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LEVERAGING GENERATIVE ARTIFICIAL INTELLIGENCE FOR EFFECTIVE RISK
MITIGATION ON ENGINEERING PROJECTS

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ABSTRACT

Since the public release of ChatGPT in November 2022, Generative Artificial Intelligence has rapidly transformed the technology landscape in government, industry, and academia. This paper explores how generative AI may proactively assist engineering leaders in the mitigation of emergent risks in new product development projects. The research methodology involves prompting ChatGPT with three realistic engineering scenarios to collect multiple versions of AI generated risk reduction plans. Qualitative and quantitative analyses are then performed on the AI generated plans, in partnership with an advisory board of three experienced engineering executives. A summary of the research is presented, including key findings, application guidance for engineering leaders, and areas for future focus.

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1 Introduction

Following the public launch of ChatGPT, Generative Artificial Intelligence captured worldwide attention throughout 2023 for its capabilities and promise. From answering broad general questions to composing music using training data, the use cases of generative AI are seemingly endless. One such capability for real-world enterprises is the effective mitigation of emergent risk.

Risk is defined as an assessment of how vulnerable an entity is to a possible situation or occurrence ("Risk - Glossary," n.d.). Risk is a reality that must be accounted for in any industry or profession. In engineering, risk is typically represented in a matrix format as the probability of risk occurrence and the impact of that occurrence ("Risk Management - Engineering and Technology History Wiki", 2015). Senior engineering leaders face risks daily in a corporate setting—ranging from simple process errors to major program issues that could significantly impact business performance.

The extent to which generative AI can effectively address risk is dependent upon the quality of user prompts that frame the challenge. A relatively new, but heavily researched topic in recent years, prompt engineering refers to the techniques of interacting with generative AI.

This study adopted a disciplined methodology to investigate three realistic engineering risk scenarios, each representing one of the primary project drivers: **technical**, **cost**, and

schedule. To gather additional data for both qualitative and quantitative analysis, the regeneration feature of ChatGPT was utilized. Additionally, the study engaged an advisory board comprised of three seasoned engineering executives to provide in-depth evaluation of the AI-generated recommendations. The paper culminates with a set of significant findings, a guide for engineering leaders, and proposed areas for future focus.

2 Generative Artificial Intelligence

2.1. History

The birth of generative artificial intelligence was powered by Hidden Markov Models (HMMs) and Gaussian Mixture Models (GMMs) in the mid-twentieth century. The HMM is based on the Markov chain—a probabilistic model used to generate new data based on input sequences—and served as the basis for many early machine-learning concepts (Cao et al., 2023).

The concept of Natural Language Processing (NLP) then emerged to combine human language with mathematics and statistical algorithms. NLP refers to the idea of machines possessing the ability to understand and process texts and sounds like humans can (“What is Natural Language Processing? | IBM”, n.d.).

In the 1960s, the first chatbot was created based on NLP principles, designed to “converse” with humans based on user input and provide proper output (Murphy, 2023). Later in the twentieth century, NLP research branched into symbolic and stochastic research. The rules and syntax aspects of symbolic NLP, along with the in-depth statistics and probability discussed in stochastic NLP, proved to be the early building blocks of generative AI (“NLP - overview”, n.d.).

2.2. Types of Generative AI

Machine Learning (ML) algorithms play key roles and act as the building blocks for generative AI. Currently, there are two different types of ML algorithms—supervised learning and unsupervised learning—each one targeted for different problems.

Supervised learning encompasses labeled data and enforces classification—which is a method used to predict data's labels based on its input. Conversely, unsupervised learning involves analysis of unclassified and unlabeled data (Delua, 2021). These two algorithms work hand in hand to complete a multitude of AI tasks from generating text to writing code.

Generative AI systems fall into one of two categories: Generative Adversarial Networks (GAN) and Transformer-based models. GANs are comprised of two neural networks, with each serving a unique purpose. The first neural network, a convolutional neural network, creates content based on the input data. The input data may include text, images, sounds, video, etc. The second neural network, a deep neural network, makes the distinction between counterfeit data and real data. Together these two networks are used to generate appropriate output based on the given input and make up the GAN (Lawton, 2023). Transformer-based models, however, are essentially deep neural networks that scrape the internet for relevant information regarding input queries and use the collected data for output generation (Merrit, 2022).

3 Large Language Models (LLMs)

LLMs are built off transformer models, specifically a neural network that establishes relationships amongst sequential data. For example, given an input of a sentence, the mechanism senses the sentence as a whole and makes key connections between each word. Two key mechanisms make up this model: positional encoding and self-attention. Positional encoding refers to the order of inputs—in our example, this can be denoted as the order of words in the sentence that is provided as the input. Self-attention involves assigning each data point/item a weight signifying its importance. Transformer networks trained on billions of parameters make up LLMs. These parameters are trained using unsupervised learning to avoid the need for extensive data labeling (“What are Large Language Models? | NVIDIA”, n.d.).

3.1. ChatGPT

One example of a Large Language Model is ChatGPT, a product launched by OpenAI in late 2022. Also referred to as GPT, it is a chatbot based on a deep neural network that incorporates reinforcement learning. What sets GPT apart from other AI models is its utilization of reinforcement learning from human feedback. Its ability to use human feedback to optimize and finetune its reinforcement algorithm has helped it become more effective and accurate. GPT offers a multitude of functions including but not limited to reading, writing, analyzing, and editing documents. It also can write code based on requirements, debug errors, and interpret many different programming languages (Dickson, 2023).

ChatGPT currently has two different active models available for public usage: GPT-3.5 and GPT-4. The former is free for all to use with an OpenAI account, whereas GPT-4 requires a \$20 monthly subscription fee. Despite ChatGPT's recent success, it has its fair share of limitations. Since the model was trained in 2021, it cannot provide information on events, new studies, etc. that have emerged after that time. GPT also has a memory limit and depending on the version used it can process up to 3000 or 8000 words of input.

Additionally, inaccuracy has been a lingering issue throughout ChatGPT's early deployment. More training data will slowly but surely increase its accuracy over time. Privacy is another concern with GPT, as all prompts entered into the chatbot are parts of the data collected by OpenAI to better train the model (Dickson, 2023). This has prompted many corporations to ban the use of ChatGPT in the workplace to protect confidential data.

4 Prompt Engineering

The practice of prompt engineering involves the optimization of prompts to yield the most desired outputs from AI/Large Language Models. Though this practice is relatively new to industry, as is the “Generative AI Era”, prompts like HTML and XML tags served as the initial building blocks for prompt engineering and software development as well. Machines interpreted these human-generated tags as prompts to perform specified functions (Yadav, 2023).

Key aspects of an effective prompt include instruction, context, input, and output being sought. Strong prompt structures may vary but all need to have clear and concise instructions with detailed context and specificity regarding desired results.

Effective prompt engineering, combined with the capabilities of generative AI, allows for the creation and refinement of a wide array of digital media (Gartner, 2023). As 2023 draws to a close, input prompts and output media now include:

- Image generation
- Image translation (image to image)
- Text-to-image conversion
- Text-to-speech conversion
- Audio Generation
- Video Generations
- AV quality enhancements

During the period in which this research was launched (2Q23), the state-of-the-art of prompt engineering consisted of four distinct tiers, designated as Levels 0-3 (Fagerlie, 2023). This text-centric prompting methodology became the basis for the research conducted.

4.2. Level 0 Prompts

Prompts at this level are generally one sentence at the maximum and propose a broad question with little to no details. For example, a traveler planning a vacation in Spain may compose the following prompt:

“What to do in Spain?”

The output of Level 0 prompts tends to be broad and at times vague (Fagerlie, 2023). Experimentally, in response to this prompt, ChatGPT touched upon many popular tourist attractions in Spain and offered many possible activities to do. Though it outputted a plethora of information regarding things to do in Spain, there was minimal structure or specificity due to the lack of context and detail in the prompt. See Appendix A for the complete Level 0 AI-generated itinerary.

4.2. Level 1 Prompts

Prompts in this level include a simple question(s) but with the addition of some context and metrics. Unsatisfied with the response to the Level 0 inquiry, our traveler then composed the following prompt:

“I am going to Madrid and Barcelona for a 10-day trip. What should I do?”

Experimentally, in response to this question, ChatGPT proposed different itineraries for Madrid and Barcelona and offered several attractions and activities in each city. There was a clear improvement in output quality, resembling the form of a budding travel itinerary. Adding specific details like the duration of the trip and the target cities helped generate an output better catered to the prompt. See Appendix A for the complete Level 1 AI-generated itinerary.

