

Utilizing Model-Based Systems Engineering (MBSE) for Tailoring an Islamic Values-Based Sounding Rocket Development Cycle

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ABSTRACT

This paper presents a novel life cycle model for developing university-scale sounding rockets, integrating technical and Islamic perspectives. The model, referred to as the 'Water Spring Model,' aims to align aerospace engineering processes with systems engineering (SE) phases and integrate Islamic values such as Itqan (perfection in work), Shura (consultation), and Jihad (intellectual struggle). The model was successfully applied in a small project that reached the simulation stage, providing a comprehensive framework connecting life cycle phases with the Aerospace Vehicle Design (AVD) process in a unified diagram. Despite the project's limited scope, the model was found to be beneficial for fostering a holistic understanding among team members and connecting their work to motivating values. Feedback highlighted the need for improved governance, cross-departmental communication, and the integration of unified project models. Future work will detail the model's processes and further integrate Tafsir and Fiqh methodologies. This initial application suggests that the model has potential for broader use in similar projects within Islamic countries, offering a balanced approach that enhances both project outcomes and team motivation.

Keywords: Systems engineering, Islamization, MBSE

I. INTRODUCTION

Sounding rockets, as unique small suborbital vehicles, offer a distinct platform for developing critical aerospace technologies. Their rapid development cycle and lower operational costs (compared to orbital missions) make them excellent subjects for tailoring and applying best-fit engineering management methodologies such as Systems Engineering (SE), which plays a crucial role in their development.

SE is an interdisciplinary approach and means for the realization of complex systems. This discipline gained

more importance during the emergence of major aerospace and defense systems post-WWII [1,2].

One of SE's main processes is the life cycle model management (LCMM) process. This process aims to establish and maintain life cycle processes for the organization. These include the enterprise concept of operation (ConOps) and the concepts of systems and components' life cycles.

In a previous article, the authors reviewed 143 references related to the life cycles of sounding rockets. Twenty-two of them were reproduced using model-based SE (MBSE) diagrams. Those life cycles were from three

categories: (1) SE standards, (2) aerospace vehicle design (AVD) references, and (3) actual sounding rocket projects. This review and analysis revealed the importance of incorporating values as the primary product life cycle (PLC) driver. It also shows different life cycle tailoring approaches and techniques, especially between Eastern and Western programs.

Figure 1 shows two examples from each dimension. From the 1st dimension, the Japanese Space Agency (JAXA) life cycle was presented [3]. This indicates that JAXA changed its life cycle after 2008 due to the failure of its sounding rocket due to insufficient requirements

analysis and conceptual design. Examples of 2nd dimension are from Fleeman [4] and Hammond [5] textbooks. The Fleeman life cycle shows how the missile/rocket development is interdisciplinary, whereas the Hammond diagram shows the interdependencies change by moving on in the development cycle. From the 3rd dimension, the Polish Sounding Rocket is shown, which is a re-composition from several references: [6-10]. Also, Portland State Aerospace Society (PSAS) sounding rocket activities, which is a re-composition from [11-17]. The 3rd dimension shows how the 1st and 2nd dimensions are integrated into an actual program.

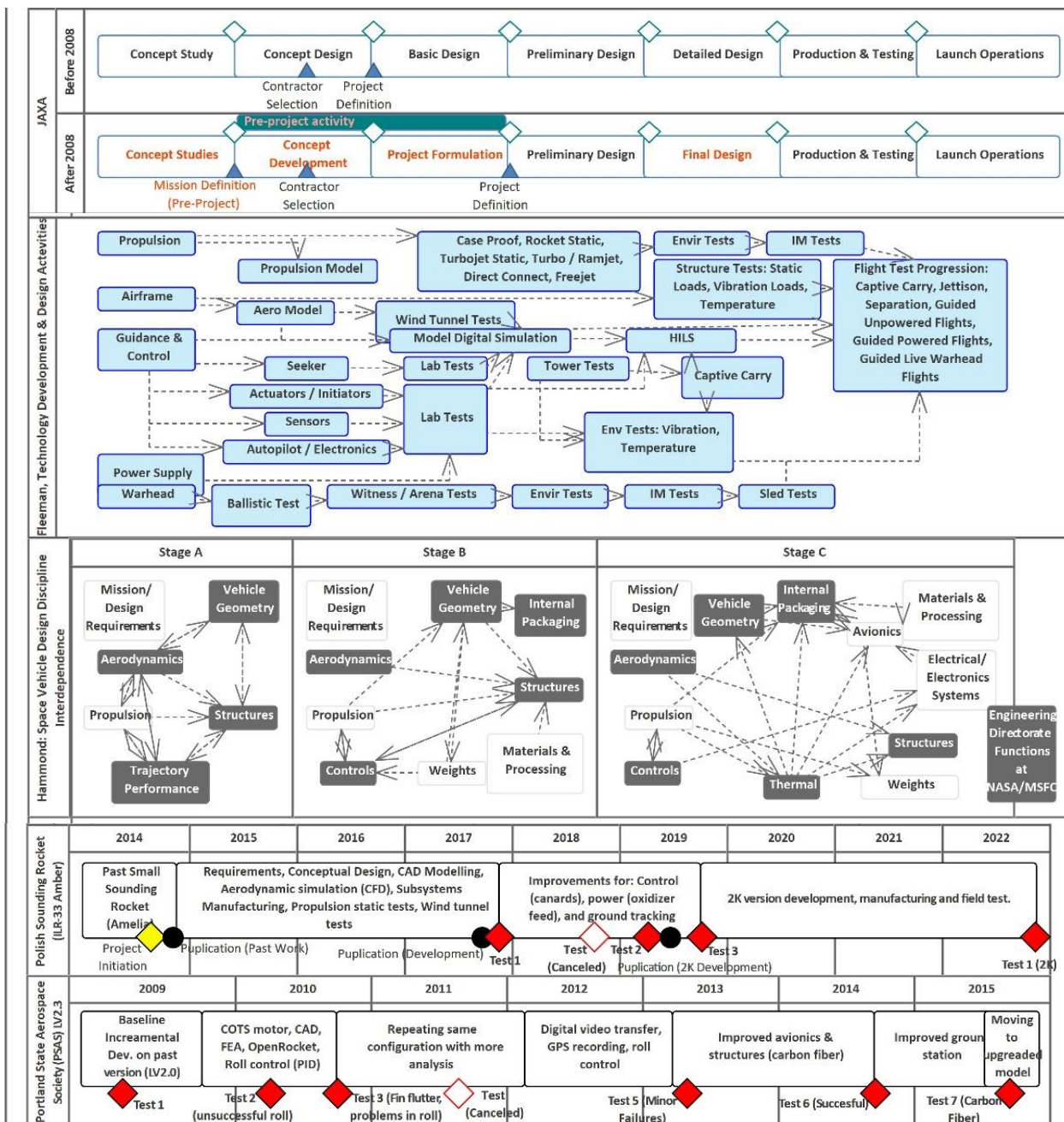


Figure 1 JAXA [3], Fleeman [4], Hammond [5], Polish Rocket is re-composition from: [6-10]
 PSAS is a re-composition from [11-17]

In that article, there was elaboration about examples of tailoring sounding rocket programs (e.g., Silva and Pernodi, 2021 [18] tailoring of Brazilian sounding rockets' life cycle). Also, advancements in sounding rocket research in Malaysia were elaborated (Aerospace Malaysia Research Center (AMRC) in Universiti Putra Malaysia (UPM) and (HEMREL) is a collaboration program between University Technology

Mara (UiTM) and MTC company, which is directed to foster rocket technology research. [19]).

