

REFINEMENT OF THE PAYLOAD-FOCUSED MISSION ASSURANCE PROCESS IN THE DESIGN PHASE AND PREPARATION OF AN EXPERT CONSULTATION ON THE REVISED PROCESS FOR SMALL SATELLITE MISSIONS IN THE CONTEXT OF NEW SPACE

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Abstract

This paper aims to evaluate and refine the PDR and CDR within a new mission and product assurance process. The primary goals are to assess how these processes are received, identify areas for improvement, and develop validation methods to ensure their effectiveness across various team sizes and expertise levels.

The paper employs a design research methodology, specifically an explanatory sequential design, to thoroughly explore the subject. Quantitative data was collected through an online survey conducted via survey.unibw.de, which provided a foundation for comprehensive data analysis. This was complemented by the preparation of expert interviews, serving as a qualitative method to gather in-depth insights from experienced professionals.

The paper focuses on several review categories that play a crucial role in the mission and product assurance process: Risk Identification, Schedule, Meeting Process, Data Management, RID, and the Rating System. These categories help structure the evaluation and identify specific strengths and weaknesses in the process. Additionally the review categories are rated by evaluation parameters such as Workload, Implementability for Small Teams, Review Duration, Flexibility, needed Space Experience, and Embedding into the Design Phase to ensure that the objectives of the new process are achieved.

Results of the performed survey indicate that the new PDR and CDR processes were generally well-received, with improvements noted over traditional processes. However, areas such as Risk Identification, Schedule, and Meeting Process were identified as needing further enhancement. Additionally, Workload and Implementability for Small Teams were noted as key challenges, that need to be addressed.

The paper proposes iterative improvements, focusing on refining evaluation parameters and review categories. These enhancements aim to effectively address the identified challenges and improve the overall process. Future interviews will delve deeper into the identified problem areas and validate the proposed improvements.

While the revised mission and product assurance process show promise, ongoing refinements are necessary to optimize their applicability for diverse teams. This paper contributes valuable insights into designing effective review processes for mission and product assurance, emphasizing the importance of participant feedback and iterative development.

Keywords

Mission Assurance; PDR; CDR

NOMENCLATURE

Formulae

$\bar{c}$	Average inter-item Covariance
$\bar{v}$	Average Variance
α	Cronbach Alpha
$\bar{x}$	Mean Value
N	Number of Components
n	Number of Data points
i	Running variable
x_i	Value of Datapoint

ECSS	European Cooperation for Space Standardization
IoT	Internet of Things
IQR	Interquartile Range
KNIME	Konstanz Information Miner
MBSE	Model-Based System Engineering
NPR	NASA Procedural Requirements
PDR	Preliminary Design Review
RID	Review Item Discrepancy
SeRANIS	Seamless Radio Access Networks for Internet of Space
UniBwM	University of the Bundeswehr Munich

Abbreviations

CDR	Critical Design Review
DSR	Design Science Research

1. INTRODUCTION

In recent years, the New Space era has transformed the space industry, driven by private companies and new entrants that demand rapid, cost-effective innovation [1]. This

shift has intensified competition, compelling organizations to deliver advanced technological capabilities under stringent budgetary and temporal constraints, a stark contrast to the resource-heavy, government-funded missions of the past. Traditional mission assurance processes, developed for large-scale projects, frequently prove inadequate for the accelerated development schedules and cost constraints characteristic of small satellite missions [2]. These missions are increasingly pivotal to modern space exploration, necessitating efficient and reliable approaches to mission assurance. A new mission and product assurance process, applied to the SeRANIS project—a multifunctional small satellite initiative—addresses these challenges by streamlining the PDR and CDR phases. This general process emphasizes modular payloads, qualified platforms, and simplified review procedures to enhance efficiency and reduce bureaucratic overhead while ensuring reliability [3]. This paper evaluates and refines this process, aiming to establish a robust, generalizable framework for mission assurance in the New Space era, with significant implications for the design and implementation of small satellite missions in a rapidly evolving industry.

The New Space paradigm marks a significant departure from traditional space exploration, characterized by increased private sector involvement, innovative approaches to technology development, and a focus on cost reduction [1]. Unlike conventional missions, which often entail prolonged development periods and substantial financial outlays, New Space prioritizes agility, scalability, and broader access to space. The SeRANIS project exemplifies this transformation, serving as a publicly accessible, multifunctional experimental facility in orbit [3]. It integrates over ten advanced technologies, including 6G mobile communications, laser communication, radiation shielding, and IoT, distinguishing it from smaller CubeSats that typically adopt a singular payload approach [4]. By establishing an interdisciplinary Space Innovation Hub, SeRANIS facilitates collaboration among industry, the German Armed Forces, and academia, fostering scientific expertise and demonstrating cutting-edge capabilities. This context underscores the critical need for a general mission and product assurance process that is flexible, efficient, and tailored to the rapid development cycles and cost constraints of small satellite missions like SeRANIS, ensuring their success in the dynamic New Space environment.

