AeroSPICE

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A proposal for a holistic development process framework for the aviation industry

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1. Abstract

The aerospace industry is undergoing a significant transformation, driven by increasing system complexity, heightened safety and cybersecurity requirements, and evolving regulatory landscapes. Existing standards, such as ARP 4754B, DO-178C, and DO-254, provide critical guidelines for system, software, and hardware development but they lack an overarching and cohesive framework that integrates safety, cybersecurity, and project management. This whitepaper proposes AeroSPICE to address these gaps by creating a unified approach to aerospace development based on the structure of ISO/IEC 330xx standards. We propose a minimum set of required processes for development and draft the details of two selected processes, which are "Aircraft Functions and Requirements Development" and "Project Management". This proposal outlines the key elements of AeroSPICE, explores its alignment with existing aerospace regulations, and defines the next steps for industry-wide adoption – addressing the needs of OEMs, suppliers, regulators, and maintenance organizations alike.

2. Introduction

In recent years, the aerospace industry has been facing a period of significant transformation, driven by the increasing complexity of systems and new concepts—and as a consequence, an increasing complexity in the landscape of development regulations and standards that need to be adhered to. The Boeing 737 MAX crisis is just one of several recent events that have exposed critical vulnerabilities in existing aerospace development processes, particularly in areas of risk management, safety assurance, and timely delivery [1-6]. These issues resulted in substantial economic losses and a serious erosion of customer trust [7] highlighting the need for a more robust and comprehensive development process framework.

In addition, the aerospace standards system become overly complex and as a reaction, the Aerospace Industries Association filed a report primarily focusing on treating standards as interoperable digital data and improving administrative integration of normative information [8]. However, this report does not provide a holistic and concrete, process-driven development framework, which is still missing in the industry.

Moreover, the rapid adoption of technologies such as 5G, the Internet of Things (IoT), and advanced machine learning in aviation has expanded the attack surface for malicious actors. These technological advancements, while beneficial for efficiency and safety, have also introduced new vulnerabilities [9]. The International Civil Aviation Organization (ICAO) and the World Economic Forum have emphasized the need for international cooperation to enhance cyber-resilience in aviation [10]. The increased complexity and interconnectedness of aviation systems make it imperative to have a unified approach that integrates cybersecurity measures with existing safety and process management standards.

The foundation of system development in aerospace is guided by standards such as ARP 4754B and ARP 4761A. ARP 4754B provides essential guidelines for the development of civil aircraft and systems, ensuring that safety is integrated from the earliest stages of design [11, 12]. Complementing this, ARP 4761A offers methodologies for conducting safety assessments to identify and mitigate risks throughout the aircraft's lifecycle. However, these guidelines, while crucial, primarily address high-level processes and safety assessments. They fall short in providing detailed guidance on implementation, particularly in planning and managing the whole engineering process. This lack of detailed planning guidance can lead to challenges in maintaining reliable delivery schedules—an issue of critical importance for customers contracting development of aerospace systems.

More detailed standards, such as DO-254 (Design Assurance Guidance for Airborne Electronic Hardware) and DO-178C (Software Considerations in Airborne Systems and Equipment Certification) [13, 14], while also not covering planning topics, are essential for ensuring that individual hardware and software components meet rigorous safety and reliability standards. These standards are specifically designed to verify the functionality and safety of components within their intended operational environments. However, as the digitalization of aerospace systems has increased, the protection of these systems from cyber threats has become just as critical as their physical safety. While DO-254 and DO-178C are vital for component safety, they do not address cybersecurity, which is covered by other standards like DO-326A, DO-356A, and NAS 9933 [15-17]. These cybersecurity standards offer detailed guidelines for assessing and mitigating risks, but integrating these requirements into the overall development process has been somewhat fragmented. This fragmentation can lead to potential vulnerabilities in the final product, underscoring the need for a more cohesive approach that includes robust cybersecurity measures as part of the broader aerospace development framework.

Given these limitations—gaps in planning and scheduling guidance, fragmented process management, and the integration of cybersecurity—there is a clear need for a more integrated framework. In parallel to Automotive SPICE (ASPICE*) , which has become a successful de-facto-standard in the automotive industry [18, 19], we propose an "AeroSPICE" framework, which aims to fill this gap by providing a universal process framework that supports organizations in fulfilling the important standards required for a safe, reliable, and well-managed development. AeroSPICE is not designed to replace existing standards, but to provide an overarching framework that supports transparent project planning and compliance with existing development regulations.

