The Future of Planning: AI-Integrated Decision Support System

Reimagining the Playbook Interface with AI-Powered Decision Support to Simplify and Enhance Mission Planning

Human-Computer Interaction Program

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Declaration

We, Jilly Li, Nhi Tran and Shivam Shukla of the Department of Computational Media, University of California, Santa Cruz, confirm that the data, designs, research findings, diagrams, photographs, and all other materials presented in this report are our own original work. We have not incorporated content from others without proper acknowledgement, quotation, and citation. We understand that any failure to do so constitutes plagiarism, a serious form of academic misconduct.

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Abstract

Playbook is a NASA software tool designed to enable mission planning, scheduling, and execution for human and robotic space missions. Currently, most mission planning at NASA remains a highly manual process, involving inputs and verifications by numerous individuals for each mission. This manual approach is time-consuming and requires significant human effort, which may limit the agility needed for future missions. As we push further into space and face increasingly complex challenges, the paradigm of mission planning and execution must evolve to meet these demands. Recent advancements in machine learning and artificial intelligence (AI) have sparked interest in how these technologies can be effectively applied to support both mission planners and execution teams, making the planning process more efficient, adaptive, and resilient.

The purpose of this project is to create research-supported design concepts for a hypothetical, AI-driven mission planning and execution interface within Playbook, intended for future deep-space exploration missions. This vision involves leveraging AI to augment human decision-making, automate re-scheduling, and provide real-time support to both mission planners on Earth and crew members in space or analogous environments. By integrating AI into Playbook, we aim to reduce manual workloads, enhance situational awareness, and ultimately improve the effectiveness of mission planning and execution in the unique and high-stakes environment of space exploration.

Our research seeks to bridge the gap between the use of artificial intelligence in the mission-planning domain and the potential of a human-centered approach to enhance decision-making during unexpected or dynamic scenarios. To achieve this, we employed qualitative research methods, including interviews and design workshops, to identify user expectations, preferences, and concerns related to the use of AI in critical environments. We identified key themes from this research, such as trust in AI systems, the need for transparency in decision-making, and the importance of maintaining human oversight. These themes informed our design process, helping us create solutions that align with user needs and expectations.

Based on these insights, we adopted an agile approach to design an AI-supported toolkit tailored to address unforeseen scenarios for both mission planners and crew members. This toolkit includes features such as real-time anomaly detection, automated scheduling adjustments, and decision-support recommendations, all of which are designed to assist users in handling unexpected events effectively. The design process involved multiple iterations, incorporating feedback from both direct stakeholders (such as mission planners) and indirect stakeholders (including engineers and other members of the Playbook team). This iterative approach ensured that our solutions were grounded in real-world user needs and practical usability considerations.

Mission planners and crew members were our primary user types, and our proposed designs are the result of continuous collaboration with these users, integrating their feedback at every stage of the development process. The resulting concepts are intended to empower users by enhancing their ability to manage complex mission scenarios, reducing cognitive load, and enabling more informed decision-making in the face of uncertainty. For instance, our designs

emphasize intuitive visual interfaces that present AI-generated insights in a clear and accessible manner, allowing users to understand the rationale behind AI recommendations and maintain control over final decisions.

The research insights and design concepts presented in this report aim to support the integration of AI into Playbook, with a strong emphasis on a human-centered approach for the future of space exploration. This approach ensures that AI is used not as a replacement for human expertise but as a tool that complements and enhances human capabilities. By focusing on human-AI interaction, we aim to build trust in AI systems, foster effective collaboration between humans and machines, and create tools that are adaptable to the unique challenges of deep-space missions. Moreover, this work can serve as foundational research for designing interfaces and integrating automation into space mission planning and execution systems, providing a roadmap for future advancements in this domain.

Keynote: Throughout our research and design phase, we focused less on the technical limitations and capabilities of AI and more on the human-AI interaction aspects of the tool and the needs of its users. By prioritizing the user experience and considering how AI can be seamlessly integrated into existing workflows, we aimed to create a system that is not only technologically advanced but also intuitively usable and beneficial for those at the forefront of space exploration.

Acknowledgements

We would like to express our heartfelt gratitude to Jimin and Katherine for their continuous guidance and support throughout the project. We also extend our appreciation to our instructors and teaching assistants, whose insights and feedback were invaluable. Additionally, we are thankful to the entire Playbook team and the HCI group from NASA Ames for their unwavering support, which proved to be crucial at various stages of the project. Their expertise and collaboration played a pivotal role in shaping the direction of this work.

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Chapter 1

Introduction

1.1 About Playbook

Playbook is a user-friendly software developed by NASA's SPIFe team to support the planning, scheduling, and execution of space exploration missions. Playbook enables planners and crew members to create, modify, and execute mission timelines in feasible and intuitive ways. It features timeline scheduling with activity modeling, resource management, and constraint checking, as well as execution capabilities like procedure integration and activity status tracking.
Playbook has been utilized in various NASA Space Exploration Missions, including:

- NASA Extreme Environment Mission Operations (NEEMO)
- Human Exploration Research Analog (HERA)
- Crew Health and Performance Exploration Analog (CHAPEA)
- Biologic Analog Science Associated with Lava Terrains (BASALT)
- Hawai'i Space Exploration Analog and Simulation (HI-SEAS)

Additionally, it has been part of two International Space Station (ISS) Technology Demonstrations, contributing to the Exploration Systems Development Division (ESDM) and the Crew Autonomous Scheduling Test (CAST).