Conventional mission assurance processes, based on ECSS and NPR standards, are designed for large-scale missions, rendering them impractical for small satellite projects [2]. These standards require extensive documentation and complex PDR and CDR procedures, posing significant challenges for universities and emerging space companies with limited expertise and funding. Such requirements often lead these organizations to rely on pre-engineered platform hosts to mitigate risks and reduce costs [2]. The new mission and product assurance process, applied in the SeRANIS project, focuses on modular payloads and qualified platforms, incorporating document-free reviews and simplified online databases to reduce bureaucracy and enhance flexibility. However, its effectiveness in meeting the specific requirements of New Space missions, particularly in terms of reliability and scalability, requires rigorous validation to ensure it can be broadly applied to small satellite missions across the aerospace sector.

This research aims to refine and validate a new general mission and product assurance process, as applied in the SeRANIS project, with a particular focus on optimizing the

PDR and CDR phases. The study evaluates the process's efficiency, usability, and reliability to ensure alignment with the cost constraints and rapid development cycles characteristic of New Space [3]. By analyzing participant feedback and performance metrics, the research identifies areas for improvement, aiming to enhance the process's applicability to small satellite missions. The objectives include developing a robust, generalizable framework that supports modular payload integration, reduces resource demands, promotes innovation in mission assurance practices, and contributes to the aerospace industry by supporting the operational use of advanced technologies.

To guide the evaluation and refinement of the new mission and product assurance process applied in the SeRANIS project, this paper researches the following questions:

- 1) How was the new mission and product assurance's PDR and CDR processes received?
- 2) How can the PDR and CDR process of the new mission and product assurance process be refined?

The paper is organized as follows: Chapter 2 outlines the research design, detailing quantitative surveys and qualitative interviews to evaluate the new process. Chapter 3 presents findings from participant feedback and process assessments, highlighting key data points. Chapter 4 interprets these results, identifying strengths, weaknesses, and potential improvements in the context of New Space requirements. Chapter 5 summarizes the key outcomes, discusses broader implications for small satellite mission assurance, and suggests directions for future research to further refine and apply the process in the aerospace industry.

2. METHODOLOGY

This chapter provides a comprehensive overview of the methods used to address the research questions, aligning with state-of-the-art practices in space sector process development. It details a systematic approach using qualitative and quantitative methods to evaluate and refine a new mission and product assurance process, emphasizing efficacy and relevance.

2.1. Research Approach

This chapter outlines a state-of-the-art research approach integrating DSR and Explanatory Sequential Design to develop and refine a mission assurance process, ensuring a rigorous, iterative methodology for space sector challenges [5]. This approach combines practical artefact creation with mixed-methods data collection to address inefficiencies in PDR and CDR processes.

Design Science Research (DSR) creates and evaluates innovative artefacts to solve real-world problems in engineering and management [5]. It involves six steps: problem identification, objective setting, design and development, demonstration, evaluation, and communication, with iteration for improvement [5]. Selected for its focus on practical solutions, DSR was applied to identify inefficiencies in ECSS and NPR standards, design a streamlined PDR and CDR process, demonstrate its application, evaluate via feedback and metrics, and iterate for reliability [6].

Explanatory Sequential Design, a mixed-methods strategy, collects quantitative data followed by qualitative methods to explain findings, as shown in Figure 1 [7]. It enhances validity through data triangulation [8]. Surveys iden-

tified trends in process effectiveness, followed by expert interviews to explore issues qualitatively, ensuring comprehensive insights [9]. This design supports iterative refinement of the mission assurance process.

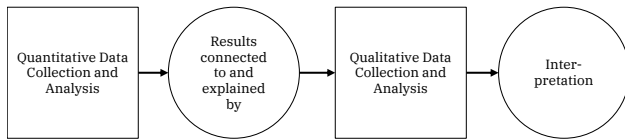


FIG 1. Flowchart of Explanatory Sequential Design adapted from [7]

2.2. Process Parameters

This chapter outlines critical process parameters for optimizing the mission assurance process during PDR and CDR phases, providing a framework to assess and enhance process development [2]. It maps parameters to evaluation criteria for systematic performance evaluation.

Parameters include a new Schedule, Meeting Process, Risk Identification strategy, Data Management process, Rating System, and RID process, aligned with performance criteria—time, cost, quality, capacity, flexibility, integration, and complexity [10]. These map to goals: reduced Review Duration (time), reduced Workload (cost), increased Embedding into the Design Phase (quality), increased Implementability for Small Teams (capacity), increased Flexibility (flexibility), improved Data Management (integration), and reduced needed Space Experience (complexity) [2].

Review Categories, defined as latent variables, include a flexible Schedule differentiating payload/platform and mission reviews, an expert-led Meeting Process with limited external consultation and preference for personal/online meetings, a Risk Identification strategy delegating responsibilities with database support, a single-source online Data Management system, a traffic-light Rating System (green/yellow/red) with a purple category for missing PDR information, and a streamlined RID process with instant resolutions [2, 6-11]. These enhance efficiency and reduce complexity.

Evaluation Parameters, established as latent variables, include Review Duration, Workload, Embedding, Flexibility, needed Space Experience, and Small Teams, aligned with performance criteria [2, 2], [10, 4]. These assess process goals via an evaluation matrix, analyzing each review category's impact on goals and vice versa, ensuring a comprehensive assessment of process effectiveness.

2.3. Data Collection

Data collection is critical for quantitatively evaluating the mission assurance process, ensuring valid and reliable findings [11]. This chapter details questionnaire design, sampling, and data collection processes, as outlined in Chapter 2.1, using Survey-UniBwM for reliable, user-friendly data gathering to support PDR and CDR process refinement.