ASPICE was initially driven by the demands of automotive OEMs such as Audi, BMW, and Daimler, who required their Tier-1 suppliers, including major companies like Bosch and Continental, to standardize and improve their software and system development processes by using the ASPICE framework. It could be shown that there is a clear correlation between the achieved ASPICE level and the predictability of delivery schedules leading to a significant improvement in the transparency of development project schedules [20]. Over time, the suppliers met the ASPICE requirements by successfully passing respective assessments, demonstrating their adherence to the quality and efficiency standards set by the OEMs. And even more, the effectiveness of ASPICE in enhancing development processes led to its adoption by the OEMs themselves for their own systems and software development.

Similarly, the AeroSPICE framework -if properly considering existing development standards- can be particularly beneficial for two main groups within the aerospace industry: OEMs and their Tier suppliers. For OEMs, AeroSPICE offers a way to improve the overall quality and safety of their products by ensuring better integration of various development processes, including cybersecurity. For Tier suppliers, it provides structured guidance that can improve their ability to meet delivery schedules and maintain the reliability of the systems they develop, ultimately leading to more predictable and successful project outcomes.

**Automotive SPICE® (ASPICE) is a registered trademark of the Verband der Automobilindustrie e.V. (VDA).*

AeroSPICE is aimed at delivering a holistic, ISO/IEC 33060-based process model that explicitly links system engineering, safety, cybersecurity, and project management into a single cohesive lifecycle. Thus, even amid existing standardization initiatives, the AeroSPICE approach is both warranted and necessary to close the gap between data-centric standard management and end-to-end process integration.

This whitepaper will explore the steps necessary to develop this comprehensive aerospace process framework. We will analyze how existing guidelines for aircraft, system, and component development can be integrated with cybersecurity requirements to create a more robust, adaptable, and future-proof process framework. By addressing these challenges, AeroSPICE aims to enhance safety, reliability, and process efficiency across the aerospace industry.

3. Main Part

To derive a consistent set of processes, in line with the SPICE norm, it is essential to first define the scope of such a holistic process framework.

We will therefore apply a top-down approach by identifying high-level domains that are fundamental to aircraft development:

- Aircraft and Systems Engineering
- Software Engineering
- Hardware Engineering

Within each of these areas, further activities must be considered that serve as a supporting yet crucial part of development:

- Safety Engineering
- Security Engineering
- Validation
- Management (in particular project management, quality assurance, configuration management, problem and change management)

For these activities, applicable regulations can be identified. From these regulations – and in combination with the systems engineering SPICE standard ISO/IEC TS 33060 – a set of processes and process outputs can be derived, that are necessary to fulfill regulations. Additionally, it is also advised to add aerospace-specific experience and good industry practices to the framework to ensure e.g. state of the art project management or to provide high-level implementation guidelines. For every process identified in that manner, its purpose, outcomes, base practices, and outputs shall be precisely defined in a way that it serves the compliance with the respective regulations. An illustration of this approach is shown in Figure 1.

While SPICE is originally intended to measure and evaluate existing processes, we want to explicitly point out that content defined in such a framework can not only be used to evaluate processes but can also effectively assist in setting up a new and compliant process landscape itself. This is why we will refer to "process requirements" in general when discussing the AeroSPICE content.

