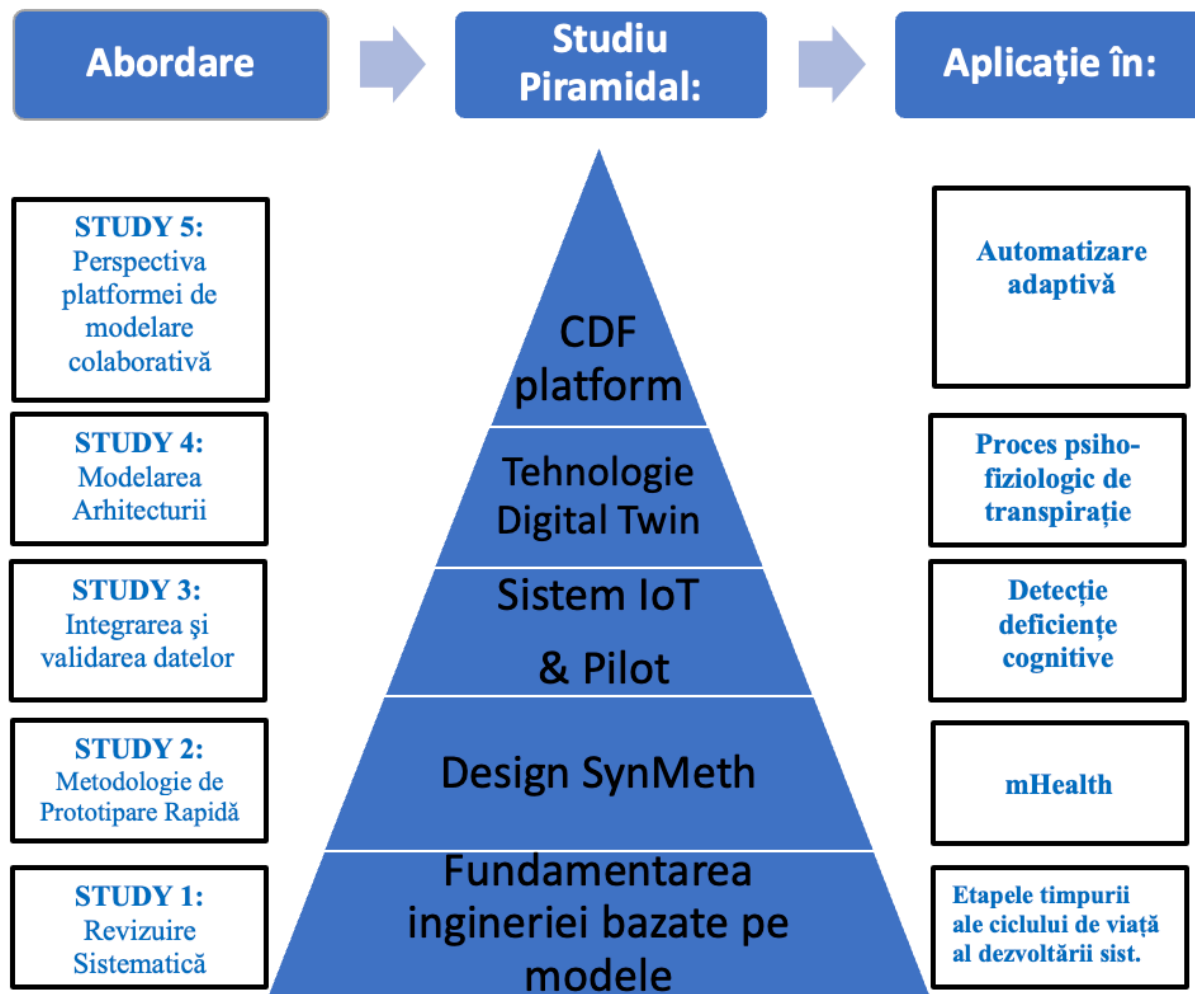


Figure1. Pyramidal view of the studies included in the doctoral thesis.
Analysis on three levels: type of approach, study per se; field of applicability.

This pyramidal approach in Figure 1 provides a structured and progressive framework for the development of complex systems, advancing from a theoretical foundation to concrete applications in mHealth, IoT, virtual twins and adaptive automation. By combining modeling, integration and validation methodologies, this paper demonstrates the importance of a sequential construction of knowledge, in which each stage strengthens the understanding and applicability of the previous levels. Thus, the proposed pyramid architecture not only facilitates a logical development of systems, but also creates a technological ecosystem capable of supporting innovation and the integration of advanced solutions in various practical applications.

The connection between the chapters of the thesis, the objectives of the research and the already published scientific works of the author, is summarized as follows:

Chapters 1–4, which theoretically substantiate the objectives of the thesis (Objective1–Objective5), are mainly based on the analysis of the literature, being partially supported by the author's contributions, made both as first author and co-author, within the doctoral program (Vizitiu, Stara et al., 2024; Vizitiu, Turcin et al., 2024; Vizitiu, Dominey et al., 2025; Vizitiu, Turcin et al., 2025; Vizitiu, Dinculescu et al., 2025), as well as relevant works

prior to the doctoral program, including the book published at Springer (Vizitiu, 2019) and related articles (Vizitiu et al., 2021; Marziali et al., 2024).

Chapter 5 addresses Objectives 1 and 2 by developing methodological contributions. Subchapter 5.1 capitalizes on and expands on the results presented in (Vizitiu, Dinculescu et al., 2025), representing the basis of the systematic analysis and methodological substantiation specified in Objective 1. Next, the chapter develops the Design SynMeth hybrid methodology and validates it through a case study, in correlation with the results of (Vizitiu, Dominey et al., 2025), in accordance with Objective 2.

Chapter 6 corresponds to Objective 3 and presents the definition, development and validation in a pilot study of a proof-of-concept system for cognitive assessment, capitalizing on and extending the contributions of (Vizitiu, Stara et al., 2024).

Chapter 7 addresses Goals 4 and 5 by defining architectures for emerging technologies. Subchapter 7.1 develops the architecture of a digital twin system for the physiology of sweating, based on the work (Vizitiu, Turcin et al., 2024) according to Objective 4, and subchapter 7.2 defines a concurrent engineering facility with adaptive automation, extending the results of (Vizitiu, Turcin et al., 2025) according to Objective 5.

Note: In the context of the high complexity of the systems analyzed, documentation-based approaches become difficult to use and scale. In this respect, model orientation provides a clearer and more coherent way to describe and understand the concepts and systems themselves, while allowing the reuse of the components and solutions developed. Thus, in this work, the approach adopted is an MBE one, complemented by the use of MBSE for architectural modeling, in order to define, develop and integrate complex systems in the field of human performance.

Structure (chapters) of the thesis

The thesis is structured in a coherent way, following a succession of chapters that reflect both the theoretical and methodological foundations of the research, as well as the results and scientific contributions obtained. The paper begins with the Introduction, which presents the research motivation defined by the need for systemic approaches in the analysis and optimization of complex systems in support of human performance, as well as the multidisciplinary and integrative vision of the five studies developed, which constitute a direct response to the four major objectives of the thesis.

The theoretical investigation and documentation part of the literature is the basis of the conceptual construction of the work and is reflected in chapters 2–4, which scientifically substantiate the experimental studies and original contributions.

Thus, Chapter 2 presents conceptual aspects regarding complex systems and their life cycle, providing the theoretical framework necessary for understanding the interdependencies between the components of these systems, implicitly the theoretical basis for the entire context of the thesis, and especially for Study 1.

Chapter 3 includes an extensive analysis of quantitative analysis methods and algorithms, both on the statistical and ML components, highlighting their relevance for applied studies.

Chapter 4 defines the context of applicability of the research, focused on human performance in two main areas: the first of monitoring and assisting human performance on the ground, through telemedicine, assistive technologies, and the plan of extreme environments, through HSC, and the second area of analysis of emerging technologies, such as Digital Twin and adaptive automation, in the context of evaluating and optimizing human performance. Thus, the first field represents the theoretical basis for Studies 2 and 3, and the second field represents the theoretical basis for Studies 4 and 5.

The applicative part of the thesis, which includes the original contributions, is detailed in chapters 5–7. Thus, Chapter 5 with Subchapter 5.1. presents Study 1, which includes the analysis and methodological demonstration of a systems design framework applied to complex systems; Chapter 5 continues with Study 2, by defining a hybrid SynMeth Design methodology, with a demonstrative case study.

Chapter 6 describes Study 3, focused on the definition and development of a CRT IoT system, implemented in a pilot study, with data analysis through statistical and machine learning methods.

Chapter 7 contains Study 4 through subchapter 7.1, oriented towards the concept of Digital Twin for the simulation of physiological sweating, including research and architectural definition; respectively Study 5 through subchapter 7.2, focused on concurrent design and adaptive automation in complex design environments.

Chapter 8 presents the general conclusions of the thesis, demonstrating how the five main objectives were successfully achieved. The chapter also includes future development perspectives and a synthesis of scientific results, highlighting the author's contributions through published papers, participation in national and international conferences, as well as involvement in RDI projects and obtaining scientific grants.