It was noted that there are cultural differences in SE implementation between East and West. Taking China, Japan, and the USA as examples, the table below summarizes the primary references reviewed for analyzing the Eastern and Western approaches to SE. It also contains the reviewed central comparative studies.

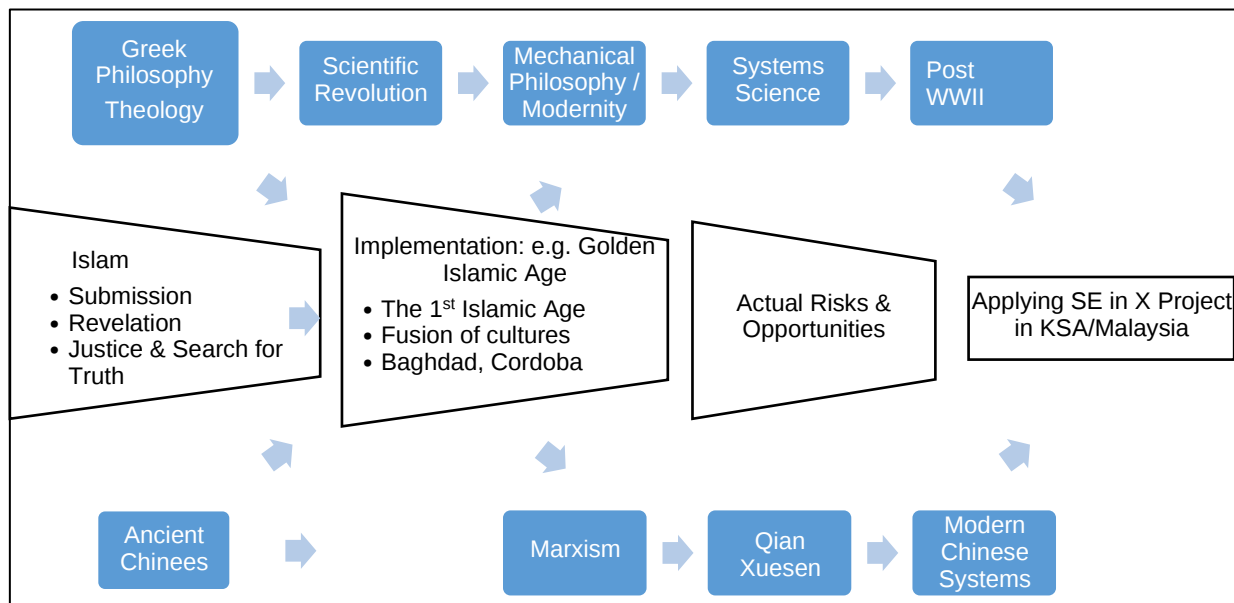


Figure 1 Eastern and Western SE foundations, and a similar process for tailoring SE to projects in Islamic countries

Figure 1 illustrates this process. The upper and lower processes in blue show how the SE methodologies developed in the East and West, according to the references in Table 1.

The orange process shows a generic method for tailoring SE for projects in Islamic countries (e.g., KSA and Malaysia). Following the same Western and Eastern approaches might be reasonable (i.e., building on the philosophical foundations of Islamic culture).

Table 1 Primary references for Eastern and Western SE approaches and comparative studies

Side	References
China & Japan / Eastern	[3], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31], [32], [33]
Comparative Studies	[34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45], [46]
USA / Western	[2], [47], [48], [49], [50], [51], [52], [53]

Islamization of Knowledge

Islamization of knowledge (IOK) is a comprehensive movement aligning various knowledge fields with Islamic

principles and values. This concept encompasses transforming knowledge to reflect Islamic teachings, ensuring that all forms of knowledge contribute positively to individual and societal development within an Islamic framework.

IOK has been an important research field for many Muslim Scholars. Two noted scholars became well-known in this field: Ismail Raji Alfaroqi [54] and Sayeed Naquib Alattas [55]. Their objective was to provide a methodology for examining modern sciences from an Islamic perspective. From the beginning of the 1960s and 1970s, the Islamization of knowledge expanded and branched out with several research and reviews.

However, the integration of modern science from an Islamic perspective did not just begin recently; it traces back to the early Islamic age. One of the earliest examples occurred when Prophet Mohammed (PBUH) established the Islamic perspective of life and economy in Madinah, challenging the existing norms of the Jews and non-believers. He also extended the message of Islam to the Persian and Roman empires, promoting the superiority of Islamic values over those of the powerful civilizations. His Companions (RAA) continued this engagement, firmly adhering to their values while skillfully adapting advanced fields to meet their needs and uphold Islamic principles.

Many scholars have consistently followed this approach. One of the most challenging examples was

when Imam Ahmad bin Hanbal was examined for tens of years due to the “creation of Quran fitnah” from Almotazilah, who were somehow influenced by Greek logic. This logic was also one of the fields that Imam Ahmad ibn Taimiah and many scholars fought until the modern age.

In the last few years, research has been increasing trying to connect Islam and science. Some of the literature comes from Islamic studies, and others from engineering colleges.

Within those approaches, two studies are particularly relevant to this article:

1. A PhD thesis titled: A Sharia View on Benefit-Based Innovation and Design of A Scale for Innovation Benefit/Harm Measurement: Application on Al-Rahman Guests Innovations, Attar, 2021 [56]. This study used the benefits and harms scales in Almaqasid science to improve the innovation of the Hajj and Umrah (Tawaf line as a case study).
2. A PhD thesis titled: Development of a Framework for Sustainable Product Design. Zain, 2021 [57]. This study used Almaqasid to design a tool for sustainable project design. Three case studies were used: designing a waste food processing device, a walking assistance device, and mechanical physics course material.

It is known that Allah Almighty revealed the Quran as "a clarification for all things, and a guidance and mercy and good tidings for the Muslims" [Surah An-Nahl: 89]. This Quran "guides to that which is most suitable and gives good tidings to the believers who do righteous deeds that they will have a great reward" [Surah Al-Isra: 9].

Based on the idea that "The Quran contains all the principles that can rectify engineering works, even if these works appear purely technical or purely scientific", this article aims to provide a tailored life cycle for small sounding rocket programs in Malaysia, taking Islamic values into consideration

II. METHODOLOGY

SE research encounters significant challenges due to the complex, real-world environments where such studies are conducted. These environments complicate the evaluation of systems engineering practices, the establishment of appropriate validation criteria, and the avoidance of bias. Muller (2013) [58] addresses these challenges by proposing a tailored approach for a master project at the University of Kongsberg. This method employs an action research methodology, utilizing an 'industry-as-laboratory' model. The process begins with an investigation of an industry problem, followed by applying the SE body of knowledge to formulate and assess a claim using observables from the industry.

As suggested by Dr. Fareed Al-Ansari [59], Western research methodologies always contain embedded biases (e.g., the definition of knowledge and science, measurement and evaluation). Islamic research methodologies should avoid those biases but benefit from them.

