Systems Engineering Management Plan Synthesis Infused with Digital Transformation for Manufacturing Startups

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1. Introduction

In a highly competitive manufacturing economic environment such as the automotive and aerospace industry, for a startup to succeed it needs a competitive advantage. This advantage is needed to excite, dominate and be innovative in the market and choice customers.

To achieve this a startup must provide quality products and/or service, on time and at a competitive price. To achieve this in today's environment, the organization must infuse digital transformation into its systems management engineering plan. A digital transformation within a startup context refers to the change that pertains to creating, processing and storing data that is utilized by a newly established organization typically within 2-5 years old from an analog platform to a digital platform with the aid of computers [1]. Digital startups are known for their ability to innovate with the aid of digital technologies and philosophies to deliver goods and services [2]. Furthermore, a systems engineering management plan is defined as a combination of all systems engineering effort into a technical engineering management plan [3].

The goal of scholarly activity is to establish a comprehensive plan (knowledge) and recommend necessary tools needed by startups to successfully conceive of a product for its launch and eventually to its retirement due to obsolescence. The roadmap from here forward is referred to as "Meta Model" or "Synthesis Model" as it is designed to meet the need of startups to succeed with minimal risk as they navigate any uncertain economic landscape.

Keywords

Graduate Student Poster, MBSE, Digital Transformation

2. Methods

The "Meta Model" or "Synthesis" was created by considering various systems engineering management plan, life cycle model and Digital transformation framework. The system engineering management plans (SEMP) considered are the following. The system engineering management plan for the National Aeronautics and Space Administration [4] is split into two stages: formulation and implementation. The formulation stage includes Concept Studies, Concept & Development, and Preliminary Design. The implementation stage covers Final Design, System Assembly & Testing, Operation & Sustainment, and Close Out. These stages are separated by approval processes. The Department of Transportation's Systems Engineering Plan (DOT) outlines a structured approach for developing and managing transportation systems. Emphasizing a lifecycle perspective, it ensures careful management at every stage—from creation to disposal. Key elements include stakeholder engagement, requirements specification, risk management, and validation. The SEP aims to enhance system safety and reliability, reduce costs, and improve project efficiency while incorporating best practices and lessons learned to continuously refine engineering processes [3].The Systems Engineering Plan utilized by the US Department of Defense (DOD) is structured into six phases: "User Needs, Material, Solution, Analysis," Technology Development, Engineering and Manufacturing Development, Production and Deployment, and Support and Operation (including retirement) [5]. These phases are organized into three main categories: Pre-Systems Acquisition (Phase A), Systems Acquisition (Phase B), and Sustainment (Phase C). It is crucial to address User Needs and technical opportunities before commencing Phase A [5].

The Systems Engineering Waterfall model is a linear approach to software development and project management, with phases including requirements analysis, system design, implementation, integration, testing, deployment, and maintenance. Each phase must be completed sequentially, which suits projects with well-defined requirements but can be criticized for its inflexibility and difficulty in adapting to changes once underway [6]. In contrast, the Systems Engineering Agile model promotes flexibility and responsiveness through iterative development. It delivers small, functional increments frequently, allowing for continuous feedback and adjustments. This model emphasizes collaboration among cross-functional teams, customer satisfaction, and regular testing, making it effective for complex and dynamic projects [7], [8], [9]. The Vee model features a sequential design process with a strong focus on verification and validation. It starts with requirements definition and progresses through system and subsystem design, component development, and integration. Verification and validation occur at each stage, ensuring that the final system meets initial requirements. This structured approach aids project management and risk reduction [10], [11]. From the three models considered, the vee model was chosen to be incorporated into our synthesis model.