The paper concludes with an extensive section of bibliographic references, written according to the Harvard style, which support both the analysis of the literature and the arguments from his own studies, followed by appendices that include additional details on the methodological and technical aspects of the contributions presented.

Research methodology

Objective 1 was successfully achieved through the design, execution and systematic synthesis of study 1. By applying a structured methodology based on evidence-based research and bibliometric analysis, the study was able to map the contributions of MBE and concurrent engineering in the early development of the system. The approach has been rigorous with clear evidence supporting the potential of integrating MBE and concurrent engineering in increasing efficiency in complex projects.

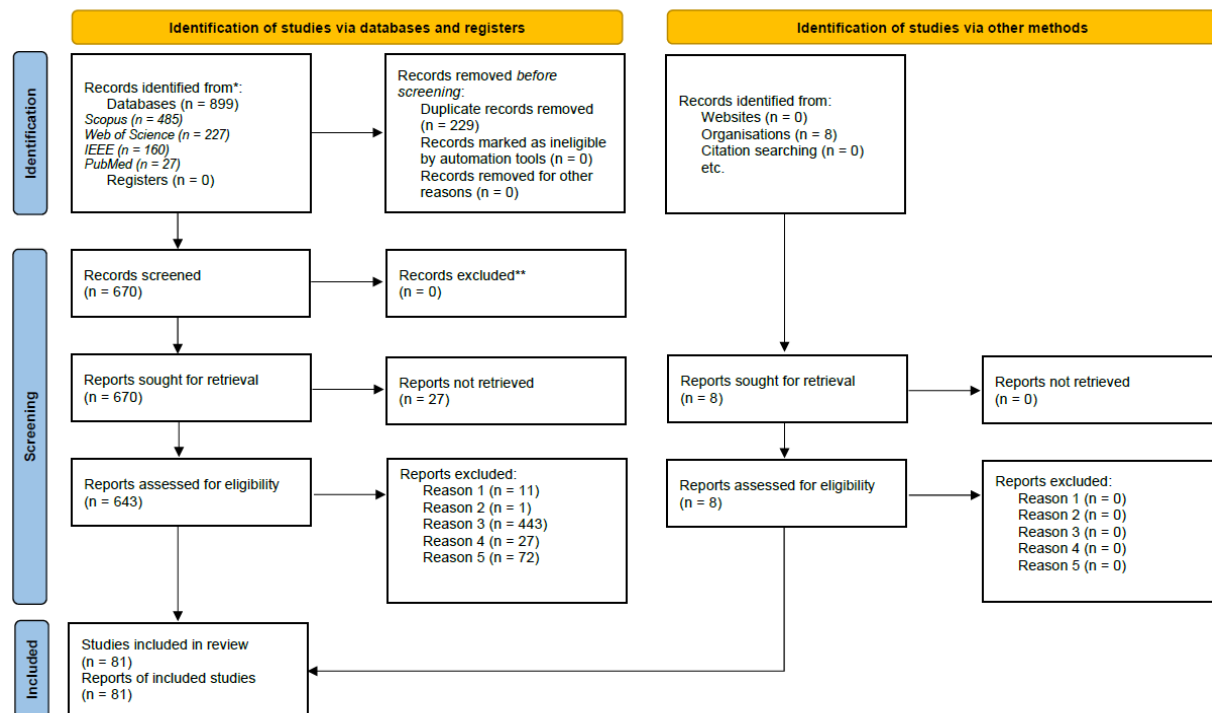
The structure of this investigation, with the purpose of substantiating MBSE and concurrent engineering in the development of complex systems, is illustrated by a diagram based on the OPM methodology, according to the ISO 19450 standard, presented in Figure 2:

Figure 2. The methodological architecture of the systematic review study.

In detail, Objective 1 was achieved through the following aspects:

The study was structured around the PICO method, targeting the early stages of the development of a complex system (Phase 0/A) and focusing on design factors such as architecture definition, risk, cost and collaboration. This ensured a precise and delineated research direction, highlighting the integration and impact of MBE and concurrent engineering in practice.

Extensive searches were conducted in IEEE, Scopus, Web of Science, and PubMed, followed by blind screening in Rayyan and the application of quality assessment rubrics. From an initially large dataset, only high-quality, methodologically sound studies were preserved, producing an evidence base that underlined the rigorous applications of MBE and concurrent engineering, rather than speculative claims.



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

Source: Page MJ, et al. BMJ 2021;372:n71. doi: 10.1136/bmj.n71.

This work is licensed under CC BY 4.0. To view a copy of this license, visit <https://creativecommons.org/licenses/by/4.0/>

Figure 3. PRISMA diagram for the study selection process.

Source: (Vizitiu, Dinculescu et al., 2025).

- Data extraction and analytical mapping;

For each selected paper, data were extracted on methodology, scope, reported benefits, tool support and technological readiness. In parallel, the bibliometric analysis with VOSviewer mapped the co-occurrence of keywords and thematic clusters. This process not only revealed the distribution of MBE applications and competing engineering in sectors such as aerospace, healthcare, smart environments, but also exposed emerging research trends (e.g., digital twins, systems of systems) and confirmed recurring benefits such as faster development-integration-verification-validation-operationalization cycles, stronger stakeholder alignment, and improved traceability of requirements.

Analysis of the co-existence of terms:

The co-occurrence analysis was performed from the . RIS to create keyword maps based on bibliographic data, using the full counting method. At the beginning of the analysis, 322 keywords appeared, when the frequency was set to 1. The keywords were analyzed so that repetitions caused by syntax did not occur. Thus, a synonym file containing 31 replacement lines was created. After this step, 292 keywords remained on the list: 7 keywords met the 5-occurrence threshold, 13 keywords met the 4-occurrence threshold, 19 keywords met the 3-occurrence threshold, and 49 keywords met the 2-occurrence threshold. The co-occurrence analysis was performed on 49 keywords that met the occurrence threshold of 2 and resulted in 6 clusters of 5 to 10 keywords, as can be seen in Figure 4.

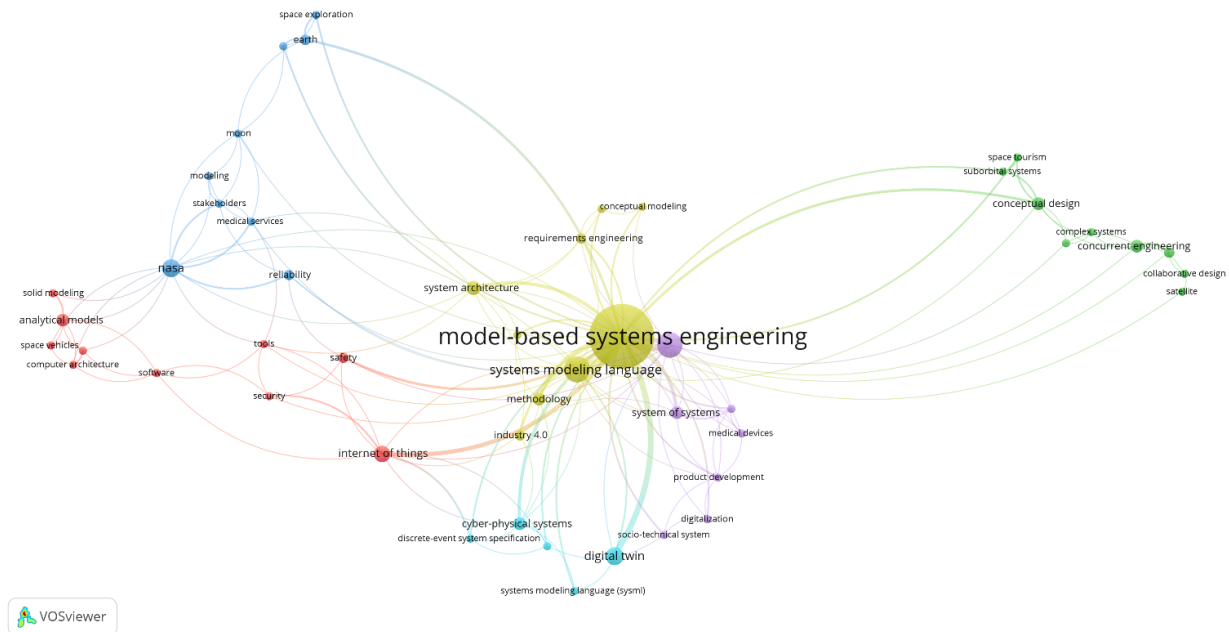


Figure 4. Keyword network view.

Source: (Vizitiu, Dinculescu et al., 2025).

- Consolidated synthesis and findings;

The evidence and bibliometric results have been synthesized in relation to the design factors initially defined. Model-based engineering and concurrent engineering were compared with sequential approaches, and their combined value was systematically evaluated. The synthesis confirmed that the integration of MBE and concurrent engineering provides a complementary framework that accelerates early-stage design processes, improves collaboration and communication, improves the clarity of the system architecture, and reduces risks and uncertainties, thus fulfilling the objective of the study. The clusters formed are defined as follows:

Cluster 1 – Analytical models: focuses on the use of analytical models, modeling methods (e.g., UML) and software tools to improve the stability and security of complex systems (e.g., IoT, spacecraft).