By taking Muller's [58] approach, Dr. Alansari [59] recommendations, and utilizing an actual small sounding rocket simulation project at the research and development (R&D) the 1st author works, the research methodology follows these steps:

1. Analysis of previous life cycle models:
 - a. From the three-dimensional review (engineering standards, AVD references, and actual sounding rocket projects).
 - b. Analyzing the cultural elements, especially the differences between Eastern and Western approaches, and defining the prejudices in those methodologies.
2. Development of a life cycle model that meets the Islamization and state of practice requirements:
 - a. Putting a centrality for the values in the development process.
 - b. Implementation of mature Islamization methodologies from Tafsir and Fiqh.
 - c. Benefit from the state of art Eastern and Western methods.
 - d. Following MBSE approaches.
3. Implementing the developed life cycle at an actual sounding rocket project in an R&D institute.
 - a. Observing the project meetings
 - b. Introducing the suggested life cycle through formal workshops and semi-structured interviews.
 - c. Taking the evaluation and recommendations for enhancements from the project members.
4. Analysis and Discussion:
 - a. Compiling the results and findings.
 - b. Building recommendations for future projects and future research.

III. MODEL DEVELOPMENT

3.1 Real “Life” Cycle Model

Islamic systems thinking can be summarized in a Real “Life” Cycle Model. There are Unseen and Witnessed worlds. The Witnessed world is from “womb to tomb”. Whereas the unseen world continues from ∞ BC to ∞ AD. The stakeholder (Allah, Glorious and Exalted Is He (SWT)) puts a very detailed and comprehensive <<Needs>> for humanity to live successful life and Hereafter. The first and most important need is Tawhid, which means believing in Allah Alone as God and Lord and attributing to Him Alone all the attributes of Lordship and divinity. The whole set of needs is documented in the Quran and explained as actual <<use cases>> in Prophet Mohammad, Peace be upon Him (PBUH), sayings (Sunnah). Quran and Sunnah constitute the Revelation, which supersedes and overarch all documents in Islam.

The implementation of the Real “Life” Cycle model follows two very mature methodologies in the Islamic Body of Knowledge: interpretation of the Quran (Tafsir) and Islamic Jurisprudence (Fiqh).

Tafsir, derived from the Arabic root *fassara*, meaning "to explain" or "to expound," refers to the exegesis or commentary on the Quran. The primary purpose of tafsir is to elucidate the meanings of Quranic verses, providing context and interpretation to enhance understanding of Allah's message as conveyed through the Quran [60].

Thematic Tafsir (Altafsir Amawdui) - is a science that addresses cases according to the Quranic objectives through one or more surahs [61]. The thematic Tafsir methodology begins by examining Quranic insights about specific topics (in SE here). Then, it represents the Muslim Scholars' interpretations and guidance about those insights.

Fiqh is Islamic jurisprudence encompassing the body of Islamic law extracted from detailed Islamic sources (the Quran and Sunnah) and interpreting and applying these laws. It is concerned with the practical implementation of Islamic principles in Muslims' daily lives, covering various aspects such as worship, transactions, marriage, divorce, criminal law, and personal conduct.[62]

The Fiqh methodology begins by specifying use cases appearing in the SE. Then, it searches for the Fiqh guidelines and judgments (Fatwa) for each use case by following the authenticated references and consulting expert Scholars.

Ethics, morals, and values are central to Islam. The whole purpose of Islam is to complete the perfect ethics of Muslims. According to Muhammad Abdullah Daraz, ethics in the context of the Qur'an is defined as a comprehensive system of moral principles that governs human behaviour, starting from the devotional (Eman) ethics, moving to the personal, family, society, until reaching the national / management level [63,64].

This approach would guarantee the best tailoring for the modern SE to fit organizations in the Islamic world.

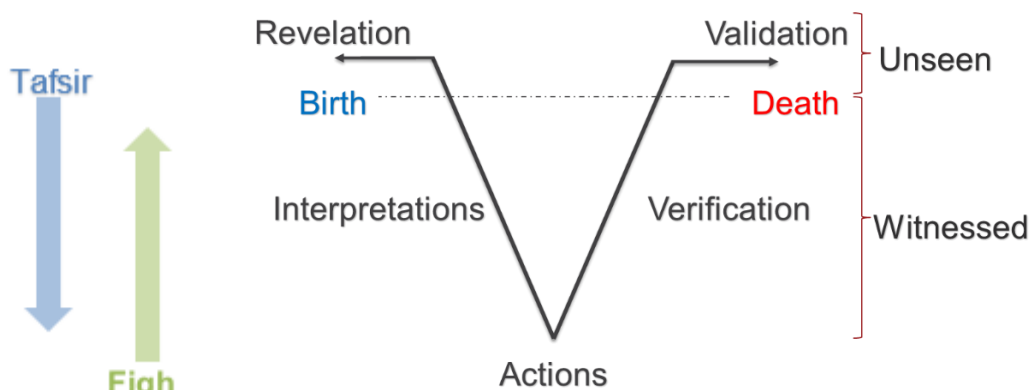


Figure 2 Real "Life" Cycle Model

3.2 Tailoring Life Cycle for University Scale Sounding Rocket

Based on the objective case (development for small sounding rockets at university scale) and on the previous screening of different life cycle approaches, which was on three related directions: engineering standards, AVD references, and on real sounding rocket projects, and based on the analysis and discussion, a life cycle model is suggested.

The graphical representation, named the "Water Spring Model," was designed to be two-dimensional, starting from a central point and expanding away from it.

Typically, the life cycles start from customer requirements. However, in the discussed case, the central element which the program shall start from is the **Values**. In this case, those values shall be tightly connected with a high source of values (i.e., Islamic values). Some references could be used for aligning those values (e.g., Malaysian Standard: Value-based Management Systems: Requirements from an Islamic Perspective [65]). The practice of values alignment would answer questions like: What are the ultimate objectives of those projects? Will it improve humanity? Or it will be harmful for society and the environment? What about personal values, ethics, and morals? Are they aligned with the high-level optimum values? Or will this project be harmful to them? Then, along the project, more questions appear, such as: Are all interactions aligned with high-level values? Examples

from the standard include [65]. Considering that Allah observes all interactions, the work is done to the highest quality capable (*itqan*), the team is consulted (*shura*), and financial dealings are halal (e.g., no interest, no cheating).

The **Requirements** are the next essential item after the values. At this point, a complete requirements analysis process should be done. It is suggested to follow the PPI process [66] for that. Because it includes all the essential items in the problem domain (requirements, physical, and functional architecture) in a task-oriented approach, some of the critical tasks include identifying the stakeholders, assessment of related documents, analyses of context, states, and modes, parsing, functional, stakeholder value and verification requirements. Lastly, the requirements must be cleaned up, and the official document must be written. This document must be written, reviewed, and updated during development. The requirements review is suggested to be done by a system requirements review (SRR) milestone. Some entrance and success criteria elements could be taken from the NASA SE Handbook. [67] (e.g., for entrance criteria, the requirements document is ready, risks are identified, and for success criteria, plans are reasonable, external interfaces, main risks, and verification requirements are identified).

The literature shows different **levels of analyses** and verifications, ranging from the initial guess based on heuristics to spreadsheet calculations based on empirical equations, to a numerical simulation, and an actual

experiment in the lab and the field. The question is how to project those activities with the life cycle stages reviewed. In the proposed life cycle, three levels of analysis are suggested: analytical, numerical, and experimental. Those levels align with three life cycle stages: conceptual, preliminary, and detailed design.