4.3. Level 2 Prompts

This level of prompting begins to add more relevant details regarding the context of the input and the type of desired output. Rather than asking one brief question, there is a richer query consisting of useful context. Seeking greater detail, our traveler now includes information regarding the number of nights aiming to be spent in each city, context regarding the age of the travelers and when the trip is occurring, and a specific request about the desired output.

Here is some context on the trip. My two friends and I are traveling to Madrid and staying there for four nights. After that, we are traveling to Barcelona for four nights. We are traveling in the month of May so keep that in mind as far as weather goes. Also, note that we are three college students and are all 20-year-olds. Provide us with a thorough day-to-day itinerary.

Experimentally, when provided with this prompt, ChatGPT generated a high-quality itinerary that segregated each day's activities, breaking it into daytime and nighttime experiences and including a travel day between cities. In comparison to the previous itineraries generated by Level 0 and Level 1 prompts, the Level 2 inquiry excelled in detail but lacked overall breadth and specificity. See Appendix A for the complete Level 2 AI-generated itinerary.

4.4. Level 3 Prompts

This prompt level involves assigning a role and persona to the AI model and asking it to acknowledge its new role. Additional context is then provided along with substantive background information. All relevant information provided can contribute to receiving a more detailed output. Finally, the expectations regarding the desired output must be made clear.

To finalize an optimum itinerary, our traveler assigns a role to the AI and provides additional details along with published guides. [Note: In the example below, words following a "Q" denote the traveler's input, and words following an "A" denote ChatGPT's output.]

Q: "Ignore everything said earlier. You are now assigned a new role. You are a travel expert and you specialize in vacations to Europe. I have hired you as my travel advisor. You

will help me by creating a thorough day-to-day itinerary (including locating restaurants for food) for the trip, which I will talk about soon. Be as helpful as you can. Acknowledge this by saying "YES" and stay idle."

A: YES, I am here to help you as your travel advisor specializing in vacations to Europe. Please provide me with the details of your trip, including the destinations you plan to visit, the duration of your trip, and specific preferences or interests you have. Additionally, let me know if you have any dietary restrictions or if there are any particular types of cuisine you would like to experience during your trip.

Q: "First, here is some information about our trip. My two friends and I are traveling to Spain. We will be spending four days in Madrid and four days in Barcelona. On the second day in Barcelona, we would like to go to an FC Barcelona match in the evening. We are also unsure which places to visit in both cities. We would like to go to a beach while in Barcelona, for at least part of one of the days. Also, during one of the days assigned to Madrid, we would like to take a day trip to Toledo. As far as dietary restrictions go, my friends don't have any restrictions, but I am vegetarian and must eat gluten-free products. As long as each restaurant has at least one or two meals that I am able to consume, we are good. Respond with "YES" to acknowledge and stay idle. I will provide more information."

A: "YES, I acknowledge your preferences and dietary restrictions. I will now proceed to create a thorough day-to-day itinerary for your trip, considering your requests. Please provide any additional information or specific interests you have, and I will incorporate them into the itinerary."

Q: I am now providing you with some links that may be helpful for you. Browse through the information and use what you feel is useful:

<https://theculturetrip.com/europe/spain/articles/10-things-to-know-before-visiting-spain/>

<https://prancier.com/blog/4-days-in-madrid-itinerary>,

<https://myvacationitineraries.com/4-days-barcelona-itinerary/>

Okay, now provide me a thorough day-to-day itinerary including places to visit and food.

Go ahead.

Experimentally, the AI itinerary for the above Level 3 prompt included far more calendar detail and highlighted specific restaurants that catered to the traveler's needs (gluten-free and vegetarian). Hyperlinks were also provided for tourist attractions and activities. The result was a fully detailed travel itinerary—far better in terms of breadth and specificity when compared to Levels 0-2 prompting. See Appendix A for the complete Level 3 AI-generated itinerary.

Given the effectiveness of Level 3 prompting, this technique became the basis for the methodology described in section 6.

5 Risk Management in Engineering

5.1. History

Risk management became a prominent global topic after the end of World War II. While financial risk was increasingly managed to reduce losses for individuals and companies, technological risk models were developed for engineering. Derivatives also emerged in the late 20th century and were routinely utilized across sectors to quantify risk (Dionne, 2013).

5.2. Industry Standards

Multiple industry standards have been published to manage risk—the favored procedure used in industry is ISO 31000. This stable framework provides detailed guidelines for companies and their leaders to manage risk. Included within the standard is a phased process for identifying, analyzing, and managing risk, best practices within each process phase, and a compliance checklist for process integrity. The standard also encourages companies to intertwine this framework into their organizational governance and senior leadership (Olechowski et al., 2016).

5.3. Risk Management Process

A generic risk management process is closed loop and includes multiple core activities.

See Figure 1 below for more details.

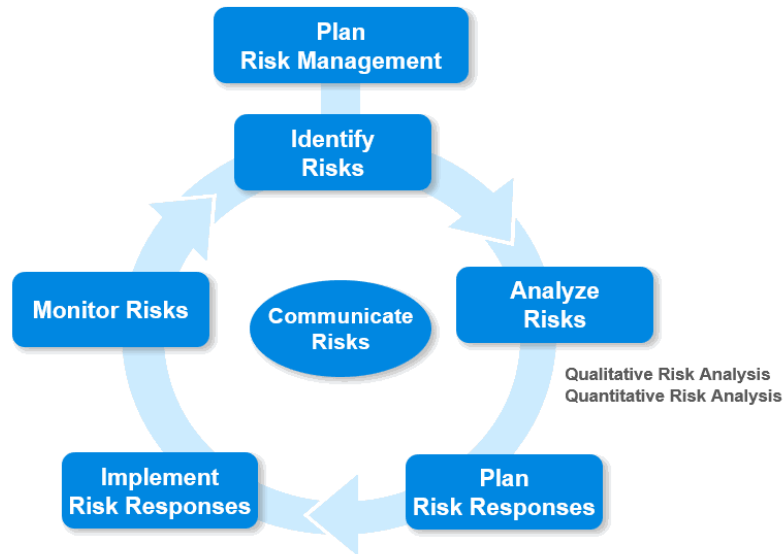


Figure 1: Generic Risk Management Process (Wanner, 2021)

Risk identification is the first step in any risk management process, and this stage involves brainstorming possible pitfalls. Second, each risk should be analyzed based on its likelihood and potential impact and then appropriately ranked.

The third step, planning risk responses, is critical and is the focus of this research. The fourth step involves implementing the responses planned in the prior step. Finally, the fifth step

consists of monitoring the risk mitigation and reflecting on the risk assessment/management process, identifying best practices and where improvements can be made (Martins, 2022).

As noted above, this paper focuses on step 3, which involves the response plans to emergent risks. In product development environments, risks and issues, whether they are expected or unexpected, are bound to arise. This step involves the implementation of strategies to mitigate risks that have been realized or are impending. Risk response planning is described further in the methodology section 6.

6 Testing Methodology

This research explored ChatGPT's ability to provide risk reduction strategies for three different scenarios—specifically, the three drivers of an engineering project: technical, cost, and schedule.

6.1. Experimental Design

To comprehensively assess ChatGPT's proficiency in risk response planning, three detailed scenarios were constructed to address the technical, cost, and scheduling dimensions of projects. Each scenario was designed to mirror complex engineering challenges that would typically require the intervention of senior management to resolve effectively. A sufficient level of detail was incorporated to provide ChatGPT with context and relevant information pertaining to the project and the pertinent risks. Level 3 prompting techniques were employed, including the assignment of roles for the AI. The scenarios were concisely composed, with each not exceeding 250 words, ensuring a consistent evaluation framework.

6.2. Experimental Control

Specific testing methodologies were employed to guarantee impartiality in the outcomes obtained from ChatGPT and to enhance the overall analysis:

- Prior to prompting ChatGPT with each scenario, the conversation history was cleared to prevent any bias
- Each scenario was composed with an equivalent level of factual detail
- ChatGPT was asked if it fully understood its role or had any questions after receiving each scenario
- A regeneration was performed after receiving the first risk reduction plan for each scenario to gather more data for analysis – the regenerated plans are available in Appendix C

6.3. Scenario #1: Technical Risk

The first scenario features MapX, a company contracted to deliver twenty lightweight payloads for high-altitude atmospheric research to NOAA. This contract is in jeopardy because the current design significantly exceeds the weight requirement, which compromises the ability of the payloads to maintain altitude.

The Level 3 prompt for the technical risk scenario is as follows, including ChatGPT's acknowledgment of its role:

Q: You are the Chief Engineer of a company called MapX.