1.2 Background

Space mission planning is an intricate and multifaceted process, requiring careful navigation of challenges that span the entire mission lifecycle. This process involves a series of complex decisions that must account for a diverse array of factors, including risk management, mission design, and operational execution. The dynamic and high-stakes nature of space exploration amplifies the need for effective and efficient planning mechanisms. One of the primary challenges in mission planning lies in the inherent risks associated with space activities. These risks, which can jeopardize mission success, are broadly categorized into physical, digital, organizational, and regulatory domains, each posing unique threats that demand meticulous management. Effective risk assessment and mitigation require a comprehensive understanding of these risks from multiple perspectives, including their cost implications and potential opportunities.

Replanning, or the realignment of strategies and actions in response to unforeseen events, is an equally critical yet cognitively demanding aspect of mission operations. The process involves mentally simulating potential courses of action to achieve specific outcomes while adapting to contingencies that may arise. This adaptability is vital for overall mission success. However, the cognitive demands of replanning vary significantly among individuals. For instance, experts tend to develop plans more quickly and with less information compared to novices, highlighting the influence of experience and mental modeling in decision-making.

Decision-making forms the backbone of mission planning, requiring the identification of optimal solutions from a range of alternatives. Both mission planners and crew members rely on their unique mental models, shaped by their respective roles and environments, to guide these decisions. While mission planners typically operate from Earth with a broader view of operational dynamics, crew members face immediate and situational challenges in space. This divergence underscores the need for tools and strategies that bridge these cognitive and contextual gaps to foster effective collaboration and decision-making.

1.3 Objectives

The objective of this project is to design a robust, research-supported, user-centered design solution that addresses the challenges and complexities of space mission planning and execution. The proposed designs aim to support mission planners and crew members by providing solutions that can enhance decision-making, improve adaptability, and streamline self-scheduling across diverse operational contexts. By focusing on the key aspects of replanning, and a Human-Centered approach toward AI, the design seeks to create solutions that cater to the unique demands of space missions while minimizing Workload and maximizing operational efficiency.

Our design goal is to conceptualize a toolkit that aligns with the decision-making processes of these distinct user groups. The design will incorporate mechanisms to ensure that the solutions are intuitive and accessible, enabling users to navigate complex scenarios with confidence and precision. Special attention will be given to the representation of mission-critical data, allowing users to process and act on information effectively. Another key objective is to enhance the flexibility and resilience of mission planning systems by incorporating adaptive features that accommodate unforeseen scenarios. These features will support real-time adjustments, provide actionable recommendations, and facilitate risk assessment, ensuring that users can respond efficiently to dynamic changes.

Chapter 2

Research

2.1 Preliminary Research

The preliminary research aimed to explore the general thought processes, challenges, and expectations individuals face during planning and rescheduling. This phase was instrumental in laying the groundwork for the project by providing a clear understanding of user behaviors, decision-making patterns, and the obstacles they encounter in general while decision-making and re-planning. The insights derived from this research were helpful to familiarize ourselves with the plan generation process itself and helped us formulate our primary set of research questions for our study.

2.1.1 Methodology

The research consisted of two main components: open-ended unstructured interviews and a group replanning activity, both designed to uncover participants' planning behaviors under realistic scenarios.

Open-Ended Unstructured Interviews

Objective: To gather qualitative insights into how individuals approach planning and rescheduling tasks, their strategies, and the challenges they face.

Procedure: The team conducted six unstructured interviews, each spanning 12–15 minutes. These interviews allowed participants to freely express their thoughts, providing a natural flow of ideas without the constraints of predefined questions.

- Participants were asked about their personal experiences with planning, how they adapted to changes, and the factors they considered during the replanning process.
- The unstructured format was especially beneficial for uncovering unexpected patterns and challenges that might not have surfaced in more structured environments. Additionally, it allowed us to consider the perspective of the people involved—what they think when they are planning or re-planning.

Outcomes: The data collected during this phase revealed common challenges and behaviors, which were then used to design the next phase of the research: the group replanning activity.

Group Replanning Activity

Objective: To observe how participants collaborate and adapt to planning challenges in a group setting, particularly under constrained conditions.

Procedure: The group activity involved seven groups, each consisting of 3–4 participants, and was conducted in person to facilitate natural interaction and collaboration.

- Each group was tasked with replanning their mid-quarter capstone project timeline under specific constraints, including limited time (one week) and resources.
- Participants were instructed to restructure their plans to deliver their capstone project within the new deadline while considering deliverable constraints.
- The activity lasted approximately 15 minutes for each group, during which participants discussed, collaborated, and finalized their replanned timelines.
- Feedback and responses were collected through manual responses and follow-up surveys, capturing both the process and the outcomes of their planning efforts.