After that, the **geometry** of the sounding rocket needs to be defined. This definition comes in conjunction with the rocket's physical architecture. The main element controlling the geometry is the propulsion system. At that point, an initial sketch of the rocket would be drawn. The material, sizes, and layout would be initially estimated.

The **analytical** computations of the **propulsion** system need to be considered at that point. Because it has the highest impact among the other systems. University programs regularly take propulsion systems development as a primary teaching element, unlike large sounding rocket programs, which consider the propulsion system a complete element and concentrate on the payload. Open-source conceptual design codes, e.g., OpenRocket and Rocket Sim, would be beneficial at that stage. Those codes would help select the closest propulsion and geometry configurations before moving to the next stage. Some small programs (e.g., extracurricular activities, small rockets without control) consider this level of simulation sufficient.

After that, the **CAD model** needs to be generated. MBSE and CAD models play the role of generic model-based engineering (MBE). The continuous update, review and governance of those models would guarantee team alignment. To achieve better **governance**, an approach similar to Cranfield AVD GDP is suggested, having weekly **reviews**, which include reviewing the project plan and progress in front of requirements, everybody's update of success, risks, actions and decisions, review of the CAD model evolution, and mass budget update. Then, having main milestones, e.g., PDR and CDR, with specific entrance and success criteria and external stakeholders' attendance.

The teams start synthesizing their technical activities from the initial CAD model. An approach like Hammond's is suggested. Each phase has its **interaction scheme between disciplines**. In the **analytical phase**, the flight dynamics team will have a high weight. They should build the mathematical models of the rockets with alignment of other models. As the propulsion model would have one more step of maturity, the concentration would be on balancing between the aerodynamic and structural models.

During the **preliminary design phase**, new players enter the game. The flight dynamics will conduct collective work with GNC disciplines. Typically, the work is performed using MATLAB & Simulink packages. The Flight Dynamics and GNC team could utilize their internal MBSE inside those packages, with the needed Configuration Management (CM) and version control. At this phase, there should be dedicated considerations for mass, Center of Gravity (CG), and moment of inertia, along with the structure's considerations, which involve finite elements analysis and dedicated material considerations. Aerodynamic models would involve more numerical simulations using CFD at that stage.

At the **detailed design phase**, efforts would be taken to materialize all rocket aspects. This is done by entering electronics and thermal analysis disciplines, starting HILS, wind tunnel, propulsion static tests, and structural and environmental tests. Putting a **flight test** as a target would increase the level of implementation (by manufacturing or purchasing COTS), integration, and testing. The Chinese example in putting the COTS definition as one of the dedicated first steps in their process is a very good example of that risk's mitigation. The detailed design phase would end with a CDR. The flight test preparations follow this, which would involve a system integration review (SIR) and test readiness review (TRR). It is vital to make sure the availability of all parts and tools before starting the final integration. It is also more essential to carry out a detailed TRR before going to the test field because the test windows are always limited and critical.

The traceability between the models is suggested to be kept to the maximum level. If the CAD model, for example, could be traced to the requirements and architecture models, there would be a massive capability for faster optimization and iteration. Learning from the SAAB method [68], it is suggested that a complete iteration not be made before realizing a complete rocket for testing.

Executing the first **flight test** might be considered the project's end. NASA SRP provides a good baseline for test planning and execution[69]. European standard Space Engineering Testing has detailed requirements for the tests needed for any object in space [70]. Moreover, fixed-wing aircraft testing methodologies have been there for more than 100 years, and their references would provide excellent information for sounding rocket testing [71,72, 73]. Some projects are supported to do more than one test. The examples shown have done 3, 5, and 12 flights of one type/family/configuration before moving to another project with more challenges. One year is a typical gap between firings. Annual rocketry events in the U.S. generated a business field besides its academic benefits. Thus, it is suggested that programs in Malaysia be designed to support an annual sounding rocket event. Those programs could start with universities, the public sector, or even the private sector. Learning from U.S. DoD AAF and how an urgent capability acquisition could evolve to a middle-tier acquisition or other life cycle models, and taking into consideration that the suggested life cycle is considering the development only (which is the university task), there should be some methods to help those kinds of programs from falling into the "death valley" which is transforming it to tangible products.

One of the typical tangible outcomes of such programs could be a journal publication. This publication might describe specific design processes or test results. Novel technologies might also appear as an outcome. This technology might be part of a larger organization strategy (e.g., Malaysian Space Agency or MOD), and it decides to support another program level. This technology could be transferred to an intellectual property (IP) if a good return on investment appears. One of the Malaysian rocketry community's evolutions was the evolution towards tiny systems by designing a business model for teaching the

design, manufacturing, and testing of small rockets to school students. Moreover, they developed a package for rocketry learning, which could be bought for RM90 only.

So, the suggested life cycle would help develop small university sounding rockets in Malaysia. It was drawn as a water spring graph using MBSE. The term "water spring" holds significant meaning for desert dwellers,

particularly for the first author, who personally experienced the distressing situation of running out of fuel and walking for rescue in the heart of the Arabian deserts. If the model continues to the post-development stages, it will be drawn as a continuous water stream. According to geological facts, the water spring could transfer to a stream if it is powerful or other water resources support it.