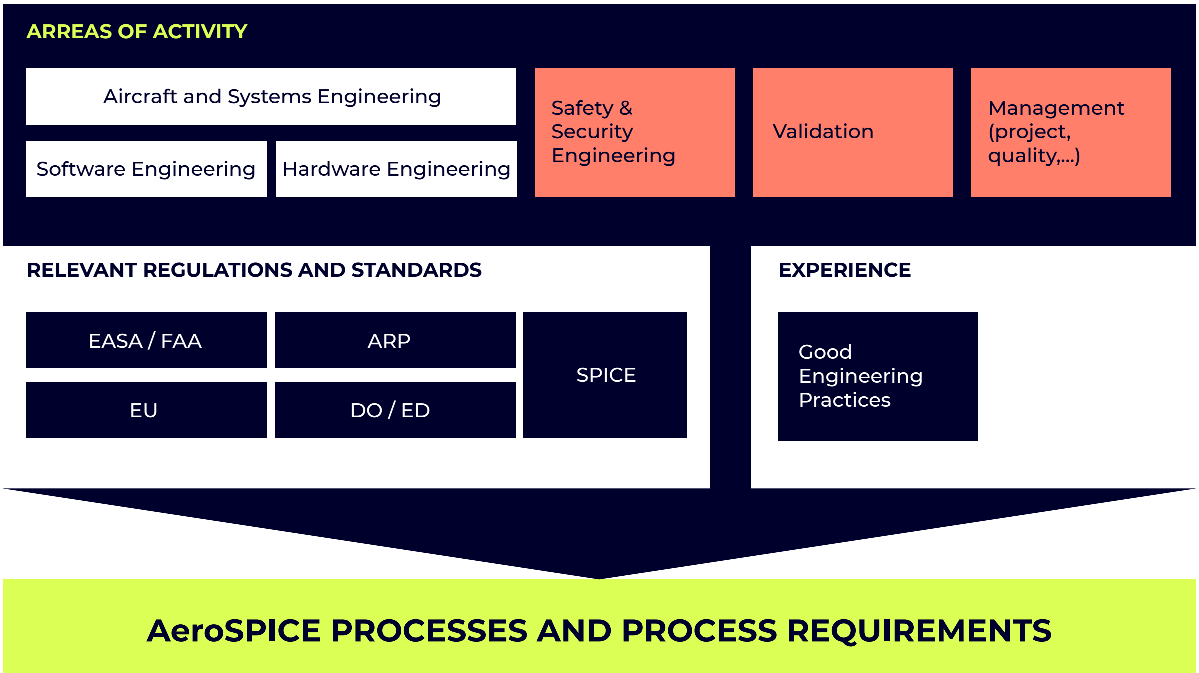

Figure 1 shows a generic dependency between applicable engineering activities, aircraft and system regulations together with state of the art experience, and the intended AeroSPICE framework.

At first, we want to focus on processes relevant for the development phase keeping in mind that requirements for production and maintenance must not be neglected in early phases of development but require further dedicated processes and activities.

AeroSPICE pilot area of activity: Aircraft and Systems Enginee-ring

Starting from the first area of activity, which is Aircraft and Systems Engineering, we consider the following regulations as a starting point and particularly relevant in the EU and USA:

- EASA/FAA regulations incl. certification requirements
- ARP 4754B (supported by ARP 4761A) – Model-based systems engineering
- DO-326A (ED-202) – Cybersecurity
- EU Taxonomy for Sustainable Activities

Table 1 depicts a derivation of processes based on these standards and illustrates, which of the standards impose requirements for processes itself and which of the regulations impose requirements for a certain product (which may be an aircraft or just a component of it).

An initial view on this list will already provide several important insights:

- Applicable regulations may provide both requirements for ***processes*** and requirements for products (i.e. aircraft or components of it).
- Some of the derived processes overlap in naming and content suggesting consolidation

Development Processes	Integral Processes	Other Processes	Stakeholder Requirements (non-exhaustive)
Development Assurance Planning	Safety Assessment	Modification Management (ARP, Part 21)	Certification Requirements (EASA/ FAA)
Aircraft Function and Requirement Development	Development Assurance Level Assignment	Project Management (good practice)	Environmental Requirements (DO-160, ICAO, ReFuelEU Aviation, EU Taxonomy)
Development of Aircraft Architecture and Allocation of Aircraft Functions to Systems	Requirements Capture	Product Quality Management (good practice)	-
Development of System Requirements	Requirements Validation	Project issue and Defect Management (ARP, good practice)	-
Development of System Architecture and Allocation of System Requirements to Items	Implementation Verification	Project and technical Risk Management (DO-326, EU Taxonomy, good practice,...)	-
Implementation	Configuration Management	-	-
-	Process Assurance	-	-

Table 1 provides an overview of processes derived from standards and good practices of systems engineering as well as a separation of stakeholder requirements.

Product-specific requirements are not in scope at this stage as the focus lies on generic process definitions rather than project-specific content. In fact, they would be addressed by a dedicated process for capturing stakeholder requirements. Also, addressing the "integral processes" of ARP4754B, we do not recommend adding them all as ***individual*** processes to avoid redundancies and to reduce complexity. Instead, we will integrate them as important concepts (i.e., base practices and/or outputs) into the applicable core development processes. In particular, the following "integral processes" should be embedded accordingly:

- Safety Assessment/Technical Risk Management
- Development Assurance Level Assignment
- Requirements Capture
- Requirements Validation

A proper integration of integral processes must ensure that the continuous cycle of "design – safety assessment – redesign – validation" is maintained.