You have been awarded a multi-year contract from the National Oceanic and Atmospheric Administration (NOAA) to develop twenty lightweight payloads for high-altitude balloon flights that will circumnavigate the Earth. The payloads consist of sensors to measure temperature, air pressure, and solar radiation at “near space” altitudes (60,000 - 100,000

feet). In addition to the onboard sensors, there is a single board processor, a GPS beacon, a two-way RF communications link, onboard memory storage, and a solar-recharged LiFePO4 battery to receive ground commands and transmit sensor telemetry. To successfully circumnavigate the Earth, the payload has been specified to not exceed 1.5 lbs (0.68 kg). Six months into the contract, your design team has notified you that their current weight projection is 2.5 lbs (1.13 kg), with no current design solutions to meet the 1.5 lbs requirement. Initial modeling and test flights suggest a payload at the current 2.5 lbs weight projection will not circumnavigate the Earth, but rather descend to the ground within 5000 nautical miles of launch.

Reply with “Yes” if you understand your role and the situation at hand. If you have any questions regarding the situation, please ask.

A: Yes.

Q: As the chief engineer for this situation, what actions will you take to minimize or eliminate the technical risk? Please provide a detailed, step-by-step action plan to optimize the outcome for MapX.

6.4. Scenario #2: Cost Risk

The second scenario features DroneX, a company contracted to deliver drones for 5G tower maintenance. The scenario includes a projected \$30 million cost overrun from a subcontractor, potentially impacting profits and projections to investors.

The Level 3 prompt for the cost risk scenario is as follows, including ChatGPT’s acknowledgment of its role:

Q: You are the Senior Engineering Executive of a company named DroneX with \$1.5 billion in annual sales.

DroneX was awarded a \$1 billion fixed-price contract by an international telecommunications company to deliver 100 remote-controlled drones over a 5-year period. The drones are essential for the remote inspection and maintenance of 5G cellular towers in third-world countries. To meet specifications, your company needs a custom GPS receiver that is immune to radio frequency interference (RFI) and GPS signal jamming. DroneX subcontracted the design, development, and production of the GPS receivers to a different company on a \$80 million cost-plus contract. Eighteen months into the contract, the GPS supplier informed you of a potential \$30 million cost overrun due to internal and supply chain cost growth. Should this occur, your company would absorb any overrun as lost profit on your fixed price contract and severely affect your financial projections to investors. Your company has a positive relationship with the customer as well as the supplier.

Reply with “Yes” if you understand your role and the situation at hand. If you have any questions regarding the situation, please ask.

A: Yes.

Q: As the senior executive in this situation, what actions will you take to minimize or eliminate the financial risk? Please provide a detailed, step-by-step action plan to optimize the outcome for DroneX.

6.5. Scenario #3: Schedule Risk

The third scenario features JetX, a company that faces significant challenges in developing Air Force One's new secure communication software due to a new systems design

methodology. JetX is projected to have an 18-month delay that the DoD will not accept and may lead to contract termination if not reduced to at most 6 months.

The Level 3 prompt for the schedule risk scenario is as follows, including ChatGPT's acknowledgment of its role:

Q: You are the Senior Engineering Executive of a company called JetX.

JetX has been awarded an 8-year cost-plus contract by the US Department of Defense (DoD) to develop a replacement for the presidential Air Force One aircraft. New software development is required for secure voice and data communication between aircraft, the US military, and federal government agencies. The systems engineering team within your company has selected a new model-based systems design (MBSD) methodology to autogenerate C++ code from behavior-based models to perform the secure communications function. Twelve months into the contract, it is clear that the company's tool infrastructure, employee training, and management culture are not ready for the transition to MBSD. It is estimated that scrapping the MBSD methodology and restarting the software development effort directly from specifications will result in an 18-month schedule delay to the delivery of the first aircraft. The DoD customer considers this delay unacceptable and will terminate the contract if the schedule delay cannot be reduced to 6 months or less. All parties, internally and externally, are frustrated with the schedule issue and interpersonal relationships must be considered.

Reply with "Yes" if you understand your role and the situation at hand. If you have any questions regarding the situation, please ask.

A: Yes.

Q: As the senior executive in this situation, what actions will you take to minimize or eliminate the schedule risk? Please provide a detailed, step-by-step action plan to optimize the outcome for JetX.

6.6. Data Collection

As soon as ChatGPT generated a risk reduction plan, the response was promptly transferred to a comprehensive master document for each scenario. Following the archival of the initial response, this procedure was replicated to capture a second risk reduction plan, generated after activating the regeneration feature for each scenario. After two plans were collected for each scenario, the conversation history on ChatGPT was cleared and the above process was repeated for the next scenario.

7 Analysis

7.1. Qualitative Analysis

7.1.1. AI Technical Risk Response Plan

The AI output for the risk response plan for the **technical** scenario included 21 recommendations grouped into 11 categories as illustrated below:

A: Certainly, addressing the technical risk requires a methodical and comprehensive approach to problem-solving. Here's a step-by-step action plan to address the weight problem and potentially other design inefficiencies:

1. Detailed Design Review:

- **Convene an urgent design review meeting with all relevant stakeholders: designers, engineers, supply chain experts, and any relevant subcontractors.**
- **Assess each component's design, its weight, and its purpose. Break down the weight contribution of each individual component to understand the major culprits.**

2. Investigate Weight Reduction Opportunities:

- **Materials: Check if lighter materials can be used without compromising the integrity or functionality of the components.**
- **Miniaturization: Consider employing newer, more compact versions of the components or see if any components can be redesigned to be smaller.**
- **Integration: Look for opportunities to combine functions of multiple components into one.**

3. Modular Design:

- **Investigate if the payload can be designed in a modular fashion, allowing it to perform primary measurements in one flight and secondary measurements in**

another. This might mean more flights but could be a solution to the weight problem.

4. Optimize Onboard Storage and Processing:

- **Re-evaluate the onboard memory: Can data be compressed more efficiently? Can some data processing be offloaded to the ground, allowing the use of a less powerful (and potentially lighter) onboard processor?**
- **Assess if the current storage solution is the lightest available in the market. Investigate alternative storage technologies or even cloud-based solutions where data can be transmitted and stored remotely in real-time.**

5. Evaluate Power Requirements and Battery Weight:

- **Calculate the exact energy requirements. Can the battery size be reduced?**
- **Investigate alternative energy-harvesting techniques, like improved solar cells or even piezoelectric generators.**
- **Assess power-saving modes for sensors and components to extend battery life.**

6. Communications Optimization:

- **Reassess the RF communication system. Is there a lighter, yet effective system available? Maybe a shift to a different communication protocol or technology that's more weight-efficient?**
- **Explore the possibility of batch transmission of data at intervals rather than continuous transmission to save energy and potentially use lighter components.**

7. Explore New Technologies and Innovations:

- **Engage with industry experts, academia, or research organizations. There may be cutting-edge solutions or research that can be applied to this situation.**
- **Consider crowdsourcing ideas or holding an internal “hackathon” to find innovative solutions.**

8. Prototyping and Testing:

- **As you make changes, prototype these new designs rapidly and test them, both in labs and in field trials. This iterative approach will ensure that the new designs still meet NOAA's requirements.**

9. Communication and Transparency with NOAA:

- **Maintain open communication with NOAA, informing them of the challenges and the steps being taken to address them. They may offer extensions, additional resources, or even alternative suggestions.**

- **Consider renegotiating certain requirements if absolutely necessary.**

10. Backup Plan:

- **In parallel, consider developing a backup plan. This could involve launching multiple balloons to achieve the desired measurements or seeking partnerships with other companies that may have complementary technologies.**

11. Continuous Monitoring and Feedback Loop:

- **Set up a continuous monitoring system to keep track of weight as modifications are made.**
- **Maintain a feedback loop with the design and testing teams to ensure that changes made are effective and don't introduce new problems.**

By approaching the problem with systematic analysis and creative problem-solving, the chances of achieving the desired weight target and ensuring the balloon can circumnavigate the Earth are maximized.

As shown above, the AI response plan proposed many innovative actions to achieve weight reduction and demonstrated superb technical acumen. Rather than limiting recommendations to one aspect of the design, the risk response plan considered the entire system architecture, including modularity, energy storage, and advanced materials. In addition, recommendations included an immediate design review with all stakeholders, an outreach to industry experts in academia, and the continuous monitoring of weight. A final noteworthy observation is that when the tool was prompted to regenerate a response for this scenario, it added a post project review and an emphasis on documentation to the initial recommendations. The complete, regenerated technical risk response plan may be viewed in Appendix C.

7.1.2 AI Cost Risk Response Plan

The AI risk response plan for the **cost** scenario included 19 recommendations grouped into 10 categories, that included contract reviews, supplier meetings and negotiation, customer communication, and contingency planning. The breadth and depth of AI recommendations were consistent with the technical response plan in Section 7.1.1 and may be found in Appendix B.