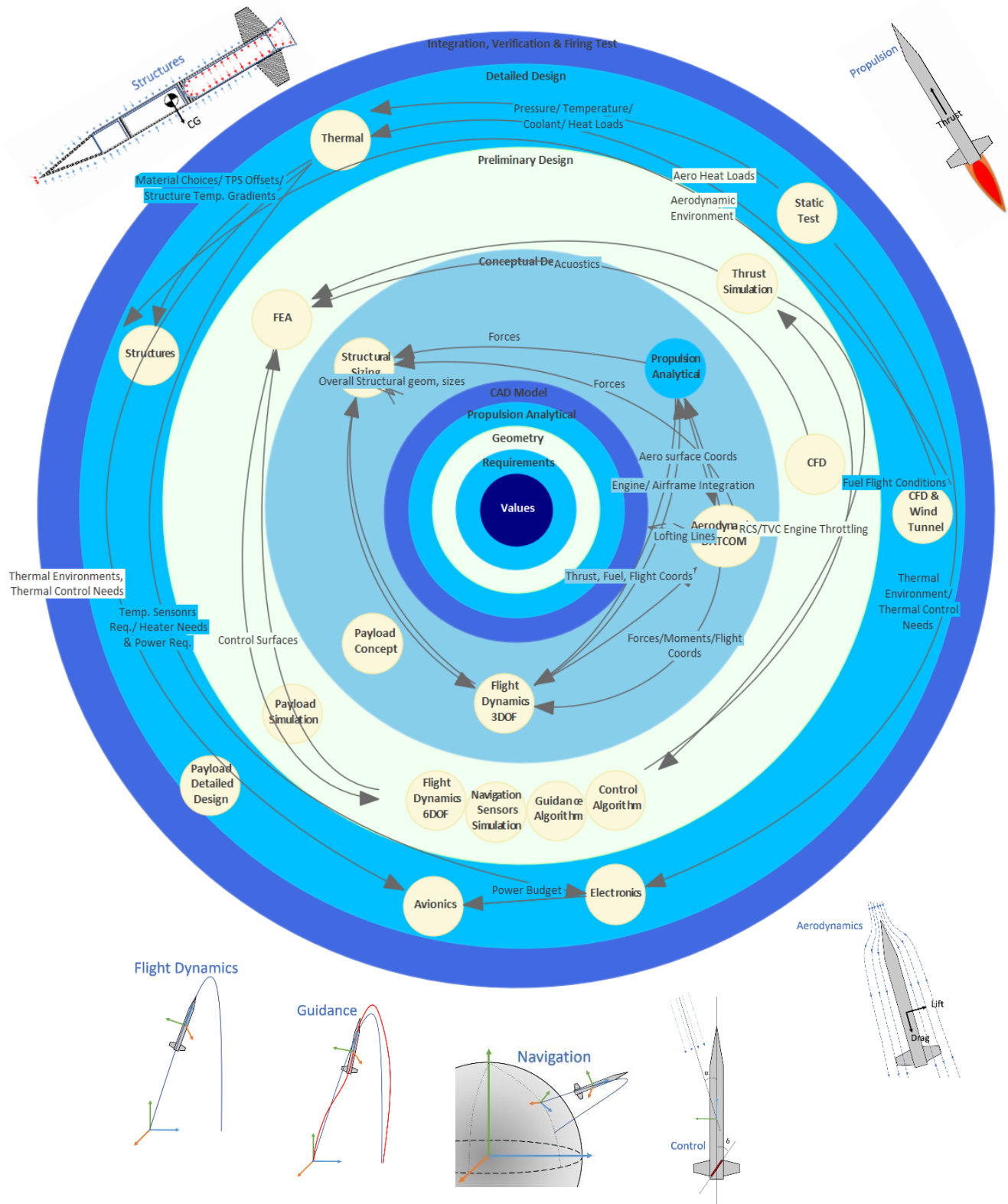


Figure 4 Suggested water spring life cycle

IV. IMPLEMENTATION

This section discusses the implementation of the life cycle model at a small-sounding rocket project in an R&D organization. As discussed in the methodology, the implementation followed Muller's SE research methodology: establishing a claim based on SE BoK and an actual industrial problem, observing that claim, and evaluating it. The claim was that looking at that project from an Islamic perspective by following mature Tafsir and Fiqh methodologies would enhance it. The project observation and analysis are below.

4.1 Project Observation

Pre-Project

The motivations for starting this project included:

1. A new group of engineers entered the center: This provided an opportunity to give them a training project to build their capability and add value to the department.
2. Availability of motor design: A previous completed project involving static tests of a motor was a perfect opportunity.
3. Alignment with other projects...etc.

Hence, the aerospace engineering department manager proposed this small project to make a full study of the sounding rocket within six months for seven new engineers, with the mentoring of 2 more senior engineers. This proposal was discussed with the management, and the green light was granted.

The project was managed simply by holding a weekly meeting, where each engineer should present their achievements. This was an excellent resource for post-project analysis. No template was specified. However, most presentations contained the following sections: the updated requirements, the last meeting outcomes, a summary of each team's achievements and challenges, and the actions of the next meeting.

The team was divided into the following members:

1. Aerospace engineering department manager (Sponsor)
2. GNC senior engineer (Mentor 1)
3. Aerospace vehicle design (AVD) engineer (Mentor 2)
4. AVD sizing engineer
5. CAD modelling and concepts researcher engineer
6. CFD engineer
7. Flight Dynamics engineer
8. GNC Engineer 1
9. GNC Engineer 2
10. Structures engineer (part-time)
11. Payload Engineer (part-time)

This list outlines the project's primary activities weekly, compiled through a thorough analysis of all weekly presentations and documentation. It also incorporates insights from the first author's active participation in meetings -since week 8- and discussions with the project team.

Week 1

1. Analysing the requirements (motor, range, altitude...)
2. Making initial configuration baseline
3. Collecting data for similar systems
4. Starting analytical aerodynamics design in spreadsheets following Fleeman [4] and Raymer [74] methodologies
5. Starting researching different guidance techniques

Week 2

1. Analysis of different nose types
2. Tail sizing
3. Weight analysis
4. Aerodynamics analysis using DATCOM

Week 3

1. Stability analysis (Static margin...)
2. Tail selection (with airfoil CFD)
3. Increasing similar systems database
4. A small internal conference was announced, with an abstract due in one month. So, the project sponsor set a target for the team to publish four articles, motivating the engineers to finish their analysis.

Week 4

1. Building 3DOF point of mass simulation
2. Aerodynamics optimization of the nose
3. Researching launcher integration requirements.
4. Selecting guidance method

Week 5

1. Transfer the analysis from spreadsheets to MATLAB code.
2. Agree on version and document control methods.
3. More aerodynamics optimization

Week 6

1. Full CFD of the rocket
2. Analytical model improvement by using different resources.

Week 7

1. Shockwave issues appeared in CFD
2. Applying shock equation to try to reduce the effects in some velocities before doing CFD
3. More detailed weight estimation
4. Extracting loads from CFD
5. Load factor calculations
6. Initial structural sizing

Week 8

1. Initial payload selection (video camera + telemetry)
2. Side forces aerodynamics calculations
3. Starting testing fast programs (XFLR5 and Flow5) and comparing them with CFD

Week 9

1. Apogee / stall detailed analysis
2. Motor detailed integration design
3. Recommended navigation sensors selection (GPS + IMU)

Week 10

1. Implementing the last aerodynamics, thrust, and weight data into the flight dynamics model
2. Generating initial 3DOF
3. Analysing stability with different tail configurations
4. Publishing four articles about the development of an internal conference.

Week 11

1. More details in the 3DOF
2. Control algorithm design
3. Control surfaces design

Until writing this article, this was the last stage of the project. The project is still ongoing. However, it now has lower priority due to more critical projects.

At this stage, the project has already achieved its objectives of building the engineers' capabilities and preparing them for more critical projects. Also, the motor project provides a good baseline for another project with a prototype and flight test.

4.2 Workshops and Interviews

Starting from Week 8, the first author attended most project meetings. Two formal workshops and several independent meetings. The water spring model was introduced and discussed. The concentration was on two

aspects:

1. Is the model relevant to the actual work? What are the pros and cons of that model? And what are the challenges and opportunities related to this model during the actual implementation?
2. How does looking at the project from an Islamic perspective, by following the suggested methodology, affect the engineers as individuals, a team, and an organization?

The data was collected from a survey of open questions, answered with around 100 words per respondent. Meeting minutes, project presentations, and individual notes were also taken as additional data sources.

V. ANALYSIS AND DISCUSSION

The workshops and interviews provided valuable insights into the implementation and reception of the proposed life cycle model for university-scale sounding rocket development, particularly within an Islamic framework. Table 2 shows the respondents' main comments. Four of them are external to the project but within the center. The following analysis highlights the key findings and discussions based on the collected data

Table 2 Summary of the respondents and their main comments

ID	Role	Main Points
R1	Aerodynamics	Emphasis on Islamic values such as knowledge transfer, consultation, and striving for excellence.
R2	Guidance	Importance of consultation and knowledge exchange for better decision-making and skill development
R3	Aerodynamics	Highlighted the significance of precision in work, team consultation, and continuous learning
R4	Aerodynamics, Research, CAD	Team cooperation, eagerness to learn, and faith in the guidance of more knowledgeable colleagues
R5	AVD Mentor	Detailed design phase focus, project contribution to national defense, and continuous self-improvement through project engagement
R6	Aerodynamics	Recognized the model's representation of real projects, early integration, and communication among different teams for better project coordination
R7	Flight Dynamics	Faced challenges with data integration and used open-source data for building the 6DOF model.
R8	AVD Mentor	Importance of requirement analysis and documentation, setting weekly goals, challenges in defining specific reference points (PDR, CDR)
R9	Mentor & Senior Aerodynamics Engineer	Comparison of Eastern and Western approaches to decision-making, the importance of precision, utilizing available resources, and adhering to external influences
R10	Sponsor & AE Department Manager	Training new engineers through practical projects, setting clear objectives and procedures, integrating previous projects as a learning base
R11	(External) Project Management and Systems Engineering Office 1	Challenges of small projects that emerge without clear life cycles and take a considerable number of resources, issues with SysML, and the need for clear policies and governance for project management