The Deductive Approach to Questionnaire Design, a theory-driven method, starts with a theoretical construct broken into facets to create precise questions, ensuring a structured framework for evaluating PDR and CDR elements [12]. Questions were refined to align with constructs like review efficiency, ensuring validity and relevance to research objectives. This approach supports logical question

flow and data traceability, enabling hypothesis testing and robust process evaluation.

Question Design, a mix of closed-ended 5-point Likert scales and open-ended questions, measures variables and gathers qualitative insights for Review Categories and Evaluation Parameters (Chapter 2.2) [13]. Likert scales quantify attitudes and satisfaction on a “strongly disagree” to “strongly agree” range, enabling straightforward analysis [14]. Open-ended comments allow respondents to elaborate, providing nuanced feedback. This combination supports the explanatory sequential design, balancing quantitative and qualitative data for comprehensive PDR and CDR process refinement.

The Questionnaire Structure, a methodical procedure, includes an introduction, personal background, PDR and CDR evaluation, comparison questions, skill evaluation, and an interview option [2]. Evaluation blocks target Review Categories with questions tailored to Evaluation Parameters (Chapter 2.2), using Likert scales and comments. Comparison sections assess overarching process goals for respondents with prior experience. This structure ensures comprehensive data collection for robust PDR and CDR process refinement.

Mixed Methods Sampling, combining cluster, convenience, and self-selection sampling, ensures a robust and representative sample for the mission assurance process [15]. Participants are grouped by roles (e.g., Payload Supplier, Review Board, Mission Owner) using cluster sampling, with surveys distributed via internal channels for convenience. Self-selection allows voluntary participation in online surveys, encouraging motivated responses [16]. This approach supports comprehensive data collection for PDR and CDR process evaluation.

For the Data Collection Process, online surveys via Survey-UniBwM, delivered through emails or mobile-optimized links (e.g., SMS, apps, QR codes), ensure cost-efficient and accessible data collection for PDR and CDR process evaluation [11]. This method supports high response rates and easy data extraction, enabling quantitative analysis and qualitative follow-up for robust process refinement.

2.4. Data Extraction

Data extraction ensures the integrity of questionnaire data for evaluating the mission assurance process, using survey.unibw.de, based on SoSci Survey [17]. This chapter outlines tools and procedures for extracting data to support robust PDR and CDR analysis.

The Tools and Software Used, survey.unibw.de, manages questionnaires for personnel groups (e.g., Payload Supplier, Review Board, Mission Owner) with consistent structure, as outlined in Chapter 2.3 [17]. Excel-based Connection Maps categorize question blocks to identify consistent and varying responses, ensuring comprehensive PDR and CDR analysis.

Extraction Procedures, data from survey.unibw.de was collected with a response period extended beyond the planned 30 days to June 15, 2024, for increased participation. The total data collection periods were as follows: for Payload Supplier, from March 17, 2024, to June 15, 2024; for Review Board, from April 3, 2024, to June 30, 2024; and for Mission Owner, from April 7, 2024, to May 30, 2024. Data was exported in XLSX format for compatibility with analytical tools [18]. A question dictionary streamlined analysis by referencing question IDs for inversion, as detailed in Chapter 2.5.

2.5. Post-Processing

Post-processing ensures the integrity and usability of questionnaire data for evaluating the mission assurance process, using KNIME, an open-source platform with visual workflows [19]. This chapter details data cleaning, transformation, and missing data handling for robust PDR and CDR analysis.

Data Cleaning refines the dataset by correcting errors for PDR and CDR analysis [20]. Duplicate removal was unnecessary due to the survey's single-response design [21]. In KNIME, automated scripts eliminated -1 ("No Answer") and -9 ("Question Skipped") values outside the 5-point Likert scale using the Math-Formula-(Multi-Column)-Node [22]. Feature selection via the Column-Filter-Node separated the database into sub-databases (personnel, comments, evaluation questions), retaining relevant data like CDR evaluation questions [23]. String data was converted to numbers, and inverted questions were adjusted, ensuring a consistent dataset.

Data Transformation modifies the dataset for consistency in KNIME. CDR answers were copied to PDR questions using the Table-Cropper-Node, with databases updated via the Table-Updater-Node. Questionnaire types were annotated (P, B, O for Payload Supplier, Review Board, Mission Owner) using the String-Cleaner-Node. Question-IDs were renamed via the Column-Renamer-Node, and databases were combined for unified analysis, ensuring an analyzable dataset for the mission assurance process.

Handling Missing Data ensures dataset validity. Listwise deletion in KNIME removed invalid cases (e.g., test-runs, incomplete responses) using the Row-Filter-Node [24, 539-540]. Unanswered or unposed questions were left empty to avoid bias. This approach maintained data integrity for reliable PDR and CDR evaluation.

2.6. Data Analysis

Data analysis transforms questionnaire data into insights for evaluating the mission assurance process, using KNIME and Excel to uncover patterns for PDR and CDR refinement [19]. This chapter details data validation, descriptive statistics, and analysis tools.