Cluster 2 – Collaborative design of complex systems: highlights the role of concurrent engineering in the simultaneous development of system components; applied aerospace practices reduce development time and improve the process of subsystem integration.

Cluster 3 – Space Exploration and Stakeholder Engagement: addresses systems engineering in space missions, with a focus on system reliability and stakeholder engagement for mission success.

Cluster 4 – Complex Systems Architecture: focuses on MBSE in the development of complex systems, integrating human factors into the design process and ensuring adaptability and scalability.

Cluster 5 – Digitalization of socio-technical systems: analyzes the impact of digitalization in the field of health and the integration of socio-technical systems, emphasizing the balance between technological complexity and social acceptability.

Cluster 6 – Cyber-physical systems: focuses on digital concepts such as Digital Twin, facilitating the simulation of complex interactions between physical and computational processes in order to develop high-performance and resilient systems.

Objective 2 was successfully achieved, study 2 successfully defining and validating the SynMeth Design methodology as an approach based on model-based engineering and rapid prototyping. The application of the proposed methodology in the case of IoT Well-Being confirmed the methodological efficiency, showing that Design SynMeth allows rapid prototyping, maintains consistency between models and provides a structured path to address complex socio-technical systems, from requirements to architecture, while engaging stakeholders effectively.

The achievement of Objective 2 followed a set of structured stages in which the methodological means (Design SynMeth principles) and practical results (implementation of the IoT case study) evolved in parallel.

In traditional development flows, prototyping is done using flexible tools that allow for rapid iterations and experimentation to refine functionality, usability, and user interaction. However, these prototyping tools often do not provide the precision and structure required for a formal system validation. To fully validate the prototype, developers must transfer the design and its functional details into a formal system modeling language, such as SysML, where they can apply rigorous verification and validation processes to ensure that the system complies with all technical requirements and constraints. Therefore, one of the main challenges in integrating prototyping with systems modeling is the need to conduct prototyping as a separate, iterative phase, and then 'translate' the final prototype into a systems modeling language to perform validation.

A major potential disadvantage of this approach of translating prototype updates into the engineering design model is that if the translated model does not pass validation, either due to unmet performance requirements, unforeseen interactions, or security vulnerabilities, the entire process must be repeated. Another challenge of this multi-phase approach is that it disrupts the traceability of requirements and changes. When prototypes are adjusted following user feedback or testing, these changes may not be fully documented in the formal system model, leading to gaps in understanding when returning to the system modeling phase.

Finally, combining prototyping with modeling the system in a fragmented way generates additional workload and inefficiency in the methodology. Each phase must be completed separately, requiring translation, revalidation and possible redesign cycles to ensure that the prototype is aligned with the requirements of the formal model. This lack of integration between system prototyping tools and current MBSE methodologies creates

significant delays and increased complexity in obtaining a validated and production-ready system for IoT developers.

To streamline IoT development, a more coherent approach is needed that allows prototyping and system modeling to be carried out in a unified framework, minimizing transposition steps and supporting the direct validation of iterative prototypes. The methodology proposed in this study, entitled Design SynMeth, implements the unification of prototyping with engineering modeling based on the MagicGrid framework, a framework modified to support the hybrid vision of rapid prototyping with precision engineering. Thus, the MagicGrid framework is modified as follows in Figure 5.

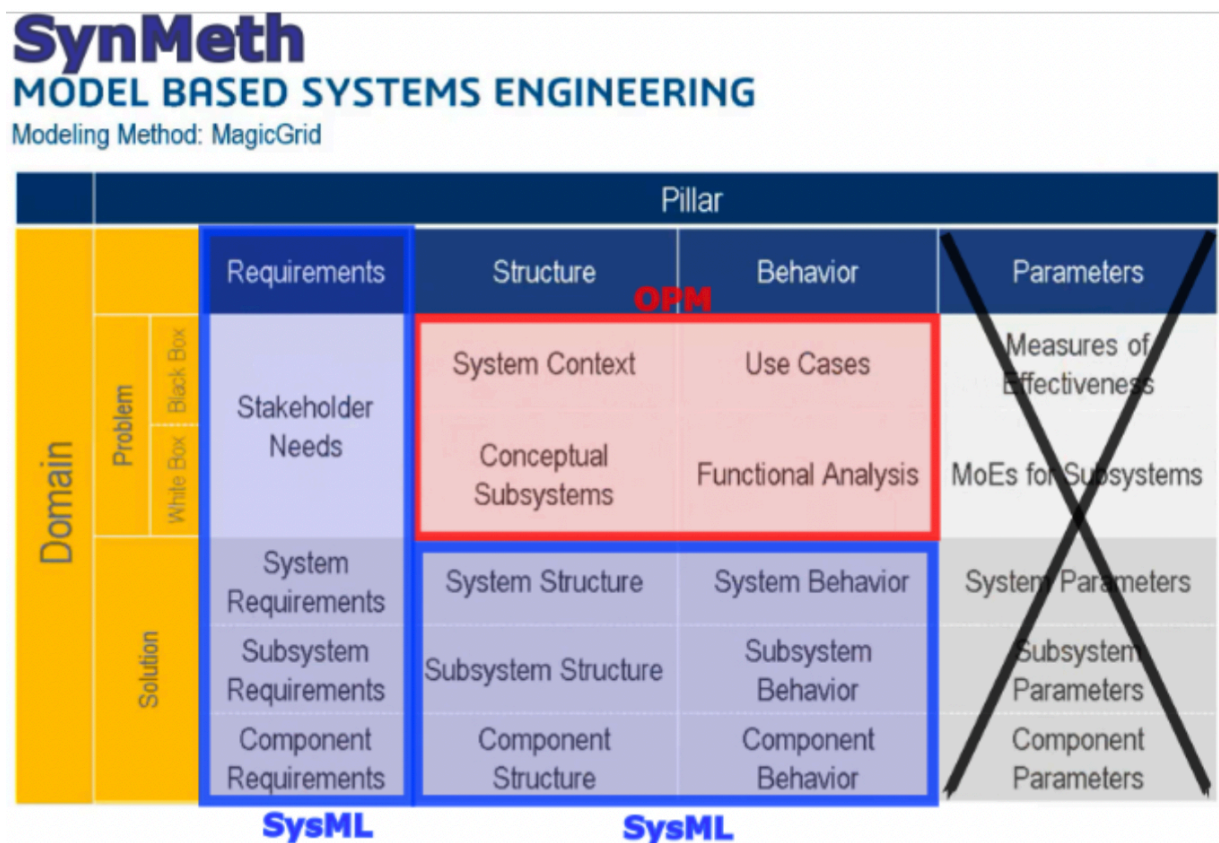


Figure 5. Definition of the Design SynMeth methodology within the modified MagicGrid.

Source: (Vizitiu, Dominey, Nistorescu et al., 2025). Image source on which the work was carried out: (Aleksandravičienė & Morkevičius, 2021).

The proposed methodology, Design SynMeth (Vizitiu, Dominey, Nistorescu et al., 2025), proposes to make structural changes within the framework of the literature, MagicGrid, explained below in detail and visually represented in Figure 35. Each of the four pillars of MagicGrid, which are traditionally expressed in both problem and solution domains, along with the associated SysML diagrams, will be considered within the Design SynMeth framework.

All retained aspects, changes and considerations will be analyzed in the following section:

- i. The MagicGrid Requirements pillar will remain unchanged.

- ii. In the area of the problem, the pillars of structure and behavior are combined to form the rapid prototyping phase, which is the central innovation of the Design SynMeth methodology;
- iii. In the solution domain, Design SynMeth adheres to the original separation of structure and behavior in MagicGrid, using SysML diagrams to accurately represent each aspect. If the problem domain is for architects, the solution domain is for engineers. This is where conceptual design is developed through OPD diagrams, becomes feasible, verifiable and optimized;
- iv. The structure pillar is modeled with block and internal block definition diagrams belonging to SysML, which define the system components, the relationships between them, and the physical configuration. The behavioral pillar is represented by activity diagrams, sequence diagrams and state machine diagrams also belonging to SysML, which capture dynamic interactions, workflows and system states;
- v. The SysML parameter pillar has been removed from both the problem and solution domains to simplify the modeling process. In traditional MBSE applications, SysML parametric diagrams are essential for defining specific constraints and performance metrics, but in IoT development they often only add volume and complexity, slowing down the prototyping process. Moreover, in the case of small IoT devices, these diagrams are often considered excessive.

The methodology consisted of the following steps:

- Formulation of the methodological framework

Define the advanced methodology in the field of MBE, Design SynMeth, by integrating SysML, OPM and MagicGrid into a structured workflow covering requirements collection, decomposition of form components, structural and functional modeling. The result was the development of a coherent modeling methodology capable of representing socio-technical systems beyond the limits of a single modeling language.