This scenario prompted the AI to recommend a greater number of people-focused and process-focused actions. The recommendations included immediate and ongoing engagement with the troubled supplier, negotiations to limit the financial impact, and back-channel communications with the customer to explore possible specification relief. Throughout its response, ChatGPT demonstrated a complete understanding of the scenario details and exhibited remarkable business acumen. When a regeneration was prompted, ChatGPT outputted similar recommendations but added a press release and post-project review. The complete, regenerated cost risk response plan may be found in Appendix C.

7.1.3 AI Schedule Risk Response Plan

The AI risk response plan for the **schedule** scenario included 21 recommendations grouped into 14 categories that included stakeholder communication, expert consultation, employee training, and resource augmentation. The breadth and depth of AI recommendations

were consistent with the technical and cost response plans in Sections 7.1.1 and 7.1.2, and may be found in Appendix B.

This scenario again prompted the AI to recommend a greater number of people-focused and process-focused recommendations. ChatGPT did well to recognize the human element of this scenario through numerous interpersonal recommendations. The emphasis on open and immediate communication is commendable and demonstrated AI responsiveness to the human-centered language in the scenario prompt. However, the multiple recommendations to embark on parallel development with two different design methodologies are questionable, at best, and will be analyzed later in this section.

When a regeneration was prompted, ChatGPT produced no additional recommendations. The complete, regenerated schedule risk response plan may be found in Appendix C.

7.2. Quantitative Analysis

To further examine ChatGPT’s performance in response to these challenging scenarios, a quantitative analysis was performed, grouping recommendations into one of three categories—people, process, and technology—as defined in Table 1.

Category	Definition	Example
People	Recommendations primarily focused on human communication and relationships	<ul style="list-style-type: none"> • Teams and task forces • Customer communications • Employee training
Process	Recommendations primarily focused on business processes	<ul style="list-style-type: none"> • Reviews and audits • Contingency planning • Process improvement
Technology	Recommendations primarily focused on design and technology	<ul style="list-style-type: none"> • Design analyses • Trade studies • R&D initiatives

Table 1: AI Recommendation Categories

The recommendation groupings for each scenario were then graphically illustrated in pie chart form, as shown in Figure 2.

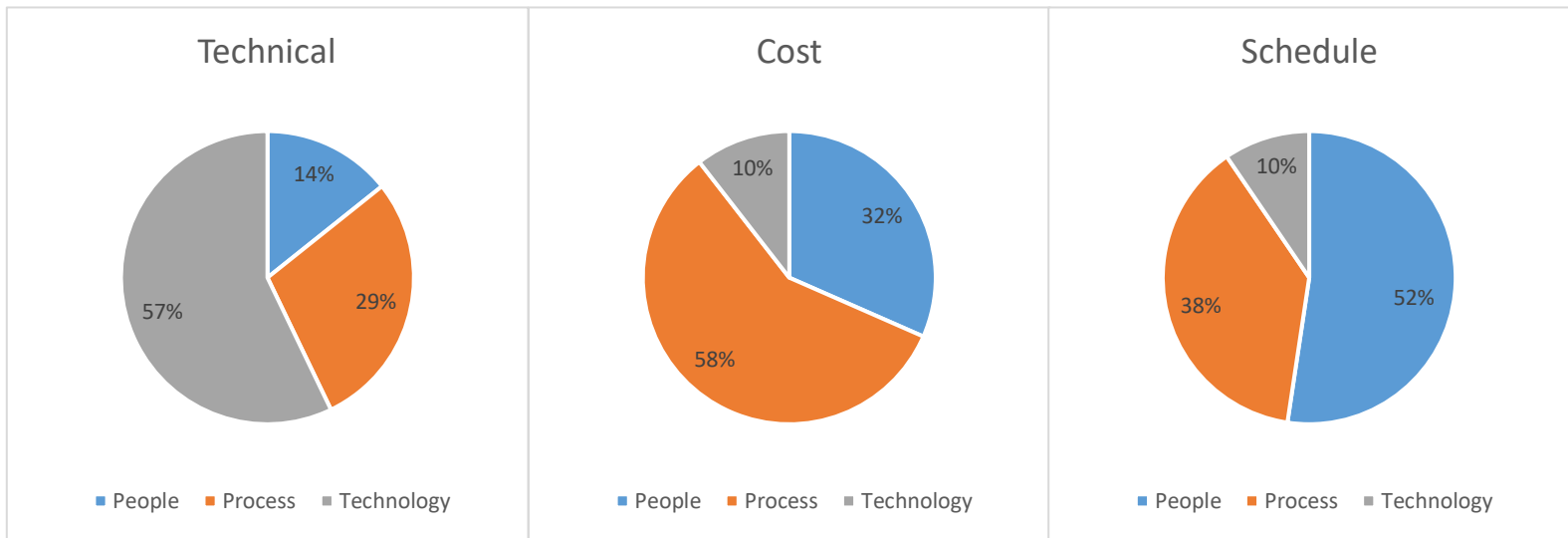


Figure 2: Category Breakdown for each Scenario

The quantitative analysis produced three key findings. First, while composing the schedule risk scenario, a phrase was intentionally included to highlight the people aspect of the issue. This resulted in a notably higher percentage of people-related recommendations (52%). Conversely, the percentage of interpersonal AI recommendations was significantly lower in the technical and cost scenarios—14% and 32% respectively. While somewhat anecdotal, this analysis suggests a tendency for ChatGPT to marginalize the interpersonal elements of project risk reduction, unless specifically prompted to do so.

Second, within the technical risk scenario, the majority of recommendations focused on technology (57%), which is notably higher in comparison to the cost and schedule scenarios. Simply stated, ChatGPT excelled in response to a difficult weight reduction challenge, providing a robust set of creative recommendations to reduce or eliminate the technical risk.

Third, the quantitative analysis revealed a large, consistent presence of process-related recommendations across all scenarios. ChatGPT values process actions as a vital part of risk reduction, including continuous process improvement to benefit future projects.

7.3. Advisory Board Analysis

As noted in the Introduction, an advisory board of three experienced engineering executives was convened early in the research process. At the board's first meeting, the research methodology was approved and a peer review of the technical, cost, and schedule risk scenarios was performed.

Following ChatGPT's creation of risk response plans, the board was reconvened to qualitatively assess the business and technical acumen of the AI. During a 90-minute review, the board identified, key strengths, deficiencies, and omissions of the AI plans for all three scenarios. These observations are summarized in Table 2.

Strengths	Deficiencies	Omissions
<p>+ The overall breadth of recommendations for all three scenarios is impressive. An experienced team of engineering leaders would brainstorm perhaps 50% of the AI recommendations in a half-day work session.</p> <p>+ Mature AI business acumen demonstrated (e.g., creation of task forces, executive interaction, contract reviews, negotiation strategies, contingency planning)</p> <p>+ Time-phased action plan generated for cost and schedule overrun scenarios (See Appendix for regeneration outputs)</p> <p>+ AI technical acumen for weight reduction scenario is superb in breadth and detail</p> <p>+ All recommendations demonstrated a clear understanding of severity and urgency</p> <p>+ Inclusion of lessons learned and process improvement actions upon resolution (frequently omitted in practice)</p> <p>+ Overall rating of action plan quality – (1) Technical, (2), Cost, (3) Schedule</p>	<p>- Multiple AI regenerations are necessary to create a “superset” of recommended actions. Human reconciliation and consolidation are then required.</p> <p>- The breadth and transparency of external communications actions are unlikely in practice until mitigation is well underway (e.g., immediate customer contact, external press releases)</p> <p>- A clear decision on MBSD/non-MBSD was required for the schedule overrun scenario. Parallel paths and real-time culture change actions are impractical in a resource-constrained environment.</p> <p>- In addition, the schedule overrun action plan was generic and non-specific in many areas.</p> <p>- Solicitation of customer assistance to solve technical challenge is unlikely in practice (i.e., suggested NOAA weight reduction assist)</p>	<p>o When prompted, no questions were asked by the AI to gather background information or nuances of scenarios (lost opportunity to gain more information and any clarifications).</p> <p>o The human elements of intercompany personal relationships, employee motivation, and team morale are underrepresented in the AI’s recommendations. In practice, these factors are essential to mission success.</p> <p>o Portfolio management of orders, sales, profit, and cash from other programs within the company is also missing. In practice, this is routinely performed to ensure the successful achievement of quarterly and annual financial goals.</p>

Table 2: Advisory Board Analysis

Overall, the results produced by ChatGPT in response to three difficult scenarios exceeded the board’s expectations. The AI’s ability to generate a detailed risk response plan within seconds demonstrated a level of efficiency that would be difficult to replicate with a human team of engineering project managers in an entire day. ChatGPT’s rapid understanding of

each scenario, coupled with its mature business and technical acumen, was very impressive to the board.