Data Validation ensures dataset reliability for PDR and CDR analysis [25]. Cronbach's alpha measured internal consistency, calculating coefficient α for unidimensional latent variables (Formula 1) [26]. Questions were sorted into an evaluation matrix for Review Categories and Evaluation Parameters (Chapter 2.2). Content validity used a rating matrix [27], with format and logic checks ensuring consistency [28]. Expert review validated instruments [29]. KNIME nodes calculated reliability, ensuring robust data quality.

$$(1) \quad \alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N - 1) \cdot \bar{c}}$$

Descriptive Statistics summarize dataset characteristics for PDR and CDR analysis, using mean (Formula 2), median, and IQR [30]. KNIME calculated mean and median, with IQR computed in Excel. Visualizations (Box and Whisker Diagrams, Radar Charts, Histograms, Violin Charts) showed distribution and trends. Mean values ranked questions across review categories, evaluation parameters, and personnel groups in Excel.

$$(2) \quad \bar{x} = \frac{\sum_{i=1}^n x_i}{n}$$

Tools for Analysis included KNIME for statistical calculations via the Statistics-Node [19], Excel for mean ranking and visualizations [31], and Power BI for Violin Diagrams [32]. KNIME exported data to Excel spreadsheets (Cleaned Survey Data, Comments Cluster, CDR/PDR Statistics, Cronbach Alpha) for seamless analysis of the mission assurance process.

3. RESULTS

This chapter presents results from the survey on the PDR and CDR process, process iteration based on findings, and preparation for follow-up interviews to evaluate the iterated process. The Summary of Extracted Data outlines survey participation and data validation. Descriptive Statistics Results analyze survey responses, highlighting satisfaction levels across review categories and evaluation parameters. Process improvement iterations address identified weaknesses. Findings are synthesized in Chapter 4, which discusses quantitative and qualitative insights and implications for future interviews. Please note that this paper will focus on the worst received review categories and evaluation parameters.¹

3.1. Summary of Extracted Data

The survey included 43 Payload Suppliers, 8 Review Board members, and 7 Mission Owners, with high participation ensuring representativeness due to shared review process experience. Cronbach Alpha values, calculated using 1 and shown in Table 1, indicate acceptable validity despite some categories falling below literature standards due to selective question design [33]. Insights were validated via follow-up interviews.

3.2. Descriptive Statistics Results

The Box & Whisker diagram (Figure 2) shows ratings on a Likert scale (1 = not satisfied, 5 = extremely satisfied) for Review Categories. The scale uses color coding: red for scores 1 – 2, yellow for 2.5 – 3.5, green for 4 – 5. Ratings above 3 (satisfied) are positive. Risk Identification's median and mean are just above 3, in the yellow-to-green zone. This suggests slight satisfaction with room for improvement. Schedule ranges from above 2.5 to 4. Its median is 3.3 and mean is 3.35. This indicates moderate satisfaction and varied opinions. Meeting Process spans unsatisfactory to satisfactory. Its median is 3.4 and mean is 3.7. This reflects average satisfaction and diverse experiences. Data Management and RID have medians and means above 3.5, in the green zone. This indicates strong performance. Rating System has the highest median and mean, around 4. This shows high satisfaction. All categories rate above 3, suggesting a satisfactory process. Means are in Table 2.

The radar chart (Figure 3) shows results by Review Categories and project role on the Likert scale (values rounded). For Risk Identification, Payload Suppliers and Review Board rate 3.5, matching the overall. Main Board rates it 4.0. The larger Payload Supplier group pulls the overall to 3.6. Equal weighting applies by importance. Schedule's overall rating is 3.5. Payload Suppliers and Review Board rate 3.3. Main Board rates 3.7. Meeting Process overall rating is 3.5. Review Board matches this. Payload Suppliers and Main Board rate 3.7. Data Management overall rating is 3.8. Review Board and Main Board align with this. Payload

¹ Complete survey data, all iterative improvements and additional diagrams may be accessed by contacting the author of this paper.

TAB 1. Values & Scale of Cronbach Alpha [33]

Review Categories		Evaluation Parameters		Scale of Cronbach Alpha	
General:	0.91	General:	0.91	Value	Internal Consistency
Schedule:	0.65	Duration:	0.65	$\alpha \geq 0.9$	Excellent
Meeting Process:	0.79	Workload:	0.79	$0.9 > \alpha \geq 0.8$	Good
RID:	0.83	Embedding:	0.63	$0.8 > \alpha \geq 0.7$	Acceptable
Rating System:	0.42	Flexibility:	0.32	$0.7 > \alpha \geq 0.6$	Questionable
Risk Identification:	0.56	Implementability:	0.59	$0.6 > \alpha \geq 0.5$	Poor
Data Management:	0.79	Space Experience:	0.79	$0.5 > \alpha$	Unacceptable

Suppliers rate 3.2. RID overall rating is 3.8. Review Board and Main Board align with this. Payload Suppliers rate 3.5. Rating System overall rating is 3.8. Review Board and Main Board align with this. Payload Suppliers rate 4.1. Payload Suppliers favor Rating System and Meeting Process. Review Board rates Data Management and RID higher. Main Board views Risk Identification and Schedule positively. This indicates perceptual differences.