- Case study application (IoT mHealth Well-Being Sol)

Application of DesignSynMeth to an IoT-based active assisted living system, integrating CRT and GSR monitoring, as a system of interest. SynMeth Design has been proven to be an agnostic methodology in terms of means of implementation, capable of capturing essential functions and modeling architectures independent of specific technologies.

- Modeling requirements and functions

Applied OPM for conceptual and functional modeling, SysML for requirements and system breakdown, both integrated within MagicGrid. The result created traceable models that link cognitive/physiological requirements to system functions and components, ensuring alignment between needs and solutions.

- Rapid prototyping methodology

Incorporating a rapid prototyping cycle into the methodology, allowing for iterative testing of system concepts, data flows, and user interactions within the model. The result allowed for

early validation of stakeholders, reduced the risk of misaligned requirements and accelerated the transition from abstract models to practical prototypes.

➤ Validation through user and domain feedback

Participatory validation was carried out with seniors and caregivers/guardians, verifying the degree of use and alignment with the objectives of independent living. It has been demonstrated that the proposed methodology, Design SynMeth, stands out for its technical rigor and efficiency in participatory design contexts, contributing to the improvement of communication between engineers and end users.

Objective 3 was successfully achieved, demonstrating the feasibility and effectiveness of an IoT-based CRT system in Study 3.

The main objective of this research was to determine the differences in reaction time and accuracy rate between two categories of participants: (a) na-MCI and SCD; (b) a-MCI-MD and a-MCI, using a device specially designed for this purpose.

The hypotheses and research methodology proposed according to (Vizitiu, Stara et al., 2024) are:

H1. Is there a significant difference in reaction time between the two groups compared?

H2. Is there a significant difference in the accuracy rate between the two groups compared?

H3. Are these differences predictive of a preclinical phase of dementia?

The methodology aims at a pilot study to test the hypotheses. Thirty-five (35) senior adults voluntarily participated in a two-day assessment. Two main approaches were considered simultaneously:

- MMSE (Folstein, Folstein & McHugh, 1975), a neuropsychological test for assessing mild cognitive impairment. The test consists of 30 questions with reference to various cognitive areas: orientation in time and space, memorization of words, attention and calculation, recall, language and constructive praxis. The total score varies between a minimum of 0 and a maximum of 30 points. A score between 26 and 30 indicates a normal cognitive state. The score is adjusted by a coefficient according to age and level of education.

- The proposed CRT test prototype defined and developed within the SAVE project (AAL Programme, 2024), co-funded by the European Commission through the AAL program, within the Institute of Space Sciences-INFLPR Branch, in the team led by Mr. Cristian Vizitiu, the author of this doctoral thesis. The CRT device can be seen in Figure 6.

- **CRT** component;
- communication system component;
- processing system component;
- power supply component.

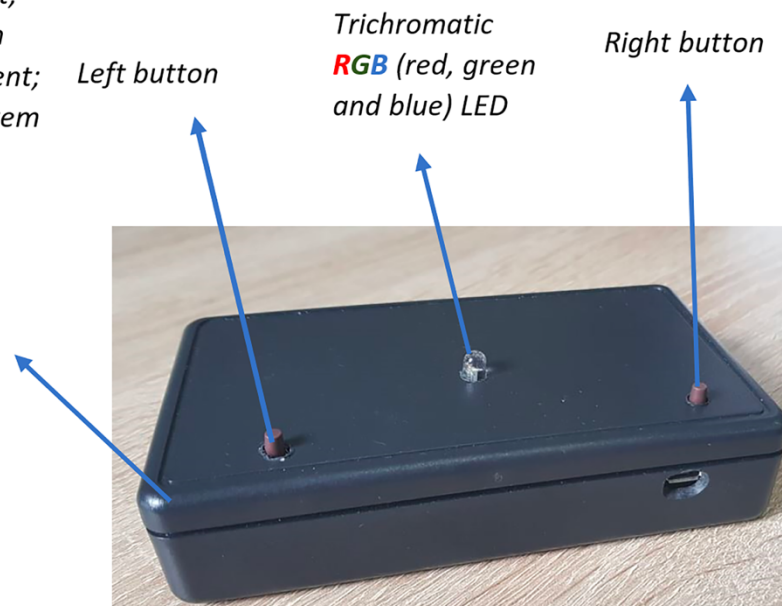


Figure 6. The CRT device.

Source (Vizitiu, Stara et al., 2024).

The parameters that the CRT device extracts from each session of the topic are described below:

- Reaction time: the time elapsed between activating the LED and pressing the button correctly, measured in milliseconds (ms);
- Wrong answers red: the number of rounds in which the subject pressed the right button (R) before the left button (L) in the allotted time after activating LED-R;
- Correct answers red: the number of rounds in which the subject pressed the left button (L) in the allotted time after activating LED-R;
- Wrong answers blue: the number of rounds in which the subject pressed the left button (L) before the right button (R) in the allotted time after activating LED-B;
- Correct answers blue: the number of rounds in which the subject pressed the right button (R) in the allotted time after activating LED-B;
- Wrong answers green: the number of rounds in which the subject pressed the right button (R) before the left button (L) in the allotted time after activating LED-G;
- Correct answers green: the number of rounds in which the subject pressed the left button (L) in the allotted time after activating LED-G;
- Total correct answers: the total number of rounds in which the subject pressed the corresponding button correctly in the allotted time after the LED was activated;
- Total Wrong Answers: The total number of rounds in which the subject pressed the incorrect button before the correct button in the allotted time after the LED was activated.

The sample consisted of 35 participants (11 men and 24 women), aged between 61 and 85 years, the mean age being 73.4 ± 5.4 with standard deviation (SD); most of the elderly

(60%) had secondary education, 20% had primary education, and the remaining 20% had higher education (undergraduate or postgraduate); the average score obtained on the MMSE was 27.7 ± 1.6 SD, and that of attention in MMSE was 4.6 ± 0.5 SD; the participants were divided into two different categories: (a) 17 subjects belonging to the SCD and na-MCI group and (b) 18 subjects belonging to the a-MCI and a-MCI-MD groups, a classification proposed by the psychologists who supervised the study, based on their expertise and clinical experience.

From the point of view of testing the hypotheses according to (Vizitiu, Stara et al., 2024):

➤ For the H1 and H2 hypotheses, a statistical analysis was performed to highlight the statistically significant differences between the two groups of subjects, H1 referring to the reaction time variable, and H2 to the accuracy rate variable. The Pearson correlation coefficient was determined to analyze the relationship between reaction time and MMSE scores, as well as between accuracy rate and MMSE scores. A Mann-Whitney test was performed to compare the accuracy rate and reaction time between the two groups. A significance level of 0.05 was considered a significant level in the statistical analysis.

➤ For the H3 hypothesis, the performance of machine learning classifiers trained for the automatic detection of the two categories of participants was evaluated. The data considered for the development of an automated cognitive diagnostic tool included aspects related to age, gender, education level, MMSE score, MMSE attention score, CRT statistics (number of wrong and correct answers, minimum, maximum and average response time, standard deviation for each light color, respectively red, green, blue) and cognitive diagnosis. The classifiers were developed using MATLAB – Classification Learner Tool and a code for Principal Component Analysis (PCA) adapted from a PCA tutorial taken from the study conducted by GeeksforGeeks (2018).

The key components that led to this achievement are:

- Device design and IoT integration

A portable and lightweight CRT device has been created with RGB LED stimuli, touch buttons, wireless connectivity, and built-in randomization. This allowed for real-time data capture and transmission to the cloud, ensuring continuous monitoring beyond episodic assessments.

- Pilot study and data acquisition:

A two-day pilot study of 35 older adults (61-85 years old) measured reaction times, accuracy, and collected demographic data. The data showed significant differences between cognitive groups, such as longer reaction times to blue light ($p = 0.042$), confirming that the device can effectively discriminate between distinct cognitive groups.

- Statistical validation

Non-parametric tests confirmed inverse correlations between reaction time and cognitive status ($R \approx -0.464$) and significant group differences in accuracy performance ($p = 0.056$), indicating that slower responses and reduced accuracy are associated with more severe cognitive impairment. The significance of $p = 0.042$ suggests that the probability of observing

such differences in reaction time by chance is below 5%, providing strong evidence that CRT load reflects the true cognitive distinctions of the groups.

- Automatic learning and predictive modeling

Using features from CRT and demographic data, classifiers such as SVM, RUSBoosted Trees, and K-Nearest Neighbors (KNN) were trained to predict cognitive categories. Of these, RUSBoosted Trees achieved the highest classification accuracy of 77.1%, demonstrating robust predictive performance in identifying people with preclinical dementia or mild cognitive deficits. RUSBoosted Trees achieved the highest classification accuracy because it effectively managed the small, slightly unbalanced dataset and captured complex, nonlinear relationships between reaction time, accuracy, and demographic characteristics, improving its ability to distinguish subtle cognitive differences.