Significance: This activity simulated real-world planning challenges, allowing us to gather data related to group dynamics, decision-making strategies, and how participants navigated interpersonal and logistical constraints.

Figure 2.1: Group Re-planning activity

2.1.2 Findings

The preliminary research uncovered several key insights, categorized into challenges, success criteria, and expectations for planning tools:

Challenges in Individual and Group Planning

- **Interpersonal Friction:** Participants often struggled to manage interpersonal disagreements when plans needed to change, particularly in group settings.
- **Feasibility of Timelines:** Both individually and in groups, participants found it challenging to create timelines that were realistic and achievable given the imposed constraints.
- **Disruption Management:** Unexpected tasks or changes to initial plans created significant difficulties, requiring participants to rethink their priorities and adapt.
- **Resource Allocation:** Efficiently managing and utilizing resources, especially under constraints, was a recurring challenge highlighted by participants.
- **Over Planning:** On an individual level, participants tended to overplan with overly optimistic expectations, which often led to difficulties when disruptions occurred.

Success Criteria

Participants defined success in planning and replanning based on the following metrics:

- **Timely Completion:** Successfully completing tasks or projects within the given time frame was the most frequently mentioned criterion.
- **Backup Plans:** Having effective contingency plans and the flexibility to account for potential errors were considered essential for success.
- **Work-Life Balance:** Some participants emphasized maintaining a healthy balance between their personal and professional commitments as an important aspect of successful planning.

Expectations from Planning Tools

Participants expressed specific expectations for tools that could support their planning and replanning efforts:

- **Plan Restructuring:** Tools should assist in restructuring plans and predicting outcomes based on various parameters and user preferences.
- **Feedback and Suggestions:** Participants wanted tools that could provide actionable feedback and suggestions to improve planning and rescheduling.
- **User-Friendly Design:** A collaborative, intuitive, and user-friendly interface was emphasized as a critical requirement for planning tools.
- **Time Management:** Participants desired tools that could help them efficiently manage time to meet deadlines and deliverables.

2.1.3 Conclusion

The preliminary research provided a comprehensive understanding of the cognitive and logistical challenges associated with planning and replanning tasks, both individually and in groups. By identifying the specific challenges, success criteria, and expectations of participants, this phase laid a foundation for the subsequent stages of the project. The findings highlighted the need for tools and strategies that not only address constraints but also facilitate collaboration and adaptability, ensuring alignment with user needs and real-world mission challenges.

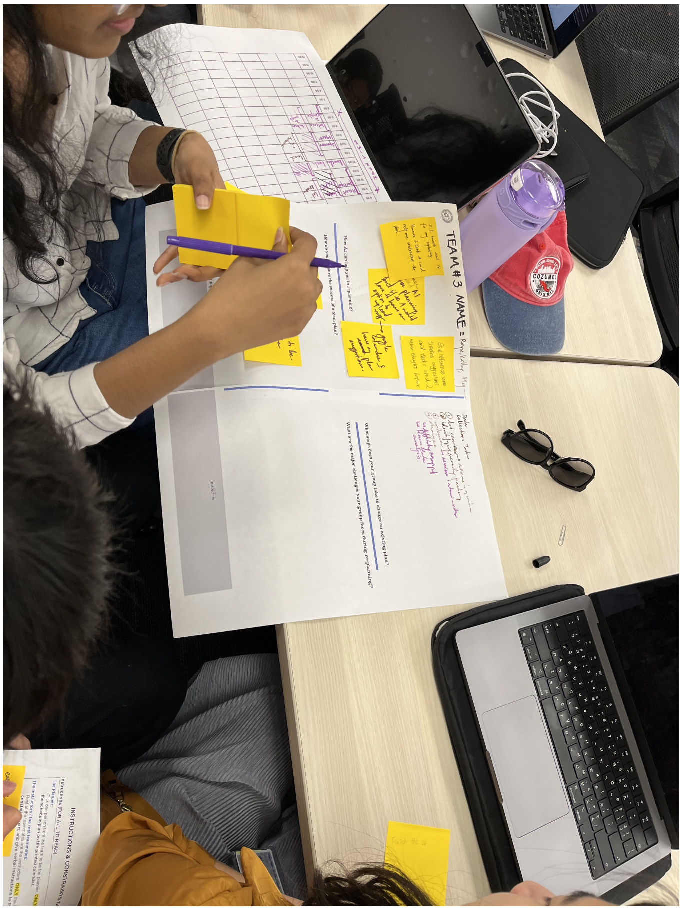

Figure 2.2: Manual data collection

2.2 Qualitative Research

Building on the insights gained from the preliminary research and the literature review, the qualitative research phase aimed to explore the challenges, processes, and expectations associated with mission-critical planning. This phase was centered around addressing the following four research questions (RQs), which guided our data collection and analysis:

1. What steps are involved in the mission planning process?
2. What are the primary challenges encountered during mission planning?
3. In what ways do various constraints influence and shape mission plans?
4. How can decision support systems, including AI-driven tools, enhance the planning, scheduling, and replanning of both contingency and nominal operations by providing improved decision-making support?