The radar chart (Figure 4) shows results by Evaluation Parameters and project role. Means are in Table 2 (values rounded). Workload's overall rating is 3.3. Payload Suppliers and Review Board match this. Main Board rates 3.8. Implementability overall rating is 3.4. Payload Suppliers and Review Board match this. Main Board rates 2.6, below 3. Review Duration overall rating is 3.5. Payload Suppliers and Review Board match this. Main Board rates 3.9. Flexibility overall rating is 3.5. Payload Suppliers rate 3.3. Main Board rates 3.6. Review Board rates 4.1. Needed Space Experience overall rating is 3.9. Payload Suppliers rate 3.7. Review Board and Main Board rate 4.0. Embedding overall rating is 3.4. Payload Suppliers rate 3.3. Review Board rates 3.6. Main Board rates 3.8. Payload Suppliers and Review Board rate Implementability positively compared to Main Board. Review Board excels in Flexibility and Space Experience. Main Board views most parameters well, except Implementability. This highlights areas for improvement.

3.2.1. Risk Identification

The average rating for the Risk Identification review category is 3.25 (Table 2). This rating makes it the lowest-rated category among all the review categories analyzed (Figure 2). The lowest-rated pairing of Review Category and Evaluation Parameter within this category is RM24_03, which concerns Flexibility. It has an average score of 2.39. The histogram of survey results in Diagram 5 depicts the ratings for RM24_03. This item was rated by Payload Suppliers. The distribution shows a "right-skewness," with the most common rating being 2 from 9 respondents with previous experience and 2 without. Respondents with no previous experience, while still rating below 3, gave slightly higher scores. The most common rating from 4 respondents without experience is 3. This compares to respondents with experience, who most commonly gave a rating of 2. Additionally, 1 respondent with previous experience gave a rating of 4. One respondent with experience and one without gave a rating of 1. Categorized by experience, participants with no experience responded with a right-skewed Gaussian distribution between 1 and 4. Participants with experience responded with a linearly increasing distribution from 1 to 3. In conclusion, there are concerns about the Flexibility of the Risk Identification in the review. Comments, available by contacting the author along with extracted data, highlight possible causes for

these problem areas. These include a lack of clear communication of individual responsibilities within the team. This can lead to confusion and inefficiency. Payload Suppliers have expressed discomfort at feeling too closely monitored. This impacts Flexibility. There is also a need to clarify the process approach for each team member. This ensures everyone understands their specific role and responsibilities within the project. Therefore, improving the Flexibility of this review category is necessary to meet the different needs of various users.

3.2.2. Schedule

The average rating for the Schedule review category is 3.36 (Table 2). This rating is the second lowest among review categories (Figure 2). The lowest-rated item, SD24_02, concerns Workload. It averages 2.60. Diagram 6 shows SD24_02 ratings by Payload Suppliers and Review Board Members. The distribution is right-skewed. The most common rating is 3 from 11 experienced Payload Suppliers, 1 non-experienced Payload Supplier, 4 experienced Review Board Members, and 2 non-experienced Review Board Members. Review Board Members typically rate 3. Payload Suppliers commonly rate 2 from 12 experienced and 3 non-experienced respondents. The rating 1 was given by 2 experienced and 2 non-experienced Payload Suppliers. The rating 4 was given by 3 experienced Payload Suppliers, 1 non-experienced Payload Supplier, and 2 non-experienced Review Board Members. Payload Suppliers show a right-skewed Gaussian distribution between 1 and 4. Experienced Review Board Members show a linear decrease from 3 to 4. Non-experienced Review Board Members rate 2. Workload and Review Duration raise concerns. Comments, available by contacting the author with extracted data, indicate small team sizes cause delays. Unclear deadlines and lack of differentiation for underdeveloped payloads create inefficiencies. Clarifying timelines and processes is needed. Reducing Workload and Review Duration is essential.

3.2.3. Meeting Process

The average rating for the Meeting Process review category is 3.42 (Table 2). This rating is the third lowest among review categories (Figure 2). The lowest-rated item, MP26_05, concerns Implementability for small teams. It averages 2.08. Diagram 7 shows MP26_05 ratings by Review Board Members and Mission Owners. The distribution is right-skewed. The most common rating is 2 from 1 experienced Review Board Member, 1 non-experienced Review Board Member, and 5 experienced Mission Owners. Review Board Members typically rate 1 from 3 experienced members. Mission Owners commonly rate 2. The rating 3 was given by 2 experienced Review Board Members. The rating 4 was given by 1 non-experienced Review Board Member.

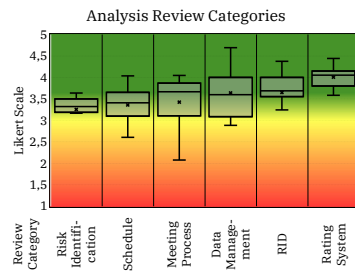


FIG 2. Survey Results categorised by Review Categories (see Chapter 2.2)

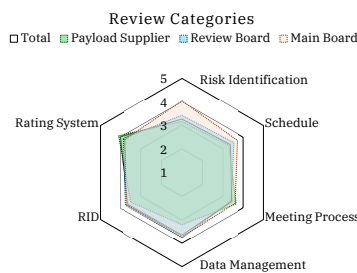


FIG 3. Survey Results categorised by Review Categories and project role (see Chapter 2.2)

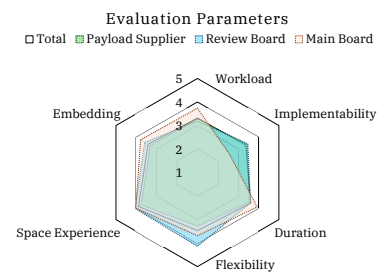


FIG 4. Survey Results categorised by Evaluation Parameters and project role (see Chapter 2.2)