- Clinical relevance

The study represents a pioneering initiative in integrating CRT assessment into a real IoT-based platform, transforming cognitive screening into a continuous, automated and scalable process. This innovation positions the device as a valuable tool for early detection, continuous monitoring, and personalized cognitive care.

Objective 4 has also been successfully achieved through the integration of two complementary technological directions, each contributing specific activities and results, through the conduct of Study 4 and Study 5 respectively.

Study 4 aimed to simulate human sweating under high-stress conditions by integrating physiological, psychological, and environmental data. The methodology aimed at the architecture of the system is developed through MBSE modeling languages, especially through OPM.

The key components that led to this achievement were:

- Digital twin architecture to optimize human performance

Activities included defining a scalable digital twin architecture, modeling sweating mechanisms, and integrating physiological data to simulate stress responses. The results demonstrated the system's ability to predict abnormal sweat patterns and connect them to cognitive and physical performance indicators, enabling targeted interventions and performance optimization in high-stress professions.

- Digital Twins Conceptual Simulation and Application Framework

The study conceptually designed a digital twin framework aimed at simulating and interpreting physiological dynamics such as sweating, based on validated physical simulation models reported in the literature. Within this theoretical architecture, predictive capabilities were presented to demonstrate how digital twins could integrate environmental, physiological, and psychological data to support health decision-making processes, stress management, and human performance optimization.

Study 5 aimed to gain an in-depth understanding of the organization of international Concurrent Design Facilities (CDFs), but also of the operating principles by defining the general needs, functional requirements in terms of software and hardware tools in accelerating the design process, as well as by approaching the Sol architecture. Thus, the research synthesizes an analysis of the user-specific needs and requirements, as a basic and at the same time a trigger process in defining and modeling a broad system architecture for a specific and unique CDF in South-Eastern Europe.

Using the working standards specific to complex systems engineering, the research captures in advance the needs of space users undertaking interdisciplinary studies (e.g., space medicine, HSC, terrestrial applications using space technologies in order to define and develop applications in the field of human health and safety).

A CDF provides the ideal environment for managing the complexity generated by the simultaneous integration of multiple medical, technological, and operational subsystems, as it allows for real-time collaboration and simultaneous development of system components. Unlike the traditional approach, where subsystems are designed separately and integrated only at the end, which can lead to compatibility issues and additional costs, working in a CDF allows teams to collaborate from the beginning using MBE, quickly resolve potential conflicts, and maintain consistency across medical, engineering, and operational components.

The analysis of the overall needs of the CDF then helps to identify the requirements and prepare a suitable plan for the implementation of the concurrent engineering-based facility. Thus, the general needs of the CDF and their connection with the basic requirements necessary for the realization of such a center are presented.

The definition of a CDF, based on the study of the needs and requirements of the previous subchapters, constitutes a foundation for the development of the system architecture of interest by providing an overview of the complexity of the CDF. Thus, the multi-storey architecture developed according to (Vizitiu, Turcin, Dominey et al., 2025) comprehensively presents the component elements, structural links and interfaces corresponding to the process and the multidisciplinary team in support of the preliminary design and feasibility assessment of the systems and missions of interest. Using MBSE and concurrent engineering, CDF has a substantial role especially in the preliminary phases of the system life cycle of interest, Pre-Phase A (conceptual studies) and Phase A (system definition and feasibility). The development of the CDF system architecture was carried out through the standardized OPM methodology ISO19450, through a dual graphical approach of object-process diagrams (OPD) and Object-Process Language (OPL) text, implemented through OPCAT v4.2, the academic version for modeling complex systems.

➤ Define CDF

A CDF architecture was developed using an MBE approach, integrating multidisciplinary workflows and enabling real-time collaborative design. The results showed significant

reductions in development time, improved traceability of design decisions and increased adaptability of the system, especially in health and safety applications in space missions.

➤ Adaptive automation in the design of complex systems of interest

The integration of artificial intelligence, IoT, and robotic process automation into the CDF enabled autonomous decision-making, rapid iteration, and optimization of engineering processes. This has led to better mission planning, risk assessment and system-level validation, demonstrating strong potential for both aerospace and industrial contexts.

Studies 4 and 5 present an approach that highlights the potential of model-driven digital modelling to guide the development of state-of-the-art intelligent systems and to serve as a fundamental framework for future applied research and real-world implementations.

In the continuation of the detailed analysis of the achievement of the objectives, the correlation between the objectives of the thesis, the studies developed and the published scientific contributions is summarized:

Objective 1 is addressed within the systematic analysis and methodological substantiation of subchapter 5.1, being supported by the results published in (Vizitiu, Dinculescu et al., 2025), which highlight the integration of concurrent engineering and MBE approaches in the development of complex systems.

Objective 2 is achieved by defining and validating the Design SynMeth hybrid methodology, presented in chapter 5, the results being correlated with the case study published in (Vizitiu, Dominey et al., 2025), which demonstrates the applicability of the methodology in the rapid development of prototypes for complex IoT systems.

Objective 3 is dealt with in chapter 6, by defining, developing and validating through pilot study an IoT system for cognitive assessment, being supported by the contributions presented in (Vizitiu, Stara et al., 2024), which highlight both the implementation and validation of the system through statistical analysis and predictive modeling.

Objectives 4 and 5 are addressed in Chapter 7, by defining and modelling architectures for emerging technologies. Subchapter 7.1 develops a digital twin system for sweat physiology, in correlation with the results of (Vizitiu, Turcin et al., 2024), and subchapter 7.2 defines a concurrent engineering facility with adaptive automation, extending the contributions of (Vizitiu, Turcin et al., 2025).

Overall, the objectives of the thesis are achieved through a progressive approach, in which theoretical studies, methodological developments and experimental applications are supported and validated through scientific papers, highlighting the coherence between the research carried out and the results obtained.

Original results, conclusions, contributions to the scientific field and relevance.

The thesis is part of the context of the increased complexity of ICT systems, characterized by multiple interdependencies and an evolutionary dynamic, which go beyond the limits of classical sequential approaches. In this context, complexity is the central issue, which requires the adoption of approaches capable of managing the simultaneity of activities and multidisciplinary integration. Thus, concurrent engineering, based on the simultaneous and coordinated development of activities throughout the life cycle of the system, provides the necessary process framework for the integration of information between disciplines. In this sense, the MBE is used as a methodological framework that supports the development and integration of architectures in a coherent and traceable way, providing the necessary support for managing complexity, and the MBSE being useful in a complementary way, as a portfolio of methodologies and techniques. This holistic integration allows the coherent definition of complex socio-technical systems, including applications in areas such as assistive technologies and IoT telemedicine for people with MCI, digital twins for human physiological processes, competing engineering systems with adaptive automation, highlighting the capacity of the proposed approach to support the design and implementation of human performance solutions. user-centric, scalable, and adaptable.

The general research presented in this paper follows a pyramid development strategy, progressively building from fundamental theoretical analysis to applied modeling, validation and advanced conceptualization of systems. This multi-step approach reflects the complexity of modern engineering processes and the critical role of MBEs and concurrent engineering in enabling them. Starting with Study 1, the research laid the theoretical groundwork through extensive and systematic literature investigation of the current state of technology and highlighting the contributions of MBEs and concurrent engineering in the early phases of the system's life cycle. This step not only demonstrated their potential for efficiency and risk reduction in the development of complex systems, but also served as a conceptual cornerstone for all subsequent studies.

Building on this foundation, Study 2 advanced research from theory to application by developing and validating the Design SynMeth methodology, a new model-based engineering approach to accelerated prototyping. Its successful implementation in the development of an mHealth IoT device validated the methodology's ability to integrate requirements, maintain model consistency, and accelerate design cycles while ensuring stakeholder alignment. This result highlighted the value of the MBE not only as a theoretical framework, but also as a practical enabler for agile, structured and traceable systems engineering processes.

The next steps focused on integration, validation and emerging technology modeling. Study 3 expanded research into applied medical technology, demonstrating the feasibility of detecting IoT-based cognitive impairment through pilot validation, data analysis, and machine learning classification. This study bridged the gap between conceptual system

design and real-world implementation, providing critical evidence of how in-depth MBE development can deliver functional, data-driven health technologies.

Study 4 and Study 5 then expanded the scope into future-oriented system architectures by exploring digital twin modeling for human physiological processes and conceptualizing a collaborative CDF framework for adaptive automation. These studies demonstrated how MBE principles and concurrent engineering can be applied to model complex, adaptive and interconnected systems, enabling advanced simulation, continuous optimization and multidisciplinary co-design in areas such as healthcare, aerospace and industrial automation.

Together, the five studies form a coherent methodological and technological path, from conceptual foundations to prototype validation and complex digital architectures. This pyramidal approach confirms the robustness and adaptability of MBE and concurrent engineering as central paradigms for the engineering of state-of-the-art socio-technical systems, capable of addressing both current challenges and emerging needs in increasingly complex, data-driven and human-centric environments.