2.2.1 Methodology

The qualitative research involved semi-structured interviews with subject matter experts (SMEs) from NASA's Ames Research Center, specifically those involved in the Playbook team and mission-critical operations. The interview process was designed to collect rich, in-depth data relevant to the research questions while remaining open-ended to explore unexpected insights.

Participants:

- The participant pool included seven experts with diverse roles, including a design lead, project manager, software developers, and mission planners from the Ames HCI group.
- Additionally, one participant was a Human Factors (HF) researcher from the Aeronautics Department at Ames Research Center.
- This diverse group provided a broad range of perspectives on mission-critical planning processes, challenges, and the potential role of technology, particularly AI.

Procedure:

- Each semi-structured interview lasted approximately one hour, allowing participants ample time to elaborate on their experiences, challenges, and expectations.
- The interview questions were aligned with the four RQs but maintained an open-ended structure to ensure flexibility and adaptability during the conversations.
- The interviews were conducted in a conversational style, encouraging participants to share detailed insights and elaborate on their responses.

Focus Areas:

- The interviews explored participants' understanding of mission planning processes and challenges, particularly within the context of Playbook.
- Participants were also asked to reflect on the integration of task constraints into planning and the potential of decision-support systems to enhance mission-critical operations.

2.2.2 Data Analysis

After completing the interviews, the collected data underwent thematic analysis, a structured process for identifying and interpreting patterns within qualitative data. The steps included:

Transcription and Familiarization:

- The interview recordings were transcribed verbatim to ensure accuracy and reliability.
- The research team reviewed the transcripts multiple times to familiarize themselves with the content and identify initial ideas and recurring patterns.

Pattern Identification:

- The coded data was reviewed iteratively to identify patterns and relationships among the codes.
- Through this process, sub themes were developed to categorize related ideas and insights.

Theme Development:

- The subthemes were refined and grouped into broader themes that captured the essence of the participants' responses.
- These themes provided a clear framework for understanding the challenges and opportunities associated with mission-critical planning and informed the development of future design concepts.

2.3 Findings and Insights

The findings from our research provide a comprehensive understanding of the challenges, processes, and expectations associated with mission planning, replanning, and contingency management. Through detailed qualitative analysis, we identified three overarching themes: navigating constraints and interdependencies, elevating user experience, and empowering human-AI collaboration. These themes not only highlight the current pain points in mission planning but also inform future design considerations to enhance efficiency, usability, and reliability in mission-critical tools.

2.3.1 Theme 1: Navigating Constraints and Interdependencies

Strategies for Effective Mission Planning: Effective mission planning hinges on the ability to manage constraints and interdependencies, which include technical, operational, and resource-based factors. Managing these complexities is critical for creating strong and feasible mission plans. However, as participants noted, accounting for every requirement and constraint with accuracy remains a significant challenge. This theme highlights the strategies employed by planners to navigate these difficulties and emphasizes the need for advanced tools to support this process.

Effective Constraints and Dependencies Management Participants consistently stressed the importance of identifying, prioritizing, and understanding various layers of constraints and dependencies to ensure effective mission planning. This includes considering how one activity influences or overlaps with others, as well as the technical and resource-based limitations involved. Despite these efforts, manually managing these dependencies poses significant challenges.
As one participant, S2 (Playbook Technical Lead at NASA Ames), explained:

"And you have to do [consider] them... Like this activity before this activity. So there's a lot of things in common, like the overlap [...] in reality is that for people it is really hard to model everything."

This quote underscores the cognitive and practical difficulties faced by mission planners in managing overlapping activities and dependencies. It reflects the challenges of accounting for the interplay between various factors in the planning process, particularly when performed manually. This finding highlights a critical gap in current practices and suggests the need for advanced tools and technologies to assist in identifying and modeling these dependencies effectively.

By simplifying the complexities of constraint management, such tools can enable planners to focus their cognitive resources on making strategic decisions, ultimately improving the robustness and feasibility of mission plans. This insight serves as a foundation for the development of user-centered tools that not only streamline dependency management but also enhance the overall planning process.

2.3.2 Theme 2: Elevating User Experience

Mission Success through User-Centered Contingency Planning: This theme focuses on the critical importance of user experience (UX) in contingency planning tools. The development of user-friendly and intuitive interfaces with functional features is essential to ensure accessibility and usability. These tools should minimize the learning curve, enabling even novice users to navigate and manage tasks effectively. Comprehensive user testing and iterative improvements are key to addressing user needs and delivering a high-usability tool that supports mission planning.

User-Friendly and Intuitive Design: The creation of visually intuitive and simplified contingency planning tools is vital for enhancing the user experience. Participants emphasized that interfaces must be designed to make navigation seamless and task management straightforward, especially for new users. Reducing the learning curve not only ensures accessibility but also empowers users to focus on mission-critical tasks without being overwhelmed by the complexity of the tool itself.