R12	(External) Project Management and Systems Engineering Office 2	Each project, even if it is small, shall have, at minimum, the following milestones: 1. System Requirements Review 2. Critical Design Review 3. Test Readiness Review 4. System Certification Review
R13	(External) Senior Structure Engineer	Challenges of initial design steps not involving all departments, leading to fundamental design errors difficult to correct later
R14	(External) Middle Aerospace Engineer	Integration of Enterprise Architect models as the center of truth for project consistency.
R15	(External) Senior Chief Technical Officer	Importance of values in the acquisition system, understanding lifecycle frameworks, development methodology as an umbrella for all detailed methodologies

Key Findings

Relevance and Applicability of the Model

- The "Water Spring Model" was highly relevant to the actual work of the sounding rocket project. The model's focus on starting with values and progressing through the requirements, design, and testing phases resonated well with the project members.
- Even though there weren't formal reviews. However, there was continued mentoring and weekly reviews of the project.
- The integration of Islamic values, such as Itqan (perfection in work), Shura (consultation), and Jihad (intellectual struggle), was seen as a positive influence on the project's progress and team dynamics.

Islamic Values and Project Implementation

The respondents triggered the Islamic values they thought were related to their project. The following three values were the highest in the respondents' feedback:

- **Shura (Consultation):** Decision-making processes involved significant consultation among team members, aligning with the Islamic principle of mutual consultation. Seven respondents highlighted the Shura value, the highest value among others.
- **Itqan (Perfection in Work):** Team members emphasized the importance of meticulousness and excellence in their work, reflecting Islamic teachings on doing one's best in all tasks. Five respondents mentioned it.
- **Jihad (Striving in the Path of Allah):** The project was perceived as a form of intellectual and technical jihad, where striving for excellence and innovation in aerospace technologies was seen to serve the community and the nation. Also, five respondents triggered this value.

Challenges and Opportunities

- **Interdisciplinary Coordination:** While the project benefited from interdisciplinary collaboration, challenges in synchronizing efforts between aerodynamics, flight dynamics, GNC, and structural teams were noted. Early integration and frequent communication were suggested to mitigate these challenges.

- **Tool Integration:** The team had difficulty integrating various tools and software platforms from different disciplines. A unified platform or better interoperability between tools was recommended for future projects.

Impact of Islamic Perspective on Team and Organization

- The Islamic perspective gave the team a solid ethical and moral foundation, fostering a sense of purpose and dedication.
- The emphasis on teamwork, knowledge sharing, and ethical conduct contributed to a positive and productive work environment.
- The project served as a valuable training ground for young engineers, enhancing their skills and preparing them for more complex future projects.

External Respondents

The external respondents (some of whom could be considered SMEs) highlighted the importance of governance, cross-departmental communication, unified project models, and the role of values and cost in project management and product lifecycle. These insights underscore the need for structured methodologies and better integration among various tools and practices in aerospace engineering projects.

V. CONCLUSIONS

Implementing the proposed life cycle model for university-scale sounding rocket development within an Islamic framework has shown promising initial results. This model was applied in a small project that only reached the simulation stage without actual testing. Despite this limitation, the respondents felt the model was helpful in several significant ways.

The "Water Spring Model" provided a comprehensive image for the entire team, connecting the life cycle phases with the Aerospace Vehicle Design (AVD) process in a single diagram. This novel approach facilitated a better understanding of the project scope and progress among team members. Additionally, the model successfully connected engineers with the Islamic values that motivated them to work, such as Itqan (perfection in work), Shura (consultation), and Jihad (intellectual

struggle).

The feedback from both internal and external respondents highlighted the importance of governance, cross-departmental communication, and unified project models. These insights underscore the need for structured methodologies and better integration among various tools and practices in aerospace engineering projects.

Future work will focus on expanding the model to reflect more detailed processes. This includes modeling how Tafsir and Fiqh methodologies are executed from a detailed perspective, ensuring a more comprehensive and practical application in more extensive and complex projects.

Overall, while the model's current application is limited, its initial success and positive feedback suggest that it has the potential to be a valuable framework for guiding the development of small sounding rockets in Malaysia and similar projects in other Islamic countries. By aligning technical processes with cultural and religious values, the model offers a balanced approach that can enhance project outcomes and team motivation.

REFERENCES

- [1] ISO/IEC/IEEE, "ISO/IEC/IEEE 15288:2023 International Standard - Systems and software engineering -- System life cycle processes," 2023. [Online]. Available: <https://www.iso.org/standard/81702.html>
- [2] INCOSE, INCOSE Systems Engineering Handbook. Wiley, 2023.
- [3] Okada M, Yamamoto S, Mukai T, "Systems Engineering Enhancement Initiative in JAXA," Trans. JSASS Space Tech. Japan, Vol. 7, No. ists26, pp. Tt_1-Tt_6, 2009. https://www.iso.org/10.2322/tstj.7.Tt_1
- [4] Fleeman EL, Schetz JA, *Missile Design and System Engineering*. American Institute of Aeronautics and Astronautics, 2012. [Online]. Available: <https://arc.aiaa.org/doi/book/10.2514/4.869082>
- [5] Hammond WE, "Design Methodologies for Space Transportation Systems," American Institute of Aeronautics and Astronautics, 2001. [Online]. Available: <http://arc.aiaa.org/doi/book/10.2514/4.861734>
- [6] Okninski A, et al., "Development of the Polish Small Sounding Rocket Program," *Acta Astronautica*, Vol. 108, March–April 2015, pp. 46-56. <https://doi.org/10.1016/j.actaastro.2014.12.001>
- [7] Sieć Badawcza Łukasiewicz - Instytut Lotnictwa, "ILR-33 Amber (Bursztyn) - world's first rocket utilising 98%+ H2O2," Nov. 27, 2017. [Online Video]. Available: <https://www.youtube.com/watch?v=Dlw61mwYI7E>
- [8] Sieć Badawcza Łukasiewicz - Instytut Lotnictwa, "ILR-33 Amber (Bursztyn): Improvements," July 19, 2019. [Online Video]. Available: <https://www.youtube.com/watch?v=Da02FBrt0M4>
- [9] Pakosz M, Noga T, Kaniewski D, Okninski A, Bartkowiak B, "ILR-33 Amber Rocket – Quick, Low Cost and Dedicated Access to Suborbital Flights for Small Experiments," 24th ESA Symposium on European Rocket & Balloon Programmes and Related Research, Jun. 2019. [Online]. Available: https://www.researchgate.net/publication/346243972_ILR-33_AMBER_ROCKET_-_QUICK_LOW_COST_AND_DEDICATED_ACCESS_TO_SUBORBITAL_FLIGHTS_FOR_SMALL_EXPERIMENTS
- [10] Sieć Badawcza Łukasiewicz - Instytut Lotnictwa, "ILR-33 Amber (Bursztyn): Going Further," Oct. 18, 2019. [Online Video]. Available: https://www.youtube.com/watch?v=x_FnALj66MU
- [11] Talik J, Luce J, Froelich J, Shang M, Rasheed RM, Roland JS, "Electric Propellant Feed System for Amateur Class High Altitude Sounding Rockets," AIAA SPACE and Astronautics Forum and Exposition, 2017, p. 5132.
- [12] Schmidt ES, Louke J, Amell K, Hickman J, Wiles B, "Development of a Low-Cost, Open Hardware Attitude Control System for High Powered Rockets," AIAA SPACE 2015 Conference and Exposition, 31 Aug-2 Sep 2015, Pasadena, California <https://dx.doi.org/10.2514/6.2015-4623>.
- [13] "LV2.3 Sounding Rocket Wiki," Accessed: Jul. 01, 2018. [Online]. Available: <http://archive.psas.pdx.edu/news/2010-10-17-2/>
- [14] Roland J, Edwards D, Harris A, "Electronic Nose Cone Separation Ring (eNSR) for Deployment of Rocket Recovery Parachute," presented at the Space Transportation Posters, AIAA SPACE 2016 13 - 16 September 2016, Long Beach, California. <https://doi.org/10.2514/6.2016-5364>
- [15] NAR, "High Power Rocket Safety Code," Aug. 2012. Accessed: Jul. 17, 2024. [Online]. Available: <https://www.nar.org/safety-information/high-power-rocket-safety-code/>
- [16] Stine GH, Stine B, *Handbook of Model Rocketry*. Wiley, 2004. Accessed: July 17, 2024. [Online]. Available: <https://www.wiley.com/en-fr/Handbook+of+Model+Rocketry%2C+7th+Edition-p-9780471472421>
- [17] Harper GDJ, *50 Model Rocket Projects for the Evil Genius*. McGraw-Hill Education, 2006.
- [18] Silva FDM, Perondi LF, "A Proposal of a Life-Cycle for the Development of Sounding Rockets Missions," *Journal of Aerospace Technology and Management*, Vol. 13, 2021, p. e2021. <https://doi.org/10.1590/jatm.v13.1193>
- [19] Anuar Bahari S, "RISE: High energy material research laboratory (HEMREL)/Dr Shahril Anuar Bahari," RISE: Catalysing Global Research