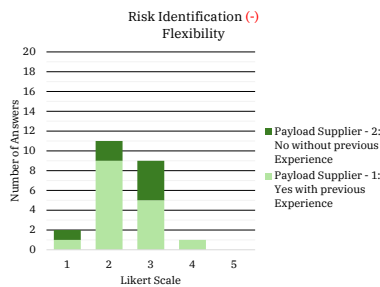


FIG 5. Histogram of Survey Results on Risk Identification Flexibility

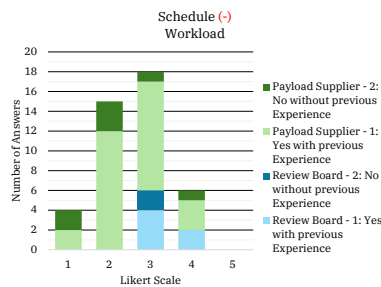


FIG 6. Histogram of Survey Results on Schedule Workload

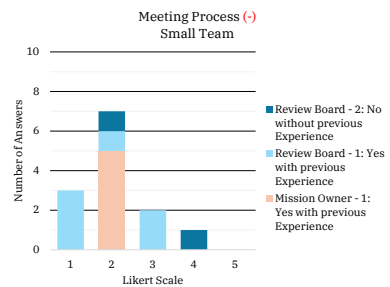


FIG 7. Histogram of Survey Results on Meeting Process Implementability

TAB 2. Mean Values of Ratings by Review Categories & Evaluation Parameters

Review Category	Mean Rating	Evaluation Parameters	Mean Rating
Risk Identification	3.25	Workload	3.22
Schedule	3.36	Implementability	3.24
Meeting Process	3.42	Embedding	3.40
Data Management	3.64	Review Duration	3.40
RID	3.65	Flexibility	3.52
Rating System	4.01	Needed Space Experience	3.89

Experienced Mission Owners show a singular point at 2. Experienced Review Board Members show a right-skewed U-shaped distribution between 1 and 3. Non-experienced Review Board Members show a two-point distribution at 2 and 4. Implementability, Workload, and Review Duration raise concerns. Comments, available by contacting the author with extracted data, indicate insufficient prior communication causes inefficiencies. The process lacks refinement, leading to unclear modes and responsibilities. General training and team-building are needed for better collaboration. Improving Implementability and reducing Workload is essential to shorten Review Duration.

3.3. Process Improvement Iteration

In this chapter, focusses on addressing the identified problem areas discussed in the previous subchapter, with a specific orientation towards improving each evaluation parameter. The improvements are guided by the comments extracted from the database as well as own interpretations and ideas.² The cluster of comments is consistent with the evaluation matrix. Where each row represents a review category and each column represents an evaluation parameter. As a result, the cells represent a pairing of review category and evaluation parameter into which the comments from the survey have been sorted. All this provides valu-

able insights into the areas for improvement identified by the survey and the corresponding histograms of responses. The focus is on improving the evaluation parameters (Workload, Implementability, Embedding, Review Duration, Flexibility and Space Experience), which will increase satisfaction with the general review categories. It also serves to improve process evaluation and its research requirements. This chapter explains the iterated process improvements implemented to refine the review process. For each evaluation parameter, a pictogram is provided to illustrate the specific process improvements made, ensuring a clear and visual representation of the enhancements.

3.3.1. Workload

The comprehensive analysis of the results of the survey on reduction of the Workload, the comments made by the respondents, their interpretation and own ideas led to the formulation of the following improvements:

- ① In general, it would be beneficial to consider increasing the size of the team to an adequate number of the required working force per payload and review board. This can alleviate individual workloads, improving efficiency and output quality. Should this be infeasible, the following main improvements shall be implemented:
- ② Implementation of additional review workshops: Hosting more review workshops will enhance collab-

²Complete survey data may be accessed by contacting the author of this paper.

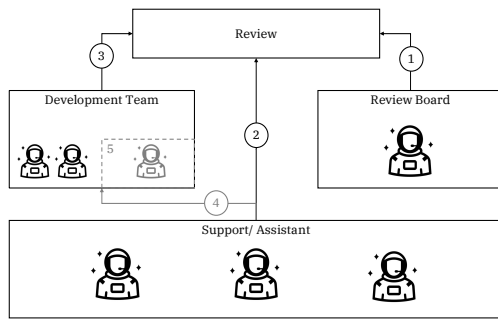


FIG 8. Pictogram of Review Process Iteration for Reduction of Workload

oration and knowledge sharing among team members, leading to more efficient problem-solving and process improvements.

- ② Access to external assistance in the form of a knowledge and documentation service:
Utilizing external resources for knowledge and documentation can reduce the internal burden on team members, allowing them to focus more on core tasks.
- ③ A shift in focus towards development, accompanied by a reduction in team-internal documentation:
By prioritizing development over internal documentation, the team can concentrate on innovation and productivity, potentially accelerating project timelines.

In addition, the following improvements are proposed:

- ④ The establishment of a standing support team for problems, which would provide documentation assistance:
Creating a dedicated support team for documentation issues will provide ongoing assistance and streamline processes, freeing up core team members to focus on their primary responsibilities.
- ⑤ The introduction of a new, internal position, responsible for Risk Identification:
Appointing a team member to focus on risk identification will proactively address potential issues, reducing disruptions and ensuring smoother project execution.