After the systems engineering management plan and life cycle model were chosen, a digital transformation (DT) framework infused into the synthesis model, or "meta model" was Deloitte's framework. Deloitte's innovation framework is structured into three phases: Imagine, Deliver, and Run. The Imagine phase focuses on identifying opportunities from market trends and customer needs, with sub-categories Sense, Aspire, and Decide, which involve defining ambition and presenting future value. The Deliver phase emphasizes understanding customer behaviors to design and test solutions, with sub-categories Deepen, Weave, and Build/Prove, aimed at creating and validating minimal viable offerings (MVOs). Finally, the Run phase refines and scales successful MVOs to ensure long-term success, with sub-categories Launch, Scale, and Operate, which involve refining solutions based on feedback, interpreting data for maturation, and enhancing operational features [12].

3. Results

Analyzing the DOD Systems Engineering Management Plan, INCOSE Vee Model, DOT Vee Model, and Deloitte Framework reveals two key trends. First, there's overlap in the Conceptualization, Development, Production, and Utilization phases across these frameworks. Second, the Support and Retirement phases overlap in the first three frameworks. The first trend links Feasibility Study, Concept of Operations, Systems, and related phases, focusing on identifying needs and developing solutions with integrated digital transformation planning. The second trend connects High-Level Design, Detailed Design, and subsequent stages, with Deloitte's framework emphasizing the creation of a minimal viable offering (MVO) to validate design viability and continuing digital transformation planning. The third trend shows a connection between Production and Run stages, including system realization, validation, deployment, and scaling, with concurrent implementation of digital transformation during production. In the utilization phase, the focus is on operating the system to generate marketplace value. This phase notably includes the "Growth" and "Mature" stages of digital transformation, as illustrated in [Fig. 1], because these stages occur during the product's operational use. For the Support and Retirement phases, common elements are found in the DOD Systems Engineering Management Plan, INCOSE Vee Model, and DOT Vee Model. However, the Deloitte Framework lacks steps for these stages. Insights from successful entrepreneurs, as reflected in [Fig. 1], suggest revisiting the transformation phases for support and selling the product to recover salvage value at retirement instead of incurring disposal costs.

Sytems Engineering Management Plan - DOD	**Framework - Deloitte**
Life Cycle Model - Vee Model (DOT & INCOSE)	
Conceptualization	**Imagine | Planning**
Feasibilty study	Sense
Concept of Operations	Aspire
Systems Requirement	Decide
User needs, Technology, Resources	
Development	**Deliver | Implementation**
System Development	Deepen
Upper Level System element development (High-Level Design)	Design
Lower level system element development (Detailed Design)	Build/Prove
Production	**Run | Growth**
Lower level system element realization	Launch
Upper level system element realization	Scale
Solution/system realization	Operate
Unit /Device Testing	
Subsystem Verification & Deployment	
System Validation	
Utilization	**Mature | (Feedback)**
Operations	Operate
Support	**Optimize | (Upgrades)**
Maintenance	(Support)
Changes and Upgrades	
Retirement	**(Retirement)**
Retirement/Replacement	(Salvage)

Figure 1: Compression of DOD systems engineering management plan, DOT & INCOSE life cycle model, Deloitte's framework, and Digital transformation infusion

4. Summary

By providing a new perspective, the synthesis highlights how engineers, managers, and entrepreneurs handle the planning and execution of lifecycle stages for manufacturing plants and products across commercial, government, private, and public sectors. The Left column in [Fig.1] shows the breakdown of deliverables and activity structure from the manager’s and engineers' perspective while right columns depict the plan of action from the entrepreneur’s perspective. The perspectives were sequenced with respect to the life stages of systems engineering.

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Bios

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Daniel is an Industrial engineering graduate student at Wichita State University. He received a bachelor's degree in mechanical engineering with a minor in mathematics from Wichita State University. He served as a lead drivetrain engineer in his university's Formula team.

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Dr. Lynch received the BS and MS degrees in Industrial and Systems Engineering from the University of Southern California. He received his Master of International Management from the Thunderbird School of Management. He completed a PhD in Industrial, Systems, and Manufacturing Engineering (ISME) from Wichita State University (WSU) in Kansas. Dr. Lynch has 30 years of global industry experience, particularly aerospace.