One significant deficiency noted by the advisory board was the AI's persistence in pursuing a parallel development process with Model Based System Design (MBSD) to address the schedule risk scenario. From decades of experience, the board unanimously agreed that a parallel development program was unadvised.

A second deficiency identified by the advisory board was the lack of ANY follow-up questions from the AI, despite encouraging it to ask for clarifications if needed. The written scenarios were clear and detailed, but a team of engineering managers would certainly have multiple questions before developing a risk response plan.

Finally, the board observed that while subsequent AI regenerations produced a few fresh recommendations and formats, the quality of regenerated plans did not exceed that of the initial output. Abridged biographies for the executive advisory board may be found in Appendix D.

8 Summary and Conclusions

ChatGPT provided impressive recommendations to address three challenging engineering risk scenarios that far exceeded the expectations of an experienced executive advisory board. Displaying creativity and critical-thinking skills, the Generative AI demonstrated a promising ability to reduce risk for engineering project managers.

Efficient prompt engineering methods were implemented to yield the most accurate and relevant results from the chatbot. A disciplined test methodology was also employed, including clearing the chat history and maintaining a consistent Level 3 prompt structure across scenarios. Multiple results AI responses were recorded for each scenario, and AI recommendations were grouped into one of three categories for analysis—people, process, and technology.

Based on the analyses completed for each scenario, the key findings of this research are as follows:

- ChatGPT’s risk reduction recommendations are comprehensive, innovative, and of high quality, offering engineering leaders valuable guidance for informed decision-making and innovative risk management
- When explicitly prompted, ChatGPT suggests a higher percentage of people-focused recommendations; if not prompted, it may offer significantly fewer recommendations focused on interpersonal relations

- While ChatGPT is a potentially valuable resource for risk mitigation, it is essential for engineering leaders to critically evaluate AI recommendations to ensure their feasibility and applicability within a business context

Engineering leaders who use ChatGPT to respond to develop risk response plans would be well advised to:

- Compose a Level 3 scenario prompt, with ample details and context, that assigns a leadership role to the AI
- Request the AI to address communications and interpersonal relationships with all relevant human stakeholders (i.e., customers, suppliers, employees, shareholders, and/or the community)
- Utilize the regeneration function within ChatGPT to gather additional recommendations that may come from a second analysis by the AI

In the rapidly growing field of generative AI, future focus areas for engineering leaders to consider include:

- The usage of plugins to enhance the user experience and/or real-time data analytics capabilities of GPT-4 and beyond
- Conversational interaction to hone optimum plans and experiment with different avenues of risk reduction
- The ethical implications of generative AI deployment across the enterprise
- New AI models and the benefits of curating/utilizing custom AI models for business-specific needs

With continued LLM learning and research breakthroughs occurring at a rapid pace in the generative AI field, ChatGPT's capabilities will continue to exponentially develop. Generative AI will have a positive impact on engineering risk management, and an exciting future lies ahead.

Appendix A: Prompt Engineering AI Outputs

This appendix includes the complete ChatGPT output for each example prompt from Level 0 to Level 3, as described in section 4 of this paper.

Level 0 Example Output

Spain offers a wide range of activities and attractions that cater to various interests. Here are some popular things to do in Spain:

- 1. Explore the cities: Visit vibrant cities like Madrid, Barcelona, Seville, Valencia, and Granada. Discover their unique architecture, museums, cultural landmarks, and lively street life.**
- 2. Marvel at architectural wonders: Spain is known for its stunning architecture. Admire Antoni Gaud's masterpiece, Sagrada Família, in Barcelona, or visit Alhambra Palace in Granada, a stunning example of Moorish architecture. The works of renowned architect Santiago Calatrava can be seen in Valencia.**
- 3. Enjoy the beaches: Spain boasts beautiful beaches along its coastlines. Relax on the sandy shores of Costa del Sol, Costa Brava, or the Balearic Islands, such as Mallorca and Ibiza.**
- 4. Experience culinary delights: Spanish cuisine is diverse and delicious. Indulge in tapas, paella, jamón ibérico, and local wines. Explore food markets like La Boqueria in Barcelona or Mercado de San Miguel in Madrid.**
- 5. Immerse in art and culture: Visit world-class museums like the Prado Museum in Madrid, the Picasso Museum in Barcelona, or the Guggenheim Museum in Bilbao. Enjoy flamenco performances, traditional festivals, and local cultural events.**
- 6. Discover historical sites: Explore historical landmarks such as the Roman aqueduct in Segovia, the Alcazar of Toledo, or the Roman ruins of Mérida. Don't miss the pilgrimage site of Santiago de Compostela.**
- 7. Hike in nature: Spain offers breathtaking natural landscapes. Hike in the Pyrenees Mountains, explore the stunning beaches of Costa de la Luz, or visit national parks like Picos de Europa or Tide National Park in Tenerife.**

8. Attend festivals: Experience the lively atmosphere of Spanish festivals. Join the Running of the Bulls in Pamplona during the San Fermin festival, witness the La Tomatina tomato-throwing festival in Buñol or enjoy the Feria de Abril in Seville.

9. Visit the islands: Spain has beautiful islands that are worth exploring. Enjoy the beaches, nature, and nightlife of the Balearic Islands (Mallorca, Ibiza, Menorca) or the Canary Islands (Tenerife, Gran Canaria, Lanzarote).

10. Engage in outdoor activities: Try water sports like surfing, snorkeling, or diving along the coast. Go hiking, cycling, or skiing in the mountains. Spain offers plenty of opportunities for adventure. Remember to check the latest travel information and COVID-19 restrictions or guidelines before planning your trip.

Level 1 Example Output

That sounds like an exciting trip! Here's a suggested itinerary for your 10-day trip to Madrid and Barcelona:

Day 1-3: Madrid

- Explore the historic center of Madrid, including Puerta del Sol, Plaza Mayor, and the Royal Palace.
- Visit world-renowned art museums such as the Prado Museum, Reina Sofia Museum, and Thyssen-Bornemisza Museum.
- Wander through the beautiful Retiro Park and enjoy a boat ride on its lake.
- Experience the vibrant food scene by trying tapas in traditional taverns and exploring the Mercado de San Miguel.

Day 4-7: Barcelona

- Discover the architectural wonders of Barcelona, including the Sagrada Familia, Park Güell, and Casa Batlló, all designed by Antoni Gaudi.
- Take a stroll down the famous pedestrian street, La Rambla, and explore the Gothic Quarter.
- Visit the Picasso Museum and explore the contemporary art scene in the El Raval neighborhood.
- Relax on the beaches of Barceloneta and enjoy the lively beachside atmosphere.

- Don't miss the opportunity to try traditional Catalan dishes like paella, fideuà, and crema catalana.

Day 8-10: Madrid

- Take a day trip to Toledo, a UNESCO World Heritage Site known for its medieval architecture and rich history.
- Explore the trendy neighborhoods of Malasaña and Chueca, known for their vibrant nightlife and unique shops.
- Visit the impressive El Escorial, a historic royal residence and monastery located just outside of Madrid.
- Enjoy flamenco performances at one of Madrid's renowned tablas, where you can experience the passion of this traditional Spanish art form.

Of course, this itinerary can be adjusted based on your preferences and interests. Both Madrid and Barcelona have so much to offer, from cultural landmarks to culinary delights. Make sure to plan ahead and check for any specific events or festivals happening during your visit. Enjoy your trip!

Level 2 Example Output

Certainly! Based on the information provided, here's a day-to-day itinerary for your 10-day trip to Madrid and Barcelona:

Day 1: Madrid

- Arrive in Madrid and settle into your accommodation.
- Spend the afternoon exploring the historic center of Madrid, starting with Puerta del Sol and Plaza Mayor.
- Enjoy a traditional Spanish dinner at a local restaurant.

Day 2: Madrid

- Begin your day with a visit to the Royal Palace and its beautiful gardens.
- Explore the art museums in Madrid, such as the Prado Museum and the Reina Sofia Museum.
- In the evening, experience the vibrant nightlife of Madrid by visiting lively areas like Malasaña or Chueca.

Day 3: Madrid

- Take a day trip to Toledo, a charming medieval city known for its historic architecture.
- Visit Toledo Cathedral, the Alcazar, and stroll through the picturesque streets.
- Return to Madrid in the evening and enjoy dinner at a local tapas bar.