Study 1: Conclusions of systemic substantiation

Throughout the literature review, as well as the bibliometric review, a strong point is the fact that the research evidence was selected and evaluated at different stages by several reviewers using updated software developed specifically for this purpose (i.e., rayyan.ai). Regarding the uncertainties and conflicts in these stages, the reviewers established consensus through discussions in the selection phase and data extraction, and less in the field of methodological quality assessment where the scores were mathematically averaged. Another strong point of this study emerged due to the expansion of the findings by the authors through a bibliometric analysis related to the most relevant keywords in the field, as well as an analysis of their interactions and the clusters of relevant authors who published works in the targeted areas discussed above.

The limitations are related to the fact that 27 articles (4.25% of the articles) could not be downloaded. The authors considered 2 articles (a conference paper and a journal paper) as duplicates during the screening phase, determining the text to be very similar and including only one journal paper (Menshenin and Crawley, 2019). One feature that made it difficult to develop the study is the relatively wide range of articles found thanks to database searches conducted without time restrictions and in a wide range of fields.

This SR-type study together with bibliometric analysis highlighted the effectiveness of MBSE and concurrent engineering in the early stages of the complex systems lifecycle, highlighting how these methodologies optimize design factors and help minimize risks and optimize performance in later stages of the project. MBSE-based approaches also improve project outcomes by increasing efficiency, facilitating collaboration across engineering disciplines, and reducing risks related to errors, lead times, and traceability issues.

The bibliometric analysis identified clusters that reflect the current state and trends in concurrent design and systems engineering. These clusters emphasized the importance of collaboration, reliability, and advanced modeling technologies with applicability in various fields such as aerospace, healthcare, and active and assisted living.

In addition, the study demonstrated that MBSE is essential for improving the traceability and integration of complex elements of systems throughout their lifecycle. The implementation of these approaches, exemplified by their use by NASA, helps to strengthen the reliability and efficiency of systems, especially in areas where performance and safety are critical, such as space missions or healthcare, especially in the early stages of their life cycle.

Thus, the trend towards integrated approaches in systems engineering, necessary to face the challenges of developing complex and interconnected systems, which urgently require innovative and adaptable solutions, can be underlined. This direction is essential for improving the performance and resilience of systems in complex technology projects.

Study 2: Conclusions and contributions to the scientific field

Design SynMeth is an advanced methodology in the field of MBE, adapted to the MagicGrid framework, developed to meet the specific requirements of IoT system design characterized by the complexity of functionality, cognitive evaluation, as well as interfaces adapted for certain types of users. By implementing a hybrid approach that combines the conceptual agility of OPM with the technical precision of SysML, Design SynMeth adapts the core structure of the MagicGrid framework to meet the specific challenges of IoT development. This approach uses OPM in the early stages of design for fast and intuitive modeling and then accesses SysML for detailed engineering, providing an effective way to design IoT systems by boosting the design vs. modeling process.

Starting from the premise that the technical rigor of MagicGrid is far too vast for the initial conceptual design stage, completely inefficient to create multiple non-intuitive diagrams for each of the four MagicGrid pillars (i.e., requirements, structure, behavior, parameters), the case study proposes to replace the problem domain with the iterative prototyping domain that encourages end-user design, adaptability to evolving stakeholder needs and an ever-changing network of external systems with which Sol must maintain a high level of interoperability.

Therefore, Design SynMeth represents a significant advance in the integration of rapid prototyping with precise system modeling for cognitive monitoring applications via IoT. By combining the flexibility of OPM with the rigor of SysML, Design SynMeth provides a unified approach that increases adaptability and accuracy in the design of IoT systems. Although early applications show promising results, continuous validation is essential to ensure successful applicability in various real-world contexts.

Design SynMeth has the potential, through further software/hardware developments, to become a highly effective methodology for designing systems in the field of human health and safety, supporting autonomy, continuous monitoring and facilitating rapid interventions.

The next stage of research in strengthening Design SynMeth could involve real-time decision-making processes based on supervised learning, applied to cognitive data and real-time feedback from users and stakeholders, to optimize even with a degree of automation rapid prototypes.

Study 3: Conclusions and contributions to the scientific field

Despite the exploratory aspect, the results of the research demonstrate that CRT tests can be used both for the screening of mild cognitive impairments and for the stratification of neurocognitive diseases (mild, moderate and severe). Similarly, CRT tests have high potential in detecting impairments of higher mental functions in stressful work environments or in other pathophysiological circumstances (e.g., dehydration, hypoglycemia, sleep deprivation) that can compromise the performance of healthy individuals.

It also highlights the potential of integrating IoT technologies with cognitive performance monitoring, in particular CRT tasks, to improve the detection and management of MCI in older adults. The development and validation of a portable, easy-to-use CRT device has demonstrated its effectiveness in distinguishing between different levels of cognitive functioning in older adults.

The pilot recruited 35 participants aged 60 and over, and using a CRT device that measured reaction times to stimuli presented in different colors, they aimed to correlate these times with levels of cognitive impairment. Statistical analysis revealed significant differences in reaction times for certain colors, indicating that the CRT device can effectively differentiate participants' cognitive abilities.

In addition, the application of ML algorithms further validated the potential of the CRT device as an effective tool for automatic diagnosis of MCI. Through PCA analysis and testing multiple classifiers, the research identified patterns that accurately classified participants into cognitive categories, either based on CRT data alone or combined with demographic information.

The research results highlight the technical feasibility of the IoT-based CRT system in the early detection and continuous monitoring of MCI in older adults. The research supports the continuous and real-time collection of data through IoT devices, thus generating significant advantages over traditional, episodic cognitive assessments, while also providing a more detailed and deeper understanding of cognitive decline.

Study 4: Conclusions and contributions to the scientific field

The research presents an advanced approach to modeling human sweat by integrating a Digital Twin model with a physical sweat simulation model, SSM. By leveraging technologies such as ML and generative AI, the system is able to accurately predict and simulate sweat patterns under high-stress conditions. This approach has a significant impact in optimizing human health and performance in critical professions, where rapid decision-making and resilience are particularly important.

The integration of the Digital Twin model with OSH provides a dynamic and responsive system that can adapt to variable physiological, psychological and environmental conditions. This allows for real-time monitoring and analysis, facilitating the detection of abnormal sweat patterns that could indicate mental overload, other potential health problems, as well as the diagnosis of various pathologies. The dual functionality of OSH, both as a validation tool and as a physical simulation device, contributes to improving the accuracy, reliability, availability and maintainability characteristics of the system.

The potential applications of this technology go beyond the realm of high-stress professions. The Digital Twin model, through its ability to integrate diverse data sources and improve prediction algorithms, can be adapted for use in consumer health, sports performance and chronic disease management.

Study 5: Conclusions and contributions to the scientific field

The findings show that a tailored CDF workflow can provide a repeatable, evidence-based procedure for capturing multidisciplinary requirements, quantifying medical risk reduction, and generating a traceable impact assessment that can be used to optimize future mission design and operations. Previous studies have catalogued individual adaptive automation tools that could be used to improve the health and safety of astronauts, but none have provided a holistic integration framework linking these tools to mission-specific risks. The CDF-centric approach proposes to bridge this gap between technological potential and system-level decision-making by enabling interdisciplinary contributions within early-stage health and safety system design for large-scale space missions.

List of publications and details

1. Dominey, K., Nistorescu, A., Marin, M., **Vizitiu, C.**, Dobre, C. (2026). Human Digital Twin for Astronauts: Integrating Microgravity Stress Testing and AI-Driven Predictive Modeling for Human Health in Space. In: Costin, HN., Magjarevic, R., Petroiu, GG. (eds) *Advances in Digital Health and Medical Bioengineering II*. EHB 2025. IFMBE Proceedings, vol 144. Springer, Cham. https://doi.org/10.1007/978-3-032-23952-5_2

Publication features:

- Paper published in the volumes of the 13th International Conference on e-Health and Bioengineering (EHB 2025), 13–14 November 2025, Iași, Romania;
- Proceedings publicat în IFMBE Proceedings Book Series (International Federation for Medical and Biological Engineering);
- IFMB Proceedings indexed in WoS, SCOPUS, SCImago.

2. Nistorescu, A., Marin, M., Dominey, K., Dinculescu, A.C., Dugan, C., **Vizitiu, C.**, and Min, P. (2025) From Search-and-Rescue to Nuclear Scenarios: AI-enabled UAS for Disaster Management, Security, and Ecosystem Monitoring. In: Costin, HN., Magjarevic, R., Petroiu, GG.

(eds) Advances in Digital Health and Medical Bioengineering II. EHB 2025. IFMBE Proceedings, vol 144. Springer, Cham. https://doi.org/10.1007/978-3-032-23952-5_3

Publication features:

- Paper published in the volumes of the 13th International Conference on e-Health and Bioengineering (EHB 2025), 13–14 November 2025, Iași, Romania;
- Proceedings publicat în IFMBE Proceedings Book Series (International Federation for Medical and Biological Engineering);
- IFMB Proceedings indexed in WoS, SCOPUS, SCImago.