- Excellence, Vol. 1, Office of the Deputy Vice-Chancellor (Research & Innovation), 2021, p. 51.
- [20] Dai R, "Complex Giant System Science: Science in 21st Century," *Chinese Journal of Nature*, 1997, pp. 187-192.
- [21] Jingyuan Y, "Systems Engineering and Its Theoretical Basis," *Chinese Journal of Nature & Electronics*, p. 17, 1990.
- [22] Lin Y, Duan X, Zhao C, Xu LD, *Systems Science: Methodological Approaches*. Advances in Systems Science and Engineering (ASSE). CRC Press, 2012. [Online]. Available: <https://books.google.com.sa/books?id=jxzSBQAAQBAJ>
- [23] Lu J, Wen Y, Liu Q, Grdr D, Trngren M, "MBSE Applicability Analysis in Chinese Industry," *INCOSE International Symposium*, Vol. 28, No. 1, 2018, pp. 1037-1051. <https://dx.doi.org/10.1002/j.2334-5837.2018.00532.x>.
- [24] Lynn LL, *How Japan Innovates*, 0 ed. Routledge, 2019. <https://dx.doi.org/10.4324/9780429049910>.
- [25] Sanders S, Jackie O, "The Rise of Systems Engineering in China." *Science/AAAS*, Washington, DC, Sep. 23, 2016. Accessed: Jul. 14, 2024. [Online]. Available: <https://www.sciencemag.org/collections/rise-systems-engineering-china>
- [26] Wakasugi R, "Why are Japanese firms so innovative in engineering technology?" *Research Policy*, Vol. 21, No. 1, 1992, pp. 1-12. [https://dx.doi.org/10.1016/0048-7333\(92\)90023-W](https://dx.doi.org/10.1016/0048-7333(92)90023-W).
- [27] Wang N, "The Making of an Intellectual Hero: Chinese Narratives of Qian Xuesen," *The China Quarterly*, Vol. 206, 2011, pp. 352-371. <https://dx.doi.org/10.1017/S0305741011000300>.
- [28] Chang I, "Thread of the Silkworm," 1996.
- [29] Xuesen Q, "On Thinking Science," Shanghai: Shanghai People's Publishing House, Vol. 141, 1986.
- [30] Xuesen Q, "Open Complex Giant System," *Pattern Recognition and Artificial Intelligence*, Vol. 4, No. 1, 1991, pp. 1-4.
- [31] Xuesen Q, Jingyuan Y, Ruwei D, "A New Discipline of Science," *The Study of Open Complex Giant System and Its Methodology*, 1993, p. 11.
- [32] Xuesen Q, Guozhi X, Shouyun W, "Qian Xuesen's Landmark Book on the Development of Systems Engineering in China," *Journal of University of Shanghai for Science and Technology*, Vol. 33, 2011, [Online]. Available: <http://www.ccose.org/about/>
- [33] Yuejie W, "Tailoring Systems Engineering Strategies in China.," *Science and Technology Review*, Vol. 36, No. 20, 2018, [Online]. Available: www.kjdb.org
- [34] Collins ST, Callahan CW, "Cultural Differences in Systems Engineering: What They Are, What They Aren't, and How to Measure Them," *INCOSE International Symposium*, Vol. 19, No. 1, 2009, pp. 670-683. <https://dx.doi.org/10.1002/j.2334-5837.2009.tb00975.x>.
- [35] Ferris TLJ, "Engineering Practice and National Cultural Context," in 2006 IEEE International Engineering Management Conference, Salvador, Bahia, Brazil: IEEE, Sep. 2006, pp. 32-36. <https://dx.doi.org/10.1109/IEMC.2006.4279810>.
- [36] Ferris TLJ, "Cross-Cultural Issues Associated with the Application of ISO/IEC 15288 Standard," *INCOSE International Symposium*, Vol. 16, No. 1, 2006, pp. 703-715. <https://dx.doi.org/10.1002/j.2334-5837.2006.tb02775.x>.
- [37] Hofstede G, "Europe Versus Asia: Truth Versus Virtue," *The Virtuous Organization*, 0 vols., WORLD SCIENTIFIC, 2008, pp. 163-169. https://dx.doi.org/10.1142/9789812818607_0008.
- [38] Hsien Khoo H, Tan KC, "Managing for quality in the USA and Japan: differences between the MBNQA, DP and JQA," *The TQM Magazine*, Vol. 15, No. 1, 2003, pp. 14-24. <https://dx.doi.org/10.1108/09544780310454402>.
- [39] Li J, Li X, "Cultural differences and process adaptation in international R&D project management," 2009 International Conference on Management Science and Engineering, Moscow, Russia: IEEE, Sep. 2009, pp. 1551-1558. <https://dx.doi.org/10.1109/ICMSE.2009.5317928>.
- [40] Lynn LH, "Engineers and engineering in the US and Japan: a critical review of the literature and suggestions for a new research agenda," *IEEE Transactions on Engineering Management*, Vol. 49, No. 2, 2002, pp. 95-106. <https://dx.doi.org/10.1109/TEM.2002.1010878>.
- [41] Lynn LH, "Culture and engineering in the USA and Japan," *AI & Society*, Vol. 17, No. 3-4, 2003, pp. 241-255. <https://dx.doi.org/10.1007/s00146-003-0280-z>.
- [42] Ogawa A, Rhodes DH, "Culture: A Key Factor for Implementing the Integrated Concurrent Engineering Approach," *INCOSE International Symposium*, Vol. 19, No. 1, 2009, pp. 1030-1043. <https://dx.doi.org/10.1002/j.2334-5837.2009.tb00999.x>.
- [43] Pan X, Valerdi R, Kang R, "Systems Thinking: A Comparison between Chinese and Western Approaches," *Procedia Computer Science*, Vol. 16, 2013, pp. 1027-1035. <https://dx.doi.org/10.1016/j.procs.2013.01.108>.
- [44] Pandikow A, Ruhe L, Herzog E, Larsson R, "Cultural Differences - and how they affect Systems Engineering," *INCOSE International Symposium*, Vol. 17, No. 1, 2007, pp. 1916-1926.