S7 (Playbook Associated Researcher at NASA Ames) highlighted this by stating:

"Our interface is very human; it expects a human to touch it."

This quote underscores the need for interfaces that align with human interaction patterns, providing a natural and intuitive experience.

Similarly, S3 (Playbook Design Lead at NASA Ames) emphasized:

"We value usability pretty highly and that's consistent with our feedback."

These insights reveal the participants' strong preference for tools that prioritize usability, making intuitive design a cornerstone for effective contingency planning.

2.3.3 Theme 3: Empowering Human-AI Collaboration

Enhancing Automation and Building Trust: This theme explores the transformative potential of integrating AI into mission planning processes to enhance efficiency, support human planners, and address concerns about reliability. While AI-driven systems offer automation and adaptive capabilities, a balanced approach emphasizing collaboration and trust between humans and AI is critical for success. The theme is divided into four subthemes: automated task planning and scheduling, continuous monitoring and adaptive adjustments, data-driven predictions and intelligent suggestions, and balancing AI with human oversight.

Automated Task Planning and Scheduling: AI-driven systems have the potential to streamline task creation and scheduling by automating these processes based on user-defined parameters. This capability significantly reduces manual effort and enhances planning efficiency, freeing up human planners to focus on higher-level decision-making.

As S2 (Playbook Technical Lead at NASA Ames) noted:

"This thing called task list, which is like a set of activities that they [planners] can pull from. [...] They currently go and manually grab things from the task list."

This quote highlights the limitations of current manual practices and the potential of AI to generate viable plans automatically. Automating task planning and scheduling would ensure greater consistency and efficiency, ultimately improving mission readiness and execution.

Continuous Monitoring and Adaptive Adjustments: One of the key utilization's of AI in mission planning is its ability to monitor operations and make real-time adjustments continuously. This ensures that plans remain current and aligned with mission objectives while enhancing flexibility and resilience. Continuous monitoring also allows for quick responses to unexpected disruptions, minimizing operational risks.

S5 (Playbook Associated Researcher at NASA Ames) emphasized this utilization:

"Like something very simple or just being able to check for errors. I think Playbook can already do that. Check when there's overlap or a resource being used by 2 different crew members at the same time."

This insight demonstrates how AI can address inefficiencies by identifying conflicts and overlaps, ensuring smoother operational workflows and more robust planning.

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This quote highlights the limitations of current manual practices and the potential of AI to generate viable plans automatically. Automating task planning and scheduling would ensure greater consistency and efficiency, ultimately improving mission readiness and execution.

Data-Driven Predictions and Intelligent Suggestions: AI systems excel at analyzing large volumes of historical and real-time data to provide predictive insights and intelligent suggestions. By offering context-aware recommendations, AI supports decision-making processes, optimizes mission plans, and improves the accuracy and reliability of outcomes.

As S4 (Playbook Project Manager at NASA Ames) explained:

"Having a collection of all that data would allow us to make reasonable predictions or potentially model things that aren't being actually modeled because of the way people are scheduling."

This illustrates the value of AI in uncovering hidden patterns and offering actionable insights that might not be immediately apparent to human planners. These data-driven capabilities empower users to make informed decisions, enhancing both efficiency and effectiveness.

Balancing AI and Human Oversight: While AI offers significant benefits, participants emphasized the importance of maintaining human oversight in critical decision-making processes. Acknowledging AI's limitations and potential for errors, participants advocated for a collaborative approach where AI supports, rather than replaces, human planners.

S1 (Playbook Human Factors Researcher at NASA Ames) highlighted this challenge:

"It's been hard for NASA in general to accept those tools [...] you can imagine scenarios where you really don't want that to happen. If you were trying to generate a procedure, for instance, and you have 10,000 other procedures, so it's got a huge data set to train on. But unless it's tied to a digital twin or something and you can test it out, it's hard for NASA to be like, yeah, let's do this because you might end up with a procedure that no one's ever seen before."

This quote underscores the critical need for human validation and the challenges of ensuring trust in AI systems. By combining AI's analytical strengths with human intuition and expertise, mission planning processes can achieve greater reliability and robustness.

2.3.4 Brief Conclusion

Based on the analysis of our research findings, several key points emerged as critical to guiding the design phase of our project. These points establish a clear foundation for creating effective, user-centered designs that address the challenges and opportunities identified in the research themes. Below is an elaboration of these design directions, connected to the themes from the findings.

2.4 Key-Highlights based on Insights from Research Findings

Based on the analysis of our research findings, several key points emerged as critical to guiding the design phase of our project. These points establish a clear foundation for creating effective, user-centered designs that address the challenges and opportunities identified in the research themes. Below is an elaboration of these design principles, connected to the themes from the findings.

2.4.1 Simplified Constraint Management and Dependency Resolution

Connected to Theme 1: Navigating Constraints and Interdependencies. Effective mission planning requires tools that simplify the management of constraints and interdependencies. Participants highlighted the difficulties of manually accounting for overlapping activities and resource limitations.