3. Min, P., **Vizitiu, C.**, Dugan, C., and Șerbanescu, D. (2025) Case Study on Romania's Nuclear Diplomacy: Balancing Technology and Security in the Context of the Green Transition and Regional Resilience. In: Costin, HN., Magjarevic, R., Petroiu, GG. (eds) Advances in Digital Health and Medical Bioengineering II. EHB 2025. IFMBE Proceedings, vol 144. Springer, Cham. https://doi.org/10.1007/978-3-032-23952-5_17

Publication features:

- Paper published in the volumes of the 13th International Conference on e-Health and Bioengineering (EHB 2025), 13–14 November 2025, Iași, Romania;
- Proceedings publicat în IFMBE Proceedings Book Series (International Federation for Medical and Biological Engineering);
- IFMB Proceedings indexed in WoS, SCOPUS, SCImago.

4. **Vizitiu, C.**, Turcin, I., Dominey, K., Dinculescu, A., Nistorescu, A., Marin, M., Dugan, C., Moraru, S. (2025). Concurrent Design Facility Definition for Advancing the Integration of Smart Automation in Human Space Applications. În: Mizuyama, H., Morinaga, E., Nonaka, T., Kaihara, T., von Cieminski, G., Romero, D. (eds.) Advances in Production Management Systems. Cyber-Physical-Human Production Systems: Human-AI Collaboration and Beyond. APMS 2025, Kamakura, Japan, August 31 - September 4, 2025, Proceedings. IFIP Advances in Information and Communication Technology (AICT), vol. 766. Springer, Cham. DOI: https://doi.org/10.1007/978-3-032-03538-7_8

Publication features:

- Paper Published in the IFIP AICT – International Federation for Information Processing series, edited by Springer.
- IFIP AICT volumes are indexed Scopus and ISI (Web of Science), being considered Proceedings, as well as book chapters in collective volumes (Springer Proceedings Series).
- Categorie: Capitol de carte / Conference Proceedings (Springer IFIP AICT, Scopus, ISI Proceedings): 44th IFIP WG 5.7 International Conference, APMS 2025, Kamakura, Japan, August 31 - September 4, 2025, Proceedings

5. **Vizitiu, C.**, Dinculescu, A.C., Marin, M.G. et al. (2025). Optimizing Early-Stage Efficiency in Complex System Development via Model-Based Systems Engineering (MBSE) and Concurrent Engineering (CE) Integration. Research in Engineering Design, vol. 36, art. 12 (2025). DOI: <https://doi.org/10.1007/s00163-025-00452-2>

Publication features:

-Paper Published in the Journal "Research in Engineering Design" (Springer Nature), international scientific journal Q2.

- Impact Factor (JCR 2023): 2.3, Q2 (Springer Nature, ISI Web of Science).

6. **Vizitiu, C.**, Dominey, K., Nistorescu, A., Dinculescu, A., Marin, M. (2025). mHealth Case Study Presenting Design SynMeth, a Rapid Prototyping MBSE Methodology, by Advancing Specific OPM-to-SysML Mapping. IEEE Access, vol. 13, pp. 53531–53545. DOI: <https://doi.org/10.1109/ACCESS.2025.3553945>

Publication features:

-Paper Published in the Journal "IEEE Access", international open-access IEEE journal.

-Impact Factor (2024): 3.6, Q2 (IEEE, ISI Web of Science, Scopus).

7. **Vizitiu, C.**, Stara, V., Antognoli, L. et al. (2024). An IoT-Based Cognitive Impairment Detection Device: A Newly Proposed Method in Older Adults Care—Choice Reaction Time Device Development and Data-Driven Validation. Digital Health, vol. 10 (2024). DOI: <https://doi.org/10.1177/20552076241293597>

Publication features:

-Paper Published in the Journal "Digital Health" (SAGE Publishing), an international interdisciplinary journal indexed in SCIE, Scopus, PubMed, DOAJ.

-Impact Factor (2023): 3.3, Q2 (SAGE Journals, ISI Web of Science).

8. **Vizitiu, C.**, Turcin, I., Dominey, K. A., Softic, S., Dinculescu, A.-C., Bocăneț, V. I., Dugan, C. and Moraru, S.-A. (2024). Digital Twin Definition for Detecting Abnormal Perspiration Patterns in High-Stress Professions. În: Proceedings of the 23rd RoEduNet Conference: Networking in Education and Research (RoEduNet 2024), București, România, pp. 1–4. DOI: <https://doi.org/10.1109/RoEduNet64292.2024.10722390>

Publication features:

-Paper Published in IEEE Xplore Digital Library, international conference indexed in Scopus and ISI Proceedings (Web of Science – CPCI).

-Category: Paper in IEEE proceedings (ISI indexed international conference).

9. Abstract and poster: Nistorescu, A., Dinculescu, A., Marin, M., Dominey, K., & **Vizitiu, C.** (2024). Exploring myoelectromyography specific applications and future perspectives in non-invasive muscle assessment. Congress of the University of Medicine and Pharmacy "Carol Davila" -UMFCD, twelfth edition, Bucharest, October 24–26, 2024, Palace of Parliament.

10. Abstract and poster: Dominey, K., Dugan, C., Marin, M., Pop, S., Dinculescu, A., Nistorescu, A., Parlatescu, I., & **Vizitiu, C.** (2024). Exploring Muscle-Computer Interfaces for Therapeutic Assessment in Microgravity: A Deep-Tech Approach to Masticatory Muscle Atrophy. Congress of the University of Medicine and Pharmacy "Carol Davila" -UMFCD, twelfth edition, Bucharest, October 24–26, 2024, Palace of Parliament.

11. Marziali RA, Franceschetti C, Dinculescu A, Nistorescu A, Kristály DM, Moșoi AA, Broekx R, Marin M, **Vizitiu C**, Moraru SA, Rossi L, Di Rosa M. Reducing Loneliness and Social Isolation of Older Adults Through Voice Assistants: Literature Review and Bibliometric

Analysis. J Med Internet Res. 2024 Mar 18;26:e50534. doi: 10.2196/50534. PMID: 38498039; PMCID: PMC10985600.

12. Dugan, C., Parlatescu, I., Popescu, B.O., Pop, C.S., Marin, M., Dinculescu, A., Nistorescu, A.I., **Vizitiu, C.**, Varlas, V.N. (2023). Applications for Oral Research in Microgravity – Lessons Learned from Burning Mouth Syndrome and Ageing Studies. Journal of Medicine and Life, vol. 16(3), pp. 381–386. DOI: <https://doi.org/10.25122/jml-2022-0285>

Publication features:

- Paper Published in the Journal of Medicine and Life, (PubMed Central, Scopus, DOAJ).
- Category: Q3 (PubMed Central).

13. Nistorescu, A., Busnatu, S.S., Dinculescu, A., Olteanu, G., Marin, M., Jercalau, C.E., **Vizitiu, C.**, Papacoea, I.R. (2022). Striated Muscle Evaluation Based on Velocity and Amortization Ratio of Mechanical Impulse Propagation in Simulated Microgravity Environment. Biology (MDPI), vol. 11, 1677. DOI: <https://doi.org/10.3390/biology11111677>

Publication features:

- Paper Published in the Journal of Biology (MDPI),
- Impact Factor (2023): 4.2, Q1 (MDPI, ISI Web of Science, Scopus).

14. Stara, V., Rampioni, M., Moşoi, A.A., Kristaly, D.M., Moraru, S.A., Paciaroni, L., Paolini, S., Raccichini, A., Felici, E., Rossi, L., **Vizitiu, C.**, Nistorescu, A., Marin, M., Tónay, G., Tóth, A., Pilissy, T., Fazekas, G. (2022). A Technology-Based Intervention to Support Older Adults in Living Independently: Protocol for a Cross-National Feasibility Pilot. International Journal of Environmental Research and Public Health (IJERPH), vol. 19, 16604. DOI: <https://doi.org/10.3390/ijerph192416604>

Publication features:

- Paper Published in the IJERPH Journal (MDPI) – journal Q1 (Public Health, Environmental Health).
- Impact Factor (2023): 5.4, Q1 (ISI Web of Science, Scopus, Public Health)

15. Dugan, C., Marin, M., Pop, S., Coculescu, E., Parlatescu, I., Dinculescu, A., Nistorescu, A.I., **Vizitiu, C.** (2022). Magnetic and Electric Noninvasive Transcranial and Peripheral Stimulation Proposed Applications for Oral Physiology and Biomechanics Research in Microgravity – Lessons Learned from Oral Pathology and Ageing Studies. Proceedings of the 73rd International Astronautical Congress (IAC 2022) – IAF/IAA Space Life Sciences Symposium.

Publication features:

- Paper Published in the International Astronautical Federation (IAF) Conference Proceedings

16. **Vizitiu, C.**, Bîră, C., Dinculescu, A., Nistorescu, A., Marin, M. (2021). Exhaustive Description of the System Architecture and Prototype Implementation of an IoT-Based eHealth Biometric Monitoring System for Elders in Independent Living. Sensors (MDPI), vol. 21, 1837. DOI: <https://doi.org/10.3390/s21051837>

Publication features:

- Paper Published in the Sensors Journal (MDPI),

-Impact Factor (2023): 3.9, Q1 (ISI Web of Science, Scopus).