3.3.2. Implementable for Small Teams

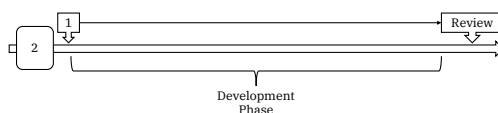


FIG 9. Pictogram of Review Process Iteration for Implementability for Small Teams

The comprehensive analysis of the results of the survey on the Implementability for small teams, the comments made by the respondents, their interpretation and own ideas led to the formulation of the following improvements:

- ① Clear communication of responsibilities:
Prior to the commencement of the development phase, it is recommended that the responsibilities of each team member be clearly communicated. In contrast to the

direct hierarchical structure typical of larger organisations, this will facilitate a more collaborative approach to Risk Identification and Meeting Processes.

- ② Workshop on single source database:
A workshop is to be conducted for the purpose of familiarising all members of the team with the single source database. This will ensure that the entire team has a comprehensive understanding of the tool, rather than merely the system administrators.

3.3.3. Embedding into Design Phase

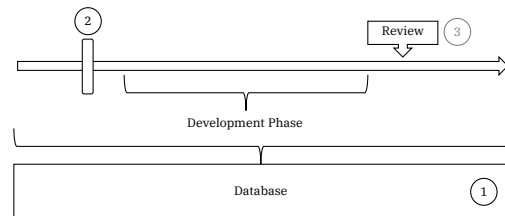


FIG 10. Pictogram of Review Process Iteration for better Embedding into Design Phase

The comprehensive analysis of the results of the survey on the Embedding, the comments made by the respondents, their interpretation and own ideas led to the formulation of the following improvements:

- ① Utilizing a superior database or alternative development process:
Exploring databases superior to "Valispace" or adopting a different development process, such as MBSE, can enhance the review process by leveraging advanced programming tools for more effective design integration and analysis. Are there any existing alternatives that could be considered?
- ② Advance Communication and Clear Definition of the Review Process:
Clearly defining the review process and its objectives, including risk identification, and communicating these elements in advance, helps ensure that all process participants understand the process and its role within the design phase, leading to more effective implementation.
- ③ Distribution of "hand-outs" at meeting about process & current situation:
Providing handouts that detail the process and the current situation during meetings allows participants to follow discussions more easily and ensures that everyone has access to consistent information, enhancing engagement and understanding.

4. DISCUSSION

This chapter offers a critical analysis of, and implications drawn from, the results presented in the preceding chapter. This chapter is structured into three subsections. The "Interpretation of Key Findings" chapter elucidates the process improvement iterations by integrating descriptive statistical results. The "Implications of Study" chapter articulates the broader benefits and contributions of this paper to the field. The "Limitations of Study" chapter addresses the challenges and constraints encountered in the analysis, providing a balanced perspective on the reliability and applicability of the findings.

4.1. Interpretation of Key Findings

This chapter provides an analysis of key findings from the descriptive statistic results for the iterative process improvement. By examining the areas of workload, implementability for small teams, review duration, flexibility, needed space experience, and embedding into the design phase, areas of lower satisfaction are identified and targeted improvement proposals are developed. The following paragraphs detail the specific issues, feedback from project roles, and proposed solutions.³

The Workload component received notably lower levels of satisfaction in several areas, particularly concerning the Schedule and RID. Payload Suppliers and the Review Board both expressed lower levels of satisfaction with the Schedule (Figure 6), while the RID received unfavourable ratings from all three personnel groups. Further insights suggest potential solutions, such as creating new positions and expanding the team size, which are reflected in the five improvement proposals outlined in Chapter 3.3.1. During the interviews, the first three improvement proposals will be presented, as they are anticipated to offer the most significant benefits.

Small teams face challenges with the Meeting Process and Data Management, with particular emphasis on the Meeting Process. The Review Board and Mission Owners both expressed lower levels of satisfaction with the Meeting Process (Figure 7), while Data Management received negative feedback from all three personnel groups. Insights suggest ways to improve communication, leading to two improvement proposals detailed in Chapter 3.3.2.

The Embedding evaluation parameter did not receive lower levels of satisfaction overall, but the worst ratings within this evaluation parameter were for the Schedule and Meeting Process. The direct thematic connection between Data Management and embedding into the design phase leads to the focus in said evaluation parameter. Insights suggest better communication and the use of different databases, such as Valispace. This resulted in three improvement proposals in Chapter 3.3.3, with the first two proposals being highlighted in the interview due to potential conflicts with workload goals.

In general, the new process was well received and the review categories were seen as improvements over the traditional process. However, the descriptive statistics described in Chapter 3.2 indicate that there is still room for improvement, particularly in the review categories of Risk Identification, Schedule and Meeting Process. These areas received different ratings across the different evaluation parameters, highlighting the different focus of the project roles during the review. Specifically, the Main Board viewed Risk Identification positively, likely due to its strategic oversight, while Payload Suppliers perceived Data Management more negatively, indicating challenges with data accessibility and integration. Conversely, positive experiences were noted with the new RID process and Rating System, with positive evaluations suggesting that these systems are accessible to users without space-specific expertise. Despite these positive aspects, Workload and Implementability for small teams were identified as areas for improvement. This suggests a need for scalable solutions that do not overwhelm team resources. Based on these findings, iterative improvements to the process were developed, as described in the Chapter 3.3.