Appendix: Poster

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SYSTEMS ENGINEERING MANAGEMENT PLAN SYNTHESIS INFUSED WITH DIGITAL TRANSFORMATION FOR MANUFACTURING STARTUPS

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Introduction

Digital startups must manage product life cycles effectively to remain competitive. This study combines the DoD's Systems Engineering Management Plan, INCOSE and DOT Vee-Models, and Deloitte's Digital Transformation Framework into a unified meta model.

Purpose

To provide startups with a comprehensive, practical tool for managing product development from start to finish.

Significance

This meta model helps startups streamline processes, reduce risks, and navigate market demands efficiently.

Literature Review

Systems Engineering Management Plan

- **DOD:** Systematic project management.
- **NASA:** Emphasizes detailed project planning.
- **DOT:** Provides a structured approach to system development.

Life Cycle Models:

- **Waterfall & Agile:** Traditional vs. iterative development approaches.
- **Vee-Model:** Emphasizes validation and verification across development phases.

Digital Transformation Framework:

- **Deloitte's Framework:** Encompasses phases from conceptualization to execution.

Methodology

- **Research Design:** Developed a comprehensive meta plan by synthesizing various systems engineering models.
- **Participants:** Theoretical study; no participants.
- **Materials & Tools:** Used SysML, Modelio, and Modelica for modeling physical and cyber systems.
- **Procedure:** Integrated frameworks into a meta plan and applied it to a cyber-physical manufacturing scenario.
- **Data Collection:** Used hypothetical data related to startup processes and equipment.
- **Data Analysis:** Focused on creating a clear, actionable artifact by reducing ambiguity.
- **Validity & Reliability:** Model is adaptable and open to future improvements.

Results

1. Conceptualization:

- **Common Phases:** Sense, Aspire, and Decide.
- **Focus:** Feasibility study, Concept of Operations, Systems Requirement, User needs, Technology, and Resources.

2. Development:

- **Common Phases:** Deepen, Design, and Build/Prove.
- **Focus:** System Development, Upper Level and Lower-Level System element development.

3. Production:

- **Common Phases:** Launch, Scale, and Operate.
- **Focus:** Lower and Upper-level system element realization, solution/system realization, Unit/Device Testing, Subsystem Verification & Deployment, and System Validation.

4. Utilization:

- **Common Phases:** Operate.
- **Focus:** Operations.

5. Support:

- **Common Phases:** Support.
- **Focus:** Changes, Upgrades and Maintenance

6. Retirement

- **Common Phases:** Salvage.
- **Focus:** Retirement/Replacement.

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Subsystem Verification & Deployment	
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Retirement	**(Retirement)**
Retirement/Replacement	(Salvage)

Figure 1: Compression of DOD systems engineering management plan, DOT & INCOSE life cycle model, Deloitte's framework, and Digital transformation infusion

Conclusion

The synthesis unlocks a new perspective. We see the emergence of the engineers, managers and entrepreneurs' perspective when it comes to planning and executing the life cycle of stages of a manufacturing plant.

Discussion

In this study, we encountered biases impacting decision-making:

1. Framing Bias:

- **Definition:** Decisions are influenced by how information is presented (gains vs. losses).
- **Impact:** Individuals may take more risks when information is framed negatively. This bias is crucial in fields like public policy and healthcare, where presentation affects behavior.

2. Representativeness Bias:

- **Definition:** People judge likelihood based on how well an event matches their existing experiences or stereotypes rather than actual probability.
- **Impact:** This can lead to errors like ignoring base rates or falling for conjunction fallacies, affecting areas such as finance and legal decisions.

3. Availability Bias:

- **Definition:** Judgments are based on how easily examples come to mind rather than actual frequency.
- **Impact:** Events that are vivid or recent are overestimated in likelihood, distorting risk perception and decision-making, as seen in media consumption and risk assessment.

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