In addition, we can deal with cybersecurity risks as required e.g. in DO-326 in a very similar way: By ensuring that at each design level, such risks are properly identified and, where necessary, addressed with derived requirements. Those derived requirements will then need to be validated and broken down into the implementation levels.

This can be achieved by introducing the term "technical risk" in a generic way, containing both safety and cybersecurity risks -among other technical risks- while ensuring that domain-specific treatment approaches are preserved within the process model. Technical risks are directly tied to development activities on the respective system, hardware or software level and should therefore be addressed explicitly within those processes to ensure consistency and traceability.

In addition to the core and integral processes, several further activities such as defect management, product quality assurance, and configuration management have been identified as relevant "other processes" (see Table 1). Project risk management is considered as an integral part of project management, which also oversees technical risks identified within the individual technical processes.

While technical risks usually span multiple development levels, their identification and treatment are inherently tied to specific engineering artifacts and design decisions. Therefore, they are best addressed *within* the corresponding development processes to maintain semantic coherence and ensure direct traceability to technical requirements and architecture. In contrast, activities such as defect management, configuration management, or quality assurance represent transversal disciplines that operate across process boundaries. Their organizational independence, toolchain-specific workflows, and responsibility structures justify their definition as dedicated processes within the framework.

With this consolidation, we can introduce a Technical Process Group and a Management Process group and attribute respective process IDs following the logic proposed by SPICE as shown in Figure 3.

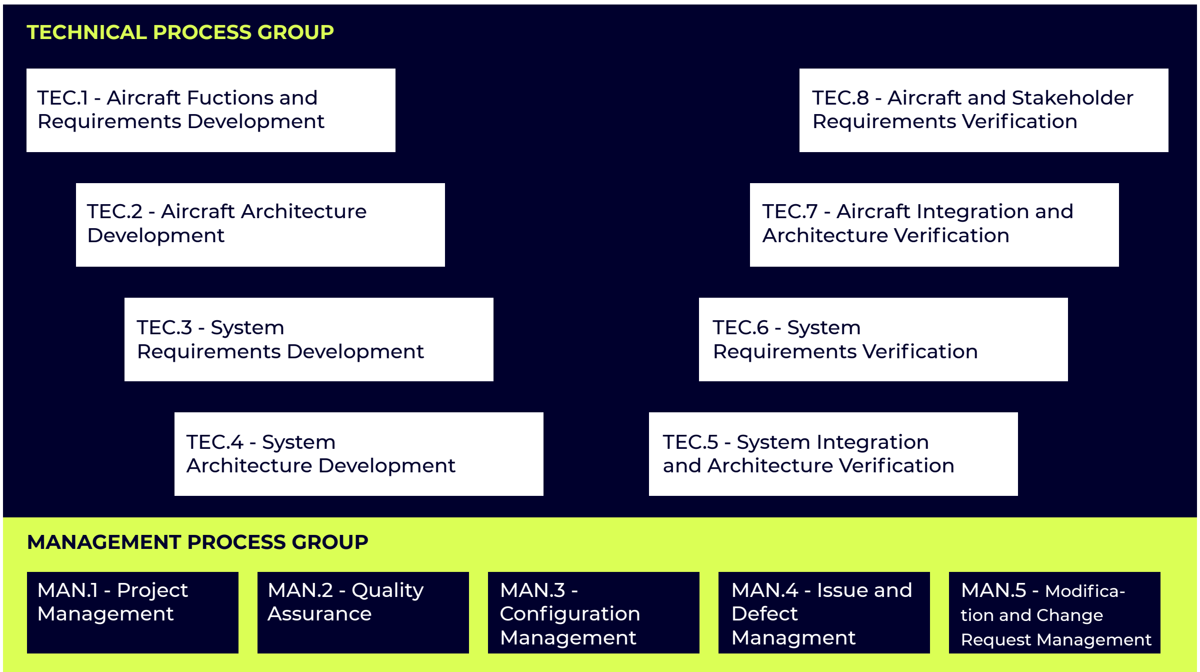

Figure 3 shows the proposed process map relevant for aircraft and systems engineering. In order to be compliant with applicable regulations, appropriate process requirements must be captured. Highlighted are the processes, that this publication will draft in more detail.