³Complete survey data may be accessed by contacting the author of this paper.

4.2. Implications of Study

This paper offers several significant benefits, starting with the completion of the first step of the explanatory sequence design as outlined in the methodology Chapter 2.1. The successful execution of the survey on the process represents a crucial foundational step. Additionally, the paper provides a comprehensive analysis of the resultant descriptive statistics.

While the new process generally received positive evaluations, the analysis identified areas where there is still room for improvement. Addressing these identified problem areas led to the development of iterative process improvements. This work lays a solid foundation for the second step of the explanatory sequence design, ensuring a refined process.

4.3. Limitation of Study

This paper, while comprehensive, has certain limitations that must be acknowledged. One significant limitation is the small number of survey participants. Since the questionnaire was limited to individuals who worked on the project, the participant pool was inherently restricted, albeit homogenous. This homogeneity gives validity to the extracted data, but also increases the statistical weight of individual answers, which may influence the results.

Additionally, the new process was only applied once, limiting the scope of the paper to comparisons with the traditional processes. This single application does not account for variability that could arise from repeated use. Repeated utilization of the new process, combined with subsequent feedback, could reveal areas for further improvement that were not initially apparent.

Further refinement and evaluation of the findings from this paper are necessary. In this context, the planned subsequent interviews will play a crucial role. These interviews are designed to provide deeper insights and serve the purpose of validating and refining the paper results, ultimately contributing to the iterative improvement of the process.

5. CONCLUSION AND OUTLOOK

This chapter summarizes the key findings of the paper, highlighting the achievements and contributions made through the research. It encompasses two main subchapters: Conclusion, which summarizes the study's primary outcomes and their implications, and Future Research Direction, which outlines potential areas for further investigation and continuous improvement. Together, these chapters provide a comprehensive overview of the study's impact and offer a roadmap for future research endeavours to build upon the work presented.

5.1. Conclusion

This paper explored the new mission and product assurance processes, focusing on how the PDR and CDR were received and how they might be refined and validated.

1) How was the new mission and product assurance's PDR and CDR processes received?

This research question is answered by the results of this paper contained in Chapter 3.2. The new mission and product assurance processes, including the PDR and CDR, were generally well received. The introduction of revised review categories was seen as an improvement over the traditional processes. However, the results of the survey conducted indicated that there is room for

improvement, particularly in areas such as Risk Identification, Schedule and Meeting Process. In addition, positive experiences with the new RID process and Rating System were noted. The evaluation parameters were largely considered satisfactory, in particular with regard to the needed Space Experience, which meant that the process was accessible to non-space experts. However, Workload and Implementability for small teams were identified as areas requiring attention.

2) How can the PDR and CDR process of the new mission and product assurance process be refined?

This research question is answered through the results in this paper contained in Chapter 3.3. The refinement of the PDR and CDR processes was driven by the identification of problem areas highlighted in the survey results, comments from the survey participants, and the interpretation of these results alongside original ideas. Iterative improvements were proposed, focusing on enhancing evaluation parameters and refining review categories to address specific issues. These refinements thereby aim to address the challenges identified.

In conclusion, although the feedback on the process used shows promising results, further refinements are required to optimise the PDR and CDR processes. The iterative process improvements have been designed to address the identified shortcomings. In order to evaluate these improvements and validate the identified problem areas, interviews are required in accordance with the explanatory sequential design of the process development. Consequently, these interviews will provide critical insights into the perceived problem areas of the review process and evaluate the effectiveness of the implemented improvements.

5.2. Future Research Directions

Building on the findings and preparations made in this paper, the immediate next step is to conduct interviews to evaluate the newly iterated process improvements. These interviews are crucial as they are designed to gather detailed feedback on the perceived problem areas of the review process and to assess the effectiveness of the recent changes. The insights gained from these interviews will inform further iterative improvements, ensuring that the process continues to evolve and better meet the needs of all stakeholders. Further analysis of the survey data should also be undertaken to deepen the understanding of how different factors influence the perceived uptake and effectiveness of the PDR and CDR processes. In particular, future research should examine the preparedness of review participants and explore the correlation between the responses of space experts and non-space experts. Understanding how these different groups perceive the process can provide important insights into tailoring the review approach to different levels of expertise. In addition, research should focus on analysing the level of complexity and skill required for payload development. These factors can have a significant impact on how effectively teams can implement the review processes and provide valuable data for further refinement. Understanding these variables can lead to more targeted improvements that address the unique challenges of payload development. The involvement of Mission Owners in reviews and payload development should also be considered. Their involvement can provide unique perspectives and insights, potentially identify new areas for improvement, and ensure that review processes are aligned with project objectives. To

achieve this, refining the existing database for further analysis will enable more nuanced investigations into process effectiveness. A robust database will support ongoing research efforts and facilitate the identification of trends and correlations that might otherwise remain hidden.

Beyond the immediate scope, future research should focus on applying the new process to other projects. This wider application will provide a more comprehensive assessment of the effectiveness of the process across different contexts and teams. Feedback from these additional applications will be invaluable in identifying any new issues or areas for improvement. By incorporating continuous feedback and making iterative improvements, the process will be able to adapt and improve with each application.

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