Day 4: Madrid

- Spend the morning relaxing in Retiro Park and rent a rowboat to enjoy a leisurely ride on the lake.
- Explore the upscale neighborhood of Salamanca, known for its high-end shops and boutiques.
- Visit the Thyssen-Bornemisza Museum, which houses an impressive collection of art from various periods.
- In the evening, indulge in a flamenco show to experience the passion of this traditional Spanish dance.

Day 5: Travel from Madrid to Barcelona

- Take a morning train or flight from Madrid to Barcelona.
- Arrive in Barcelona and check into your accommodation.
- Spend the afternoon exploring the Gothic Quarter, including a visit to Barcelona Cathedral.
- Enjoy dinner at a local restaurant and savor the flavors of Catalan cuisine.

Day 6: Barcelona

- Start the day by visiting the famous Sagrada Familia and admiring its incredible architecture.
- Explore Park Güell, another Gaudi masterpiece, with its colorful mosaic tiles and stunning views of the city.
- In the evening, take a leisurely stroll along the vibrant promenade of La Rambla and enjoy street performances.

Day 7: Barcelona

- Spend the morning at the Picasso Museum, home to an extensive collection of the artist's works.
- Visit the trendy neighborhood of El Born and explore its narrow streets and boutique shops

- **Head to Barceloneta Beach to relax by the sea and have a delicious seafood lunch at a beachside restaurant.**
- **In the evening, enjoy the nightlife in the El Raval neighborhood, known for its eclectic bars and live music venues.**

Day 8: Barcelona

- **Take a day trip to Montserrat, a stunning mountain range outside Barcelona, and visit the Montserrat Monastery.**
- **Explore the natural beauty of the area through hiking trails or a scenic cable car ride**
- **Return to Barcelona in the evening and enjoy a farewell dinner at a local restaurant**

Day 9: Departure

- **Depending on your departure time, spend the morning exploring any remaining sights or shopping for souvenirs**
- **Check out of your accommodation and make your way to the airport or train station for your journey back home.**

This itinerary allows you to experience the highlights of both Madrid and Barcelona while also incorporating day trips to Toledo and Montserrat. Remember to check for any specific events or festivals happening during your visit and adjust the itinerary accordingly. Enjoy your trip!

Level 3 Example Output

Thank you for providing the links. I will incorporate the information from those sources while creating your day-to-day itinerary. Based on your preferences and the provided links, here is a thorough day-to-day itinerary for your trip to Spain:

Day 1: Arrival in Madrid

- **Arrive in Madrid and settle into your accommodation.**
- **Take a walk around the city center to get acquainted with the atmosphere and visit iconic landmarks such as Puerta del Sol and Plaza Mayor.**
- **Enjoy a traditional Spanish dinner at a local restaurant. For gluten-free and vegetarian options, consider trying Botanique Bistro or Viva Burger.**

Day 2: Exploring Madrid

- Start your day with a visit to the Royal Palace, a magnificent architectural masterpiece.
- Explore the renowned Prado Museum and discover its impressive collection of art.
- For lunch, head to Celicioso, a gluten-free bakery and cafe offering a variety of delicious options.
- Spend the afternoon in Retiro Park, where you can relax, rent a rowboat, or visit the Crystal Palace.
- In the evening, explore the vibrant Malasaña neighborhood, known for its trendy shops, bars, and restaurants. For dinner, try La Hummuseria, which offers vegetarian and gluten-free Mediterranean dishes.

Day 3: Day Trip to Toledo

- Take a day trip to Toledo, a historic city renowned for its rich cultural heritage.
- Explore Toledo Cathedral, the Alcázar, and wander through the charming streets of the Jewish Quarter.
- For lunch, visit Restaurante Locum, which offers gluten-free and vegetarian options along with traditional Spanish cuisine.

Day 4: Madrid and Travel to Barcelona

- Spend the morning visiting the Reina Sofia Museum, home to an extensive collection of contemporary and modern art.
- For lunch, head to Rayén Vegano, a vegan restaurant that offers gluten-free options.
- In the afternoon, visit the vibrant Mercado de San Miguel, where you can try various local delicacies.
- Take a flight or train to Barcelona.
- In the evening, enjoy dinner at Flax & Kale, a trendy restaurant offering healthy vegetarian, gluten-free, and vegan options.

Day 5: Exploring Barcelona

- Start your day by visiting the magnificent Sagrada Familia, one of Barcelona's most iconic landmarks.
- Explore Park Güell, another masterpiece by Gaudi, with its stunning views and unique architecture.
- For lunch, try Teresa Carles, a vegetarian and vegan restaurant with gluten-free options.

- In the afternoon, take a walk along the lively promenade of La Rambla and explore the Gothic Quarter.
- In the evening, enjoy an FC Barcelona match at Camp Nou, immersing yourself in the excitement of Spanish football.

Day 6: Beach Day in Barcelona

- Spend the day relaxing at Barceloneta Beach, one of Barcelona's most popular beaches.
- Enjoy the sun, swim in the Mediterranean Sea, and have a beachside lunch at a chiringuito (beach bar).
- In the evening, explore the vibrant neighborhood of El Born and try traditional Spanish tapas at La Plata, which offers gluten-free options

Day 7: Barcelona Exploration

- Visit the Picasso Museum and explore the works of this renowned artist.
- Discover the enchanting streets of El Raval and have lunch at Rasoterra, a vegetarian and vegan restaurant with gluten-free options.
- Visit Casa Batlló, another architectural gem by Gaudi.
- Enjoy dinner at Teresa Carles, a vegetarian and vegan restaurant offering gluten-free options.

Day 8: Departure

- Depending on your departure time, spend the morning exploring any remaining sights or shopping for souvenirs.
- Check out of your accommodation and proceed to the airport or train station for your journey back home.

Please note that restaurant availability and offerings may change, so it's a good idea to check their websites or contact them in advance to confirm menu options and make reservations if needed. Enjoy your trip to Spain!

Appendix B: Initial AI Recommendations

This appendix includes the complete ChatGPT risk reduction plan for each scenario: technical, cost, and schedule.

Scenario #1: Technical

Certainly, addressing the technical risk requires a methodical and comprehensive approach to problem-solving. Here's a step-by-step action plan to address the weight problem and potentially other design inefficiencies:

1. Detailed Design Review:

- **Convene an urgent design review meeting with all relevant stakeholders: designers, engineers, supply chain experts, and any relevant subcontractors.**
- **Assess each component's design, its weight, and its purpose. Break down the weight contribution of each individual component to understand the major culprits.**

2. Investigate Weight Reduction Opportunities:

- **Materials: Check if lighter materials can be used without compromising the integrity or functionality of the components.**
- **Miniaturization: Consider employing newer, more compact versions of the components or see if any components can be redesigned to be smaller.**
- **Integration: Look for opportunities to combine functions of multiple components into one.**

3. Modular Design:

- **Investigate if the payload can be designed in a modular fashion, allowing it to perform primary measurements in one flight and secondary measurements in another. This might mean more flights but could be a solution to the weight problem.**

4. Optimize Onboard Storage and Processing:

- **Re-evaluate the onboard memory: Can data be compressed more efficiently? Can some data processing be offloaded to the ground, allowing the use of a less powerful (and potentially lighter) onboard processor?**
- **Assess if the current storage solution is the lightest available in the market. Investigate alternative storage technologies or even cloud-based solutions where data can be transmitted and stored remotely in real-time.**

5. Evaluate Power Requirements and Battery Weight:

- **Calculate the exact energy requirements. Can the battery size be reduced?**
- **Investigate alternative energy-harvesting techniques, like improved solar cells or even piezoelectric generators.**
- **Assess power-saving modes for sensors and components to extend battery life.**

6. Communications Optimization:

- **Reassess the RF communication system. Is there a lighter, yet effective system available? Maybe a shift to a different communication protocol or technology that's more weight-efficient?**
- **Explore the possibility of batch transmission of data at intervals rather than continuous transmission to save energy and potentially use lighter components.**

7. Explore New Technologies and Innovations:

- **Engage with industry experts, academia, or research organizations. There may be cutting-edge solutions or research that can be applied to this situation.**
- **Consider crowdsourcing ideas or holding an internal “hackathon” to find innovative solutions.**

8. Prototyping and Testing:

- **As you make changes, prototype these new designs rapidly and test them, both in labs and in field trials. This iterative approach will ensure that the new designs still meet NOAA's requirements.**

9. Communication and Transparency with NOAA:

- **Maintain open communication with NOAA, informing them of the challenges and the steps being taken to address them. They may offer extensions, additional resources, or even alternative suggestions.**
- **Consider renegotiating certain requirements if absolutely necessary.**

10. Backup Plan:

- **In parallel, consider developing a backup plan. This could involve launching multiple balloons to achieve the desired measurements or seeking partnerships with other companies that may have complementary technologies.**

11. Continuous Monitoring and Feedback Loop:

- **Set up a continuous monitoring system to keep track of weight as modifications are made.**
- **Maintain a feedback loop with the design and testing teams to ensure that changes made are effective and don't introduce new problems.**

By approaching the problem with systematic analysis and creative problem-solving, the chances of achieving the desired weight target and ensuring the balloon can circumnavigate the Earth are maximized.