From here, we can dive into individual processes and ensure that applicable regulations are properly captured in the process requirements. As this publication intends to initiate the discussion within the industry instead of providing a complete framework, we will set up the proposal for one process within each of those process groups, namely TEC.1 and MAN.1 according to the defined SPICE structure. In addition to the base practices (reflecting required activities), we provided more detailed expectations (regular writing) and additional hints and comments in the form of annotations (italic writing).

TEC.1 – Aircraft Functions and Requirements Development

Process ID	**TEC.1**
Process Name	**Aircraft Functions and Requirements Development**
Process Purpose	The purpose of the Aircraft Functions and Requirements Development process is to identify, analyze, and formalize stakeholder expectations and regulatory requirements into a structured set of aircraft functions, that are suitable to derive the aircraft architecture.
Process Outcomes	a) Aircraft functions, requirements and assumptions are grouped, documented and reviewed b) Necessary safety and technical risk assessments have been executed c) Functional Design Assurance Level (FDAL) are assigned to aircraft functions d) Requirements are analyzed e) Requirements and functions are validated f) Traceability to project goals is established g) Stakeholders are informed about new and updated requirements

TEC.1

Base Practices	**TEC.1 BP.1: Collect and document aircraft functions, regulatory requirements, and assumptions.** [Outcome: a] Assumptions shall cover any gaps required for the development, which cannot be directly derived from project goals or regulatory requirements. *Note: Regulatory requirements strongly depend on the project goals (e.g. target markets or aircraft category). They may contain e.g. certification requirements or environmental requirements (EASA, FAA, ICAO, EU Taxonomy for sustainable activities, or other)* **TEC.1 BP.2: Group functions and requirements.** [Outcome: a] *Note: Grouping or structuring can be set up e.g. according to priority, criticality, preliminary product architecture, assigned development teams or other.* **TEC.1 BP.3: Assess technical risks.** [Outcome: b, d] Identify and assess technical risks related to the aircraft functions, regulatory requirements, and assumptions. This includes at a minimum, conducting an aircraft functional hazard analysis (AFHA) for safety assessment. In addition, a threat analysis should be performed to identify potential cybersecurity risks. *Note: Cybersecurity risks may not necessarily cause safety impacts and must thus be additionally considered.*

Base Practices	
	TEC.1 BP.4: Assign Functional Design Assurance Level (FDAL) to aircraft functions. [Outcome: c] Based on identified failure conditions in the safety assessments, FDAL shall be derived and assigned to the aircraft functions. *Note: An update of FDAL assignment will be required after the design of the aircraft architecture and Common Cause Considerations.* **TEC.1 BP.5: Derive requirements from technical risks.** [Outcome: a, b] *Note: Derived requirements would have to be continuously reassessed and updated during later stages of development.* **TEC.1 BP.6: Analyze requirements.** [Outcome: d] The Analysis of requirements should cover at least a feasibility check and an estimation of efforts for implementation and verification. **TEC.1 BP.7: Define verification methods and verification criteria.** [Outcome: a] *Note: Verification methods may include tests, reviews, or expert inspection. Verification criteria can be set e.g. according to certain tolerance levels, comparative values, equivalence classes or other.*

TEC.1

Base Practices	**TEC.1 BP.8: Validate functions and requirements.** [Outcome: d, e] The validation must address the correctness, completeness, and consistency. Appropriate methods for validation shall be defined and documented. **TEC.1 BP.9: Establish traceability to project goals.** [Outcome: f] *Note: Assumptions are not required to be assigned to goals.* **TEC.1 BP.10: Review new and updated functions and requirements.** [Outcome: a, e] Reviews shall include both formal criteria and content-related criteria. *Note: Use of a review checklist is advised.* **TEC.1 BP.11: Inform stakeholders about new and updated functions and requirements.** [Outcome: g] If communication of requirements to necessary stakeholders can be concluded from the course of actions, no evidence of documentation is required. *Note: Relevant stakeholders could include e.g. project manager, configuration manager, test manager, or aircraft architect.*

Table 2 shows the proposal for the process TEC.1 in the form of the SPICE standard.