- Visualize constraints and dependencies clearly, reducing cognitive load.
- Automatically identify and resolve conflicts between activities.
- Provide structured, hierarchical representations of dependencies to aid in decision-making.

2.4.2 User-Centered and Intuitive Interfaces

Connected to Theme 2: Elevating User Experience. A user-friendly and intuitive interface is essential for accessibility and ease of use.

- Simplifying navigation with visually intuitive layouts that guide users seamlessly through tasks.
- Reducing the learning curve, making the tool approachable for novice users while still supporting advanced functionalities for experts.

- Providing interactive, real-time feedback to assist users in adapting their plans effectively.

2.4.3 Functional Features for Enhanced Efficiency

Connected to Theme 2: Elevating User Experience Participants emphasized the importance of functional features to streamline planning and replanning processes. For example:

- Prebuilt templates and customizable frameworks to facilitate quick plan creation.
- Collaborative tools that enable planners and crew to work seamlessly on plans.
- Automated suggestions and operational hints that assist users in making efficient decisions.

2.4.4 Integration of Automation for Task Scheduling and Monitoring

Connected to Theme 3: Empowering Human-AI Collaboration Automation emerged as a key element for improving efficiency and ensuring plans remain aligned with mission objectives. The design should support:

- Automated task scheduling features that generate viable plans based on user-defined parameters.
- Continuous monitoring capabilities that identify errors, conflicts, and deviations in real time.
- Adaptive adjustments to dynamically update plans in response to unexpected disruptions.

2.4.5 Data-Driven Insights for Decision Support

Connected to Theme 3: Empowering Human-AI Collaboration Data analysis is critical for providing predictive insights and intelligent suggestions that optimize mission planning. For example:

- Advanced data visualization designs to present insights clearly and concisely.
- Predictive modeling features that use historical and real-time data to suggest optimal actions.
- Context-aware recommendations that help users make informed decisions during both nominal and contingency planning.

2.4.6 Balancing Automation with Human Oversight

Connected to Theme 3: Empowering Human-AI Collaboration While automation offers significant advantages, maintaining human oversight is crucial for ensuring reliability and trust in the system. For example:

- Transparent decision-making processes, allow users to understand how automated suggestions are generated.
- Customizable levels of automation, enable users to control the extent of AI involvement.
- Clear validation steps where users can review and approve AI-generated plans before execution.

2.5 Key Note

AI Assumptions: These are the AI assumptions we made before proceeding to our design phase. We made our design decisions with these points under consideration.

- Integrates and oversees all data within Playbook.
- Evaluates key metrics like risk, workload, and other key metrics.
- Monitors real-time updates (e.g., unexpected weather or missing resources) to adapt plans dynamically.
- Utilizes historical plan data as a reference for decision-making.
- AI system already exists in the Playbook (neglecting capabilities and scope)

Chapter 3

Design

3.1 Identifying User Types and Pain Points

To ensure the design solutions were tailored to the needs of the users, we categorized the primary user groups and analyzed their roles, expertise, and challenges. This analysis informed the subsequent design decisions and helped prioritize the features and functionalities of the proposed system.

3.1.1 User Types

Two primary user types were identified based on their involvement in mission planning and execution:

Mission Planners:

- **Role:** Mission planners are the architects of mission operations, responsible for creating, managing, and validating mission schedules. They possess extensive expertise in planning, decision-making, and contingency management.
- **Key Needs:** Tools that streamline the planning process, reduce manual workload, and support scenario-based decision-making.
- **Challenges:** Managing complex workflows, ensuring plans are executable, and addressing constraints under time-sensitive conditions.

Crew Members:

- **Role:** Crew members, including astronauts, are primarily responsible for executing the mission plan. They rely on the schedules and guidelines provided by mission planners and often need to adapt to real-time changes during the mission.
- **Key Needs:** Intuitive and clear plans that allow for adaptability, real-time decision support, and effective plans.
- **Challenges:** Understanding complex plans and adapting to unexpected changes.

3.1.2 Pain Points

Through qualitative research and user interviews, we identified several pain points common to both user groups. These were organized into key themes that directly influenced the design phase:

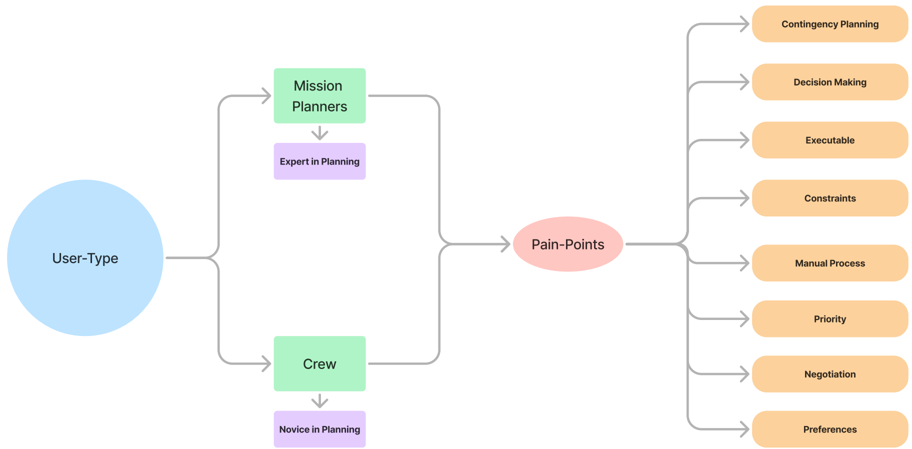

Figure 3.1: User types and pain points

3.1.3 Refining Design Focus

After identifying the user types and their associated pain points, we evaluated the scope and feasibility of addressing each pain point in the design phase. While all identified pain points were relevant to the overall mission planning and execution process, we decided to exclude **priority**, **negotiation**, and **preferences** from the immediate scope of our design work. This decision was based on the following considerations:

Rationale for Exclusion

- The core focus of this project is to enhance decision-making and adaptability under unexpected scenarios using AI. While priority, negotiation, and preferences are important, they are less critical to the immediate goal of developing AI-driven tools for handling contingency planning and supporting mission-critical decision-making.
- Addressing priority, negotiation, and preferences would require the development of additional features and workflows, significantly expanding the scope of the project. To maintain a focused and manageable design process, we prioritized pain points directly related to mission-critical tasks, such as contingency planning and decision-making.
- Incorporating these elements would have diluted our ability to deliver a robust and functional prototype addressing the primary challenges identified in the research phase.
- By narrowing our focus to these pain points, we ensured that the proposed solutions would have the greatest immediate impact on user workflows and mission outcomes.
- While priority, negotiation, and preferences were excluded from the current design phase, they remain relevant for future iterations of the tool. These aspects could be explored

in subsequent phases of development, once the foundational AI-driven functionalities are established and validated.

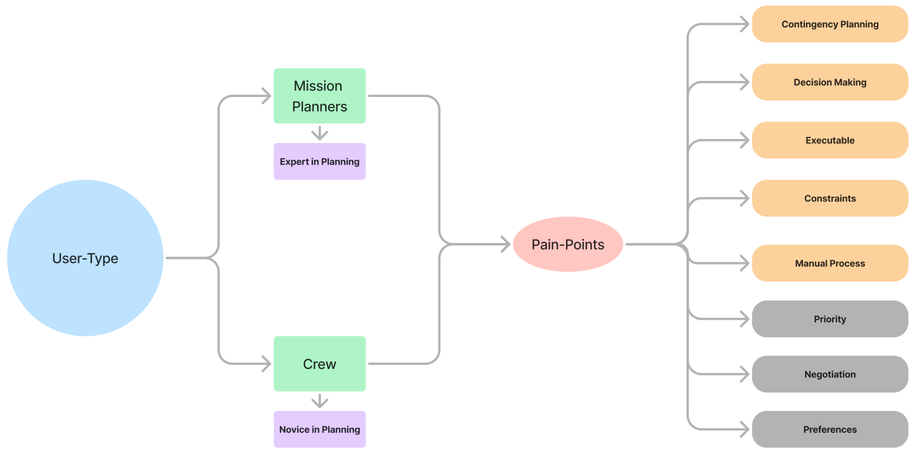

Figure 3.2: Narrowed design focus

3.2 User Flows

Building on the insights from the research phase and our refined understanding of user types and pain points, we conducted a user flow analysis to lay the foundation for our design concepts. This step was critical in identifying the key interaction points and decision-making moments in the re-planning process, particularly during contingency events.

Purpose of User Flow Analysis: The user flow analysis aimed to map out the re-planning process and identify opportunities to address user challenges effectively. This process allowed us to:

- Break down the workflow into distinct stages and identify where users interact most with the system.
- Highlight moments where users face challenges such as cognitive overload, hesitation, or frustration, particularly during complex decision-making tasks.
- Use insights to inform high-level design directions, ensuring the concepts address the critical needs of mission planners and crew members.

Key stages of the user flow include:

- **Contingency Detection:** Users identify an unexpected event that requires re-planning.
- **Scenario Assessment:** Users evaluate available options, constraints, and potential outcomes to formulate an updated plan.
- **Plan Adjustments:** Users make changes to the plan based on scenario analysis, often involving complex decision-making and trade-offs.
- **Validation and Execution:** Users review and finalize the updated plan, ensuring it is actionable and aligned with mission objectives.

3.2.1 Insights from User Flow Analysis

The user flow analysis revealed that the **scenario assessment** and **plan adjustments** stages were the most critical for user engagement and decision-making. These stages aligned directly with the identified design directions:

- During **scenario assessment**, users benefited most from *Pathways Exploration* tools that helped them evaluate and compare alternative options.
- In the **plan adjustments** stage, users required support in navigating *Simplified Constraints*, ensuring they could focus on solving problems without being overwhelmed by data.
- Across all stages, **Enhancing Human-AI Collaboration** was essential for creating a system that users could rely on for guidance, support, and adaptability.