Scenario #2: Cost

Certainly. Here's a step-by-step action plan to manage the situation at hand:

1. Contract Review:

- **Begin by revisiting the contract with the GPS supplier to ascertain the exact terms, especially the conditions surrounding cost overruns and any change orders.**
- **Check if there's any clause that can protect DroneX from such overruns or, at least, limit the extent of the financial risk.**

2. Supplier Meeting:

- **Arrange an urgent face-to-face meeting (or virtual, if physical isn't feasible) with the top executives of the GPS supplier.**
- **Gain a deeper understanding of the root causes of the overrun: Is it labor, materials, unanticipated technical challenges, or another issue?**
- **Question if the overrun could have been foreseen and communicated earlier.**

3. Investigate Alternative Solutions:

- **Ask the supplier for alternative technical solutions that could reduce costs without compromising the primary requirements of the GPS receivers.**
- **Explore whether modifying some non-essential requirements could lead to cost savings.**

4. Negotiation:

- **Determine if there's room for negotiating the overrun costs with the supplier, perhaps splitting it in some way. Given the ongoing relationship, they might be open to cost-sharing to maintain business ties.**
- **Consider discussing any future business prospects or incentives that could help reduce the immediate impact.**

5. Internal Evaluation:

- **Assess internal company resources and see if there's any expertise within DroneX that could assist the supplier, perhaps in terms of design optimization, bulk buying of components, or other collaborative methods to bring down costs.**

6. Customer Communication:

- **Engage in proactive communication with the telecommunications company. Being transparent about challenges while assuring them of the delivery can sustain the good relationship.**
- **Without compromising your position, explore the possibility of any adjustments in specifications or other alternatives that could indirectly alleviate some of the cost pressures.**

7. Contingency Planning:

- **Given that the relationship with the supplier is positive, work on contingency plans for potential future overruns or challenges. This might include renegotiating contracts, seeking alternative suppliers, or investing in in-house capabilities.**
- **Build a financial contingency in your forecasts for similar large projects in the future.**

8. Share with Stakeholders:

- **Update investors and relevant stakeholders about the situation, assuring them of the measures in place. This transparency can prevent any sudden shocks to stock prices or investor relations.**

9. Project Management Improvement:

- **After the immediate issue is handled, focus on improving the company's project management, monitoring, and risk assessment protocols to prevent similar situations in the future.**
- **This could include more regular check-ins with subcontractors, setting up early warning systems for potential overruns, and tighter project management controls.**

10. Future Contracts:

- **For future contracts, especially those that involve subcontracting crucial components, consider having more stringent oversight and clarity on terms related to overruns and change orders.**
- **Consider the introduction of penalty clauses for late communication of cost overruns.**

These steps should optimize the outcome for DroneX and maintain its good relationship with both the supplier and the telecommunications company.

Scenario #3: Schedule

Given the complex situation, here is a step-by-step action plan to address the challenges faced by JetX:

1. **Immediate Risk Assessment:**
 - Assemble a core team including the lead systems engineer, software development lead, and project manager.
 - Conduct a rapid assessment to understand the core reasons for the failure in transitioning to MBSD.
2. **Stakeholder Communication:**
 - Schedule an urgent meeting with the DoD customer. Explain the challenges faced, ensure them of JetX's commitment to the project, and ask for their understanding and collaboration. Maintain transparency to build trust.
 - Communicate the situation internally to all staff to ensure they are informed, aligned, and ready to support the necessary changes.
3. **Quick Wins:**
 - Identify any components where the MBSD methodology has been successful and can be salvaged. This will help in reducing some development time.
 - If there are components that are close to completion using the MBSD methodology, consider completing them as-is to save time.
4. **Parallel Development:**
 - While you reassess the MBSD methodology, begin a parallel software development effort using traditional methods. This would ensure that if MBSD does not work out, you already have some progress made in the traditional model.
5. **Expert Consultation:**
 - Bring in experts who have experience with MBSD in similar contexts. They might provide insights into mistakes being made, training required, or modifications needed for successful implementation.
 - Consider hiring or consulting with specialists to address tool infrastructure and training gaps.
6. **Employee Training and Change Management:**

- **Organize immediate and intensive training sessions for staff on the MBSD methodology, including real-world applications and hands-on workshops.**
 - **Consider bringing in change management experts to guide the cultural transition and address resistance.**
- 7. Resource Augmentation:**
- **If budget allows, hire temporary software development experts or firms to speed up the process. This would be a short-term solution to help reduce the delay.**
- 8. Process Streamlining:**
- **Remove any bureaucratic hurdles or unnecessary steps in the development process. Implement agile methodologies to iterate and deliver faster.**
- 9. Quality Assurance and Testing:**
- **While speeding up the process is essential, ensuring the quality of the software is crucial, especially given its secure communication function. Set up a dedicated quality assurance team to test functionalities as they are developed.**
- 10. Feedback Loops:**
- **Set up short feedback loops with the DoD to ensure the software being developed aligns with their requirements. This reduces the chances of prolonged revisions later.**
- 11. Regular Updates and Reporting:**
- **Establish a bi-weekly reporting structure with the DoD customer to update them on progress and gather feedback.**
 - **Internally, hold weekly progress meetings to identify any bottlenecks or challenges.**
- 12. Contingency Planning:**
- **While the primary goal is to deliver within the 6-month window, it's essential to develop contingency plans. This could involve offering other value propositions to the DoD if the delay is inevitable.**
- 13. Relationship Management:**
- **Given the interpersonal issues, consider holding team-building exercises and workshops to improve collaboration and morale. This can help teams work more efficiently together.**
 - **For external stakeholders, especially the DoD, ensure consistent communication and show good faith efforts to address the challenges.**
- 14. Review and Lessons Learned:**

- **After navigating this crisis, hold a retrospective review to understand the root causes, what went well, and what could've been done better. This would be crucial for future projects and organizational learning.**

The combination of technical expertise, stakeholder management, and rapid action can help JetX navigate this challenge. The key is maintaining transparency, continuously seeking feedback, and remaining adaptive.

Appendix C: Regenerated AI Recommendations

This appendix includes all regenerated risk reduction plans for each scenario—technical, cost, and schedule—after clicking on the “Regenerate” button prompted by the chatbot.

Technical Output Regeneration

Certainly. Addressing the weight issue while still maintaining the functional requirements of the payload will be a critical endeavor. Here’s a step-by-step action plan I would propose:

Step 1: Convene a Crisis Management Team

- 1.1 Gather a Multidisciplinary Team: Assemble a team of experts from various departments (Design, Materials Science, Aerodynamics, etc.) to bring a diverse range of solutions to the table.**
- 1.2 Establish a Central Command: Create a project task force which will meet daily to monitor progress and quickly address emerging issues.**

Step 2: Identifying Areas for Weight Reduction

- 2.1 Component Weight Analysis: Conduct a thorough analysis of the current design to pinpoint the heaviest components and potential areas for weight reduction.**
- 2.2 Benchmarking: Research and analyze lighter components in the market or in similar projects, which can potentially replace the existing heavy components.**

Step 3: Design Re-evaluation and Modification

- 3.1 Re-design Critical Components: Focus on re-designing the heaviest components, possibly using lighter materials or optimizing the design for weight reduction without compromising functionality.**
- 3.2 Incorporate Lightweight Materials: Explore the use of high-strength, lightweight materials like carbon fiber composites or other advanced materials to replace heavier ones.**

3.3 Minimize Redundancies: Identify and eliminate any redundancies in the system, consolidating functions where possible to save weight.

Step 4: Prototype and Testing

4.1 Prototype Development: Develop prototype versions of the revised payload to validate the new design and ensure it meets the weight target.

4.2 Rigorous Testing: Conduct a series of ground and flight tests to ensure the revised payload meets the necessary performance and safety standards.

Step 5: Collaborative Partnerships

5.1 Engage Suppliers: Work closely with suppliers to identify and source lightweight materials and components.

5.2 Collaborate with Research Institutions: Seek collaboration with research institutions for advanced materials and design optimization solutions.