TEC.1

Process Outputs	Aircraft requirements (including functions, regulatory requirements, derived requirements, and assumptions) [Outcome: a] AFHA [Outcome: b] Technical risks [Outcome: b] FDAL assignment [Outcome: c] Requirements analysis [Outcome: d] Validation plan [Outcome: e] Validation results [Outcome: e] Traceability [Outcome: f] Communication evidence [Outcome: g]

MAN.1 - Project Management

MAN.1

Process ID	**MAN.1**
Process Name	**Project Management**
Process Purpose	The purpose of the project management process is to establish and maintain a structured framework for planning, executing, and controlling project activities and risks to ensure compliance with technical, regulatory, and business objectives within defined constraints. It enables coordination of project stakeholders in order to achieve the project's goals.
Process Outcomes	a) Project goals are agreed with the sponsor or client and communicated with relevant stakeholders. b) Key project information are documented and made available to relevant project stakeholders c) The project plan is up to date. d) The project milestones can be achieved as planned based on estimated efforts and available resources e) The risk management is effective. f) Project communication is effective

MAN.1

Base Practices	
	MAN.1 BP.1: Define the goals and constraints of the project. [Outcome: a] Project goals shall at least include a brief description of the product to be developed and the markets/countries where the product is intended to be operated. They shall be stated in a SMART way. *Note: Goals should be defined based on factors such as business needs or certification objectives. Product requirements derived from these goals may strongly depend on target markets with individual regulatory requirements. Stating aspects, that the project is not responsible for, may also be useful. Constraints may include factors such as budget limitations, development timelines or resource availability.* **MAN.1 BP.2: Establish and maintain the project life cycle and milestones.** [Outcome: b, c] Required milestones shall include certification milestones such as Stages of Involvement (SOI) with regulatory authorities. *Note: The project life cycle breaks down the project goals and time constraints into a high-level schedule with different milestones. It shall be suitable for the complexity and innovative character of the product. For each milestone, appropriate release criteria (required outputs and quality) and release method (e.g. a joint review meeting) should be defined. It can be useful to define different types of milestones (time-based milestone, results milestone, quality gate, etc.) with different release criteria.*

Base Practices	
	MAN.1 BP.3: Setup and maintain key project information. [Outcome: b] Key project information shall include at least the project goals, applicable roles and their assignees within the project, links to relevant plans, schedules and risks, and a documented communication mechanism. **MAN.1 BP.4: Define the work breakdown.** [Outcome: c] The work breakdown shall contain the necessary activities and their dependencies to achieve the milestones. *Note: The work breakdown will strongly depend on the selected method for development (classical, agile or hybrid). If necessary, adjust the project lifecycle after review of the work breakdown. Depending on the complexity of the project, it may be useful to focus iteratively on subsequent milestones. The granularity of defined activities must be appropriate for the complexity of the project.* **MAN.1 BP.5: Establish and maintain project plan.** [Outcome: c, d] The project plan shall contain the effort estimation, scheduling, and identification of required resources (incl. knowledge and budgeting) for each project activity. It shall be derived from the work breakdown, potential dependencies across individual activities, and available resources.

Base Practices	
	Note: Regular updates ensure early identification and communication of timeline risks and delays. Definition and assignment of roles to project activities is advised. *Documenting "Make or Buy" decisions may support the assignment of resources to project activities.* **MAN.1 BP.6: Ensure provision of required resources.** [Outcome: c, d] Required resources may comprise project team availability, skills and knowledge, required tools or budget for suppliers. *Note: Appropriate role descriptions including required competencies support a streamlined definition of project responsibilities.* **MAN.1 BP.7: Establish and maintain risk management.** [Outcome: e] Identified risks shall at least cover the areas of project risks and technical risks (safety and security risks). *Note: It is suggested to identify initial project risks based on a project feasibility analysis.* *For any technical requirement derived from a risk, an appropriate traceability shall be established.*

MAN.1

Base Practices	**MAN.1 BP.8: Establish and maintain effective project communication.** [Outcome: f] Effective project communication includes the identification of content/goal of communication, frequency, appropriate communication channels (e.g. reports, meetings, dashboards), and addressed stakeholders. A centralized documentation of decisions is suggested. *Note: Effective project communication may be based on a stakeholder analysis considering both internal (development team, production, quality assurance) and external stakeholders (customer, authorities). A communication matrix may serve as a suitable mechansim*
Process Outputs	Project Contract [Outcome: a] Project Handbook [Outcome: b] Project Plan [Outcome: c, d] Effort Estimation [Outcome: c, d] Risks [Outcome: e] Communication Mechanism [Outcome: f]

Table 3 shows the proposal for the process MAN.1 in the form of the SPICE standard.