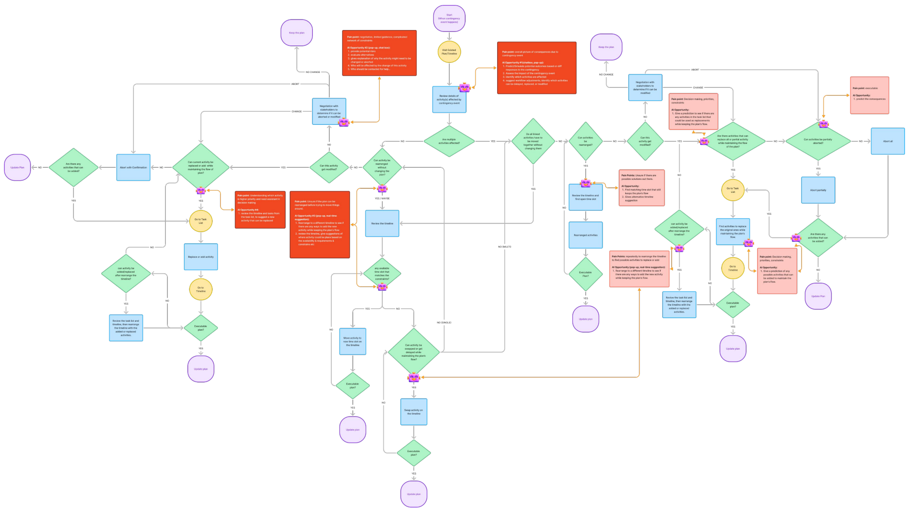

Figure 3.3: Key stages in red highlights

3.3 Brainstorming and Sketching

As a natural progression in the design process, we engaged in brainstorming and sketching sessions to transform the insights from the user flow analysis and the high-level design directions into tangible ideas. These sessions were highly collaborative, involving stakeholders and team members to generate a wide range of potential solutions. The primary focus was to explore diverse ways of addressing critical pain points, such as empowering users through pathways exploration, simplifying constraints, and enhancing human-AI collaboration. Through rapid ideation and low-fidelity sketches, we visualized various design concepts, emphasizing flexibility, clarity, and usability. These sketches served as a foundation for discussions, allowing us to identify promising ideas, refine them based on feedback, and ensure alignment with the user needs identified in earlier phases. This iterative and creative process ensured that the designs evolved organically, keeping the core objectives and user requirements at the forefront.

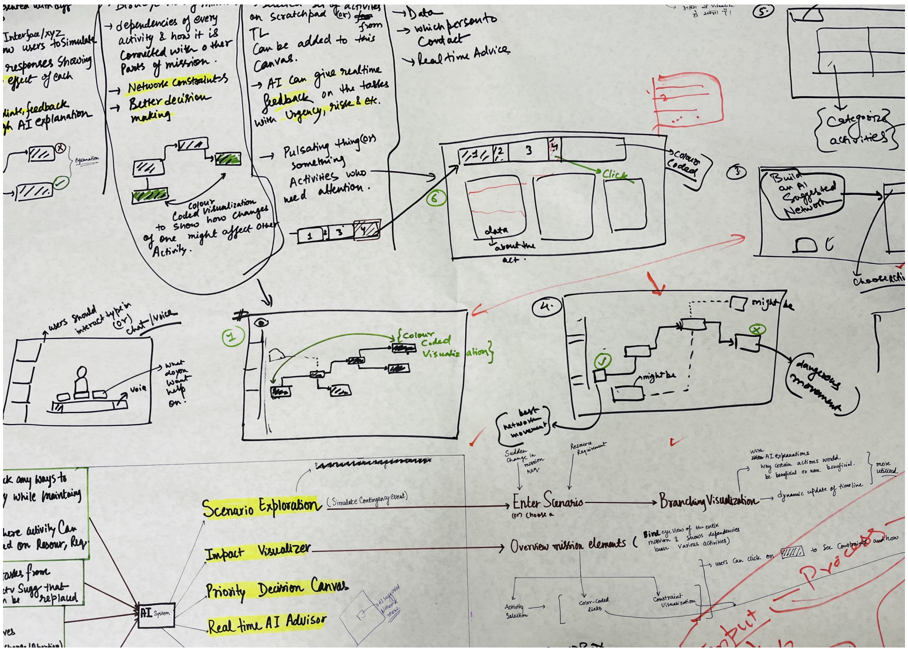

Figure 3.4: Brainstorming and sketching session

3.4 Initial Design Concepts and Iterations

Based on insights from our research, user flow analysis, and brainstorming sessions, we developed six initial design concepts to address key user pain points and align with our design directions. These concepts aim to empower users, simplify constraints, and enhance human-AI collaboration while maintaining usability and efficiency in critical mission scenarios. Below is a detailed breakdown of each concept:

3.4.1 AI Assitant