Step 6: Contingency Planning

6.1 Develop Contingency Plans: Develop contingency plans for further design iterations, in case the initial attempts do not achieve the desired weight reduction.

6.2 Budget and Timeline Re-evaluation: Concurrently, re-evaluate the project timeline and budget to account for the changes and the potential need for additional resources.

Step 7: Regular Communication with NOAA

7.1 Regular Updates: Maintain open lines of communication with NOAA, providing them with regular updates on the progress and any challenges encountered.

7.2 Leverage NOAA's Expertise: Leverage NOAA's expertise and seek their inputs or assistance if necessary to ensure the project's success.

Step 8: Final Integration and Testing

8.1 Integration: Integrate all redesigned components and conduct final tests to validate the payload's functionality and readiness for deployment.

8.2 Final Approval: Seek final approval from NOAA before proceeding to mass production and deployment.

Step 9: Review and Documentation

9.1 Post-Project Review: After the project completion, conduct a review to identify lessons learned and best practices for future projects.

9.2 Documentation: Document the entire process meticulously for future reference and as a guideline for similar projects.

By following this detailed action plan, I aim to steer the project back on track, ensuring that we meet the stringent weight requirement without compromising on the payload's functionality and performance.

Cost Output Regeneration

Absolutely, in a situation like this, it is crucial to act decisively to safeguard the financial stability and reputation of DroneX. Here is a detailed step-by-step action plan:

Step 1: Assess the Situation (Immediate Action - Week 1)

- **1.1 Hold an emergency meeting with the project management team to understand the extent of the issue.**
- **1.2 Request a detailed report from the supplier about the cause of the projected cost overrun.**
- **1.3 Conduct a preliminary financial analysis to understand the potential impact on the company's financials and projected earnings.**

Step 2: Strategic Planning (Week 2)

- **2.1 Create a task force consisting of financial analysts, project managers, and legal advisors to tackle the issue.**
- **2.2 Develop potential strategies to mitigate the financial risk, including renegotiating the contract, finding alternative suppliers, or absorbing the cost and making internal adjustments.**
- **2.3 Begin talks with the customer about potential adjustments or changes to the project, while keeping their needs and expectations in focus.**

Step 3: Engaging with the Supplier (Week 3-4)

- **3.1 Organize a meeting with the supplier to discuss the projected overrun and potential solutions.**
- **3.2 Negotiate with the supplier to share part of the overrun cost or to explore cost-cutting measures within the scope of quality requirements.**
- **3.3 Explore the possibility of technical adjustments or alterations to the project that can reduce costs without compromising the project's objectives.**

Step 4: Internal Adjustments and Optimization (Week 5-8)

- **4.1 Conduct an internal audit to identify areas where costs can be reduced to absorb part of the overrun.**

- **4.2 Initiate R&D efforts to potentially develop cost-effective solutions internally.**
- **4.3 Develop a contingency plan in case the negotiations with the supplier do not yield the desired outcomes.**

Step 5: Communication and Transparency (Week 9-10)

- **5.1 Communicate transparently with shareholders and stakeholders about the potential financial impact and the steps being taken to mitigate it.**
- **5.2 Hold discussions with the customer to explore potential adjustments or changes to the project that can help in reducing costs.**
- **5.3 Prepare a press release and communication strategy to manage the public perception of the company during this period.**

Step 6: Implementation and Monitoring (Week 11 onwards)

- **6.1 Implement the chosen strategies and closely monitor their progress.**
- **6.2 Establish regular communication channels with both the customer and the supplier to prevent any further unforeseen issues.**
- **6.3 Review and adjust the project's financial projections and communicate the revised projections to investors.**

Step 7: Learning and Future Planning (Post-Project)

- **7.1 Conduct a post-project review to identify lessons learned and to develop strategies to prevent similar issues in future projects.**
- **7.2 Enhance the company's risk management strategies to include provisions for potential cost overruns in subcontracted projects.**
- **7.3 Develop a stronger supplier vetting process to prevent similar issues in the future.**

I believe that following this plan should help DroneX navigate this challenging situation in the most optimal way possible.

Schedule Output Regeneration

To mitigate the ongoing risks and to align with the expected delivery schedule as closely as possible, a structured, and carefully crafted plan needs to be put in place. Here's a step-by-step action plan to optimize the outcome for JetX:

Step 1: Comprehensive Assessment and Immediate Engagement (Week 1-2)

1. **Critical Evaluation:** Undertake an immediate and comprehensive assessment to understand the depth of the current issues, particularly focusing on the gaps in infrastructure, training, and management culture.
2. **Engagement with Stakeholders:** Have candid conversations with all parties involved, including the DoD, to clearly communicate the current situation and the steps being taken to rectify it.
3. **Consultation with Experts:** Consult with experts in MBSD and other methodologies to gather insights and potential solutions.

Step 2: Formulate Action Plan and Resource Allocation (Week 3-4)

4. **Action Team Formation:** Form a high-power action team composed of internal and external experts to fast-track the transition process.
5. **Rapid Employee Training:** Develop a fast-track training program to get the existing team up to speed with the new methodology, if MBSD is still considered to be viable.
6. **Infrastructure Setup:** Parallely, upgrade the existing infrastructure to support the new methodology, ensuring it can support autogenerated C++ code effectively.
7. **Resource Allocation:** Identify and allocate resources judiciously to facilitate the swift progression of the project, possibly hiring temporary experts to fill the skill gaps.

Step 3: Implementation and Progress Monitoring (Month 2-4)

8. **Parallel Development Paths:** If feasible, pursue parallel paths of development - one with MBSD and another with a more traditional approach to hedge the risks.
9. **Continuous Monitoring:** Establish a real-time monitoring system to track the progress of the project and to make swift decisions based on the developments.

- 10. Feedback Loop: Create a feedback loop with the DoD to keep them informed of the progress and to obtain necessary guidance and approvals swiftly.**

Step 4: Risk Management and Contingency Planning (Month 5-6)

- 11. Risk Management: Identify potential risks and formulate strategies to mitigate them in advance.**
- 12. Contingency Planning: Develop contingency plans to address possible delays, focusing on keeping the delay within an acceptable range.**
- 13. Crisis Communication Strategy: Develop a crisis communication strategy to manage information flow effectively, maintaining transparency with stakeholders.**

Step 5: Review and Final Adjustments (Month 6-7)

- 14. Progress Review: Conduct a comprehensive review of the progress made and make necessary adjustments to the plan to optimize the outcomes.**
- 15. Resource Optimization: Based on the review, reallocate resources to optimize the output and to minimize delays.**

Step 6: Deliver and Post-Delivery Management (Month 8)

- 16. Delivery: Facilitate the successful delivery of the project, ensuring that all quality and security parameters are met.**
- 17. Feedback and Adjustments: Post-delivery, gather feedback from all parties and make necessary adjustments to the project, if necessary.**
- 18. Relationship Management: Work on rebuilding and strengthening relationships with all stakeholders, focusing on long-term collaboration and partnership.**

By following this action plan, I aim to optimize the outcomes for JetX, minimizing or potentially eliminating the schedule risk, and delivering a successful project within an acceptable timeframe.

Appendix D: Advisory Board Biographies

Steve Betza

Steve Betza is a retired executive with a distinguished 36-year career at IBM and Lockheed Martin, where he held senior roles in engineering and program management. As Lockheed Martin's corporate director, he spearheaded strategic partnerships and led advanced manufacturing initiatives. Steve now contributes his expertise to the National Science Olympiad, where he serves on the executive board of the Science Olympiad Foundation. A Penn State alumnus with numerous accolades, he remains engaged with the university, fostering undergraduate research and serving as a Professor of Practice.

Paul Mittan

Paul Mittan is currently the Director of Engineering Leadership Development at Penn State University. He formerly served roles at Lockheed Martin in design innovation and multidisciplinary technical leadership for 15 years. Experienced in advanced integrated products and the digital workforce, Paul assumed leadership roles that encompassed software and hardware development and systems integration. A Penn State University and Cornell University alumnus, Paul now prepares ELD graduates to tackle real-world problems using his expertise and knowledge gained from serving high-performance teams in industry.

Brian Zajac

Brian Zajac served in technology development and senior leadership roles at the Carnegie Mellon Robotics Institute and Uber Technologies, after earning bachelor's and master's degrees at Cornell University. His 15-year industry career culminated as Head of Hardware Engineering at Uber, where he led a large, advanced technology team in the development of autonomous vehicles, during Uber's transition to a publicly held company. Brian now serves as an Adjunct Instructor at Penn State University Park and Penn State Altoona, where he designs new courses and mentors undergraduates in freshman engineering design and senior capstone design.

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