In the table above, the proposed "process requirements" for the project management process are listed. Most of the base practices are phrased with "establish and maintain", which shall ensure a proper feedback of project management activities according to suitable methods (such as a PDCA cycle).

Another term often used is "(project) activities". This is intended to reflect a more understanding to account for both classical and agile or hybrid working methods. Thus, it can be regarded as work products, user stories, epics or similar. It is at the discretion of the organization itself, which granularity of activities is required. In the end, the required process outcomes have to be kept in mind when selected a certain level of granularity.

It could be discussed whether regular reviews and continuous improvement should be considered as basic project management activities. However, we believe the requirement for maintaining different activities and defining milestones is sufficient to achieve the process outcomes. The inclusion of continuous improvement would be more appropriate within a well-defined process measurement framework e.g. according to ISO/IEC 33020, which would be a logical step for future implementation.

Finally, it shall be noted that organizations are not required to set up processes according to the defined AeroSPICE process requirements. Yet, its goal is to enable a holistic development approach supporting the compliance with applicable regulations. And even beyond that, process checks based on AeroSPICE process requirements could be carried out in development projects in order to identify potential process risks and weaknesses. In that case, the checks must purely focus on the expected process purposes agnostic of the actual process implementation in the project - following the intention of SPICE.

Who may benefit?

Before concluding our work, we would like to highlight which stakeholders could benefit from the proposed approach

1. **Established OEMs** and approved design organizations (DOA under EASA / ODA under FAA) may define target process maturity levels for their suppliers to ensure consistent product quality and improve schedule adherence across the supply chain.
2. **Certification authorities** benefit from increased process transparency and traceability, enabling more efficient and structured compliance assessments.
3. **Start ups** particularly in emerging fields like drones or urban air mobility, can adopt the framework as a structured entry point for establishing airworthiness-compliant development processes.
4. **Suppliers** are supported by clearer process expectations, enabling more accurate effort and timeline estimations, thus reducing commercial and contractual risk.
5. **Airlines and maintenance organizations** may benefit from a dedicated and structured maintenance process group, enabling better risk control, improved traceability of modifications, and reduced operational incidents caused by maintenance errors.

All these stakeholder groups bear significant responsibility in ensuring that passengers and end customers ultimately benefit from improved product quality and a safer, more reliable flight experience.

Final Conclusion

The aerospace industry is undergoing a significant transformation, facing increasing complexity in systems engineering, cybersecurity, sustainability, and regulatory compliance. While existing standards such as ARP 4754B, DO-326A, or the EU Taxonomy for sustainable activities address critical aspects of system development, there is currently no holistic process framework that integrates these elements into a structured, transparent and efficient engineering process.

AeroSPICE, as proposed in this whitepaper, aims to bridge this gap by providing a universal process framework that ensures compliance with existing aviation regulations while improving process efficiency and project transparency. By defining structured processes, base practices, and process outputs, AeroSPICE aligns with well-established ISO/IEC 33060 principles and follows a top-down approach to derive development processes directly from regulatory and industry standards.

The key benefits of AeroSPICE include:

- A structured, process-driven approach to compliance with regulations like ARP 4754B, DO-326A, and sustainability requirements.
- Enhanced transparency and predictability in development schedules, benefiting both OEMs and Tier suppliers.
- Better integration of cybersecurity and safety processes within the engineering lifecycle.
- Improved traceability and standardization, reducing risks in certification and ensuring high-quality, robust aerospace products.

Call to Action

The content presented serves as an initial point of discussion. Further work is required to detail the remaining processes and to define a process assessment model in accordance to ISO/IEC 33020 including the definition of capability levels. However, for AeroSPICE to become an industry-recognized framework, collaboration with regulatory authorities (EASA, FAA), OEMs, suppliers and industry experts is essential. Aligning AeroSPICE with regulatory audit practices may reduce certification efforts and establish it as a key industry benchmark.

We invite all interested stakeholders to join this initiative by:

- Participating in expert discussions and workshops to define the details of AeroSPICE.
- Providing insights and industry experience to shape process outcomes and requirements.
- Supporting the institutionalization and dissemination of the framework within the aerospace sector.
- Collaborating in pilot implementations to test and validate the framework in real-world aerospace projects.

Let's build AeroSPICE together! If you are interested in contributing, please reach out to initiate a discussion on the next steps toward a structured, efficient, and industry-wide accepted aerospace process framework.

Interested in more Insights? Do not hesitate to contact us.

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