17. Dinculescu, A., Dugan, C., **Vizitiu, C.**, Parlatescu, I. (2021). Study on Choice Reaction Time as a Complementary Method in Idiopathic Orofacial Pain. Proceedings of the 2021 International Conference on e-Health and Bioengineering (EHB 2021). DOI: <https://doi.org/10.1109/EHB52898.2021.9657580>

Publication features:

-Paper Published in IEEE Xplore Digital Library, Scopus indexed conference, ISI (CPCI).

18. Dugan, C., Parlatescu, I., Dinculescu, A., Vizitiu, C. (2021). Therapeutic Potential of Noninvasive Transcranial Magnetic Stimulation in Burning Mouth Syndrome. Proceedings of the 2021 International Conference on e-Health and Bioengineering (EHB 2021). DOI: <https://doi.org/10.1109/EHB52898.2021.9657555>

Publication features:

-Paper Published in IEEE Xplore Digital Library, Scopus indexed conference, ISI (CPCI).

19. **Vizitiu, C.** (2019). Systems Engineering and Organizational Assessment Solutions Ensuring Sustainability within Telemedicine Context. Book published by Springer Nature, Germany. ISBN (online): 978-3-658-23538-3, DOI: 10.1007/978-3-658-23538-3.

Publication features:

- Book published by Springer Verlag (Springer Nature), in the collection of Springer Books in Business and Economics.

Coordinator/Responsible for R&D projects

Participation in Scientific Research Projects (non-exhaustive list of):

1. Period 2024 – 2025: (PROJECT DIRECTOR) First Responder UAS for SAR Missions advancing automated Real Time hUman dEtection – VIRTUE. Project International desfășurat în cadrul Agenției Spatiale Europene (European Space Agency-ESA) <https://business.esa.int/projects/virtue>

2. Period 2022 – 2024: (RESPONSABIL PROIECT) Increase sElf Management and counteract social IsoLatIOn using a vocal assistant enabled virtual concierge (EMILIO). Project International în cadrul Programului "Active and Assisted Living" AAL, Comisia Europeană.

3. Period 2019 – 2023: (PROJECT RESPONSIBLE) SAFety of elderly people and Vicinity Ensuring – "SAVE". International project within the "Active and Assisted Living" Program of AAL, European Commissionă.

4. Period 2023-2026: (RESPONSIBLE PHASE 1, Part I and Part II): PN 23 03 02 01 – Technological, applied and frontier research developments for space economy and related fields (LAPLAS VII Core Programme, code 23 03 P). Phase 1 – Part I and Part II: Analysis study of the organization of the Concurrent Design Facility (CDF) and of the design tools specific to concurrent engineering according to spatial standards, in order to streamline the feasibility studies. Magurele: Institute of Space Science-INFLPR subsidiary, 2023–2026.

5. Period 2020 – 2021: (SPACE AND SECURITY EXPERT) within the project "Strategy of national participation in the new European context of research coordination in the fields of security and space industry (3S Strategy)", funded by Program P2 – Increasing the competitiveness of the Romanian economy, Subprogram 2.1 Competitiveness through research, development and innovation / SOLUTIONS 3.
6. Period 2017 – 2021: (SYSTEM ENGINEER) "Extensive Capitalization of Experience in Space and Security Activities" - Complex Projects (PCCDI). PN-III-P1-1.2-PCCDI-2017.
7. Period 2017 – 2018: (RESPONSABIL PROIECT) „In vitro evaluation of potential biomedical strategies aimed to prevent bone loss during spaceflight”. Programul STAR (Space Technology and Advanced Research)-Agentia Spatiala Romana (ROSA).
8. Period 2017 – 2018: (SYSTEM ENGINEER) „SUPERLENS using metasurfaces and graphene thin coatings as a photonic component for micro and nanosatellites”. Programul STAR (Space Technology and Advanced Research)- Agentia Spatiala Romana (ROSA).
9. Period 2013 – present: (Secretary General of the Governing Board of the Competence Center) "Space Technologies Competence Center in Support of Human Crewed Space Exploration – STARWALKER". STAR (Space Technology and Advanced Research)-ROSA Program.
10. Period 2013 – 2015: (SYSTEM ENGINEER) PORTABLE TELEMEDICINE WORKSTATION FULL PROTOTYPE, Proiect ESA-PECS (European Space Agency - Plan for Cooperating States).
11. Period 2013 – 2014: (SYSTEM ENGINEER) Knowledge Management Infrastructure – KAMI; The STAR, ROSA program.
12. Period 2010 – 2013: (SYSTEM ENGINEER) PORTABLE TELEMEDICINE WORKSTATION FEASIBILITY STUDY, DEFINITION AND SPECIFICATION- PTW, Project within ESA-PECS (European Space Agency - Plan for Cooperating States).

Summary references:

- Aleksandravičienė, A., & Morkevičius, A. (2021). MagicGrid book of knowledge: A practical guide to systems modeling using MagicGrid from Dassault Systèmes. Vitae Litera.
- Folstein, M.F., Folstein, S.E. & McHugh, P.R., 1975. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. Journal of Psychiatric Research, 12(3), pp.189–198.
- GeeksforGeeks. (2018). Principal Component Analysis with Python. Available from: <https://www.geeksforgeeks.org/principal-component-analysis-with-python/>. [Accessed May 15, 2024].
- Marziali RA, Franceschetti C, Dinculescu A, Nistorescu A, Kristály DM, Moşoi AA, Broekx R, Marin M, Vizitiu C, Moraru SA, Rossi L, Di Rosa M. Reducing Loneliness and Social

Isolation of Older Adults Through Voice Assistants: Literature Review and Bibliometric Analysis. *J Med Internet Res*. 2024 Mar 18;26:e50534. doi: 10.2196/50534.

Page, M. J., Moher, D., Bossuyt, P. M., et al. (2021). PRISMA 2020 explanation and elaboration: Updated guidance and exemplars for reporting systematic reviews. *BMJ*, n160. <https://doi.org/10.1136/bmj.n160>

Vizitiu, C. (2019) 'Systems Engineering and Organizational Assessment Solutions Ensuring Sustainability within Telemedicine Context', Book in Sustainable Management, Wertschöpfung und Effizienz. Wiesbaden: Springer Fachmedien Wiesbaden. DOI: 10.1007/978-3-658-23538-3.

Vizitiu, C. et al. (2017). Potential Astronauts' Speech and Language Disorders: Astronaut Interviews Analysis Before and After Space Mission. *E-Health and Bioengineering Conference (EHB)*.

Vizitiu, C., Bîră, C., Dinculescu, A., et al. (2021). Exhaustive description of the system architecture and prototype implementation of an IoT-based eHealth biometric monitoring system for elders in independent living. *Sensors*, 21, 1837, <https://doi.org/10.3390/s21051837>

Vizitiu, C., Dinculescu, A.C., Marin, M.G. et al. (2025). Optimizing early-stage efficiency in complex system development via model-based systems engineering (MBSE) and concurrent engineering (CE) integration. *Res Eng Design* 36, 12. <https://doi.org/10.1007/s00163-025-00452-2>

Vizitiu, C., Dominey, K., Nistorescu, A., Dinculescu, A., Marin, M. (2025). mHealth Case Study Presenting Design SynMeth, a Rapid Prototyping MBSE Methodology, by Advancing Specific OPM-to-SysML Mapping. *IEEE Access*, vol. 13, pp. 53531–53545. DOI: <https://doi.org/10.1109/ACCESS.2025.3553945>

Vizitiu, C. et al. (2024). An IoT-based cognitive impairment detection device: A newly proposed method in older adults care—choice reaction time-device development and data-driven validation. *Digital Health*, 10. <https://doi.org/10.1177/20552076241293597>.

Vizitiu, C., Turcin, I., Dominey, K. A., Softic, S., Dinculescu, A.-C., Bocăneț, V. I., Dugan, C. and Moraru, S.-A. (2024). Digital Twin Definition for Detecting Abnormal Perspiration Patterns in High-Stress Professions. În: *Proceedings of the 23rd RoEduNet Conference: Networking in Education and Research (RoEduNet 2024)*, București, România, pp. 1–4. DOI: <https://doi.org/10.1109/RoEduNet64292.2024.10722390>

Vizitiu, C., Turcin, I., Dominey, K., Dinculescu, A., Nistorescu, A., Marin, M., Dugan, C., Moraru, S. (2025). Concurrent Design Facility Definition for Advancing the Integration of Smart Automation in Human Space Applications. În: Mizuyama, H., Morinaga, E., Nonaka, T., Kaihara, T., von Cieminski, G., Romero, D. (eds.) *Advances in Production Management Systems. Cyber-Physical-Human Production Systems: Human-AI Collaboration and Beyond. APMS 2025, Kamakura, Japan, August 31 - September 4, 2025, Proceedings. IFIP Advances in Information and Communication Technology (AICT)*, vol. 766. Springer, DOI: https://doi.org/10.1007/978-3-032-03538-7_8