- <https://dx.doi.org/10.1002/j.2334-5837.2007.tb02994.x>.
- [45] Qian YL, "Investigating the Influence of Cultural Differences on Systems Engineering: A Case Study of the Manned Spaceflight Programs of the United States and China," Massachusetts Institute of Technology, 2013. Accessed: Jul. 14, 2024. [Online]. Available: <https://dspace.mit.edu/handle/1721.1/99562>
- [46] Warner M, "Japanese Culture, Western Management: Taylorism and Human Resources in Japan," *Organization Studies*, Vol. 15, No. 4, 1994, pp. 509-533. <https://dx.doi.org/10.1177/017084069401500402>.
- [47] von Braun W, "Management in Rocket Research," *Business Horizons*, Vol. 5, No. 4, 1962, pp. 41-48. [https://dx.doi.org/10.1016/0007-6813\(62\)90012-5](https://dx.doi.org/10.1016/0007-6813(62)90012-5).
- [48] Castellani B, "Map of the Complexity Sciences," Art & Science Factory. Accessed: Jul. 07, 2020. [Online]. Available: https://www.art-sciencefactory.com/complexity-map_feb09.html
- [49] Copley FB, Frederick W. Taylor, father of scientific management. 1923.
- [50] Ferris TLJ, "The interplay of modernism, postmodernism and systems engineering," 2004 IEEE International Engineering Management Conference (IEEE Cat. No.04CH37574), Singapore: IEEE, 2004, pp. 1003-1007. <https://dx.doi.org/10.1109/IEMC.2004.1408842>.
- [51] Hieronymi A, "Understanding Systems Science: A Visual and Integrative Approach: Understanding Systems Science," *Systems Research*, Vol. 30, No. 5, 2013, pp. 580-595. <https://dx.doi.org/10.1002/sres.2215>.
- [52] Maurer M, "History of Complexity Management," in *Complexity Management in Engineering Design – a Primer*, Berlin, Heidelberg: Springer Berlin Heidelberg, 2017, pp. 43-88. https://dx.doi.org/10.1007/978-3-662-53448-9_4.
- [53] Ramage M, Shipp K, *Systems Thinkers*. London: Springer London, 2020. <https://dx.doi.org/10.1007/978-1-4471-7475-2>.
- [54] Alfarooqi I, *Islamization of Knowledge: General Principles and Work Plan*, 1983.
- [55] Al-Attas SMN, *Islam and Secularism*. Muslim Youth Movement of Malaysia, 1978. [Online]. Available: <https://books.google.com.sa/books?id=qZTVnQEA CAAJ>
- [56] Attar A, "A Sharia Perspective on Innovation Focused on Benefits, Including the Design of a Scale for Benefits and Harms of Innovation, and Its Application to the Innovations of the Guests of the Merciful," Arabian Gulf University, 2021.
- [57] Zain SB, "Development of a Framework for Sustainable Product Design," International Islamic University Malaysia, 2020.
- [58] Muller G, "Systems Engineering Research Methods," *Procedia Computer Science*, Vol. 16, 2013, pp. 1092-1101. <https://dx.doi.org/10.1016/j.procs.2013.01.115>.
- [59] Al-Ansari F, "The Alphabets of Research in Sharia Sciences: An Attempt in Methodological Consolidation," 1997.
- [60] Al-Khalidi SA, *Thematic Tafsir between Theory and Practice*, 3rd ed., Dar Al-Nafae Publishing and Distribution, 2012.
- [61] Muslim M, *Investigations into Thematic Tafsir*, 3rd ed., Dar Al-Qalam, Damascus, 2000.
- [62] Department of Islamic Research and Encyclopedias, *Encyclopedia of Islamic Jurisprudence*, 2021
- [63] Daraz MAA, *The Moral World of the Qur'an*. London: Bloomsbury Academic, 2008. Accessed: Jul. 17, 2024. [Online]. Available: <https://www.bloomsbury.com/uk/moral-world-of-the-quran-9781860644221/>
- [64] Daraz MAA, *Constitution of Ethics in the Quran*, Al-Risala Foundation for Printing and Publishing, Dar Al-Furqan for Publishing and Distribution, 1956.
- [65] Department of Standard Malaysia, *Value-based Management Systems: Requirements from an Islamic Perspective*. Department of Standards Malaysia, 2009. Accessed: Jul. 17, 2024. [Online]. Available: <https://archive.org/details/ms.2300.2009>
- [66] Halligan R, "Requirements Analysis that Works!," Project Performance International (PPI), 2017. Accessed: Jul. 17, 2024. [Online]. Available: <https://www.ppi-int.com/wp-content/uploads/2019/02/PPI-005261-4-Requirements-Analysis-that-Works171115.pdf>
- [67] NASA, *NASA Systems Engineering Handbook*, 2007.
- [68] Herzog E, Axehill J, Larsson Å, "Perspectives on Models," presented at the INCOSE Europ, Middle East, Africa Workshop and Conference 2023, Apr. 2023. Accessed: Jul. 13, 2024. [Online]. Available: https://www.researchgate.net/publication/370398531_Perspectives_on_Models
- [69] NASA, *NASA Sounding Rockets User Handbook*. NASA Goddard Space Flight Center, Wallops Flight Facility, Wallops Island, VA 23337: NASA Goddard Space Flight Center, 2015.
- [70] ECSS Secretariat, *ECSS-E-ST-10-03C Space Engineering Testing*, 2012.
- [71] Kimberlin RD, "Flight Testing of Fixed Wing Aircraft," American Institute of Aeronautics & Astronautics, 2003. [Online]. Available: <https://books.google.com.my/books?id=IdWmOwc eEtIC>
- [72] Ward DT, *Introduction to Flight Test Engineering*, Elsevier, 1993. [Online]. Available: <https://books.google.com.my/books?id=gaNTAAA AMAAJ>

- [73] Stoliker FN, Introduction to Flight Test Engineering = Introduction aux techniques des essais en Vol. Neuilly-sur-Seine Cedex: N.A.T.O., Research and Technology Organization, 2005.
- [74] Raymer D, Aircraft Design: A Conceptual Approach, Sixth Edition. American Institute of Aeronautics and Astronautics, 2018. Accessed: Jul. 17, 2024. [Online]. Available:
<https://arc.aiaa.org/doi/book/10.2514/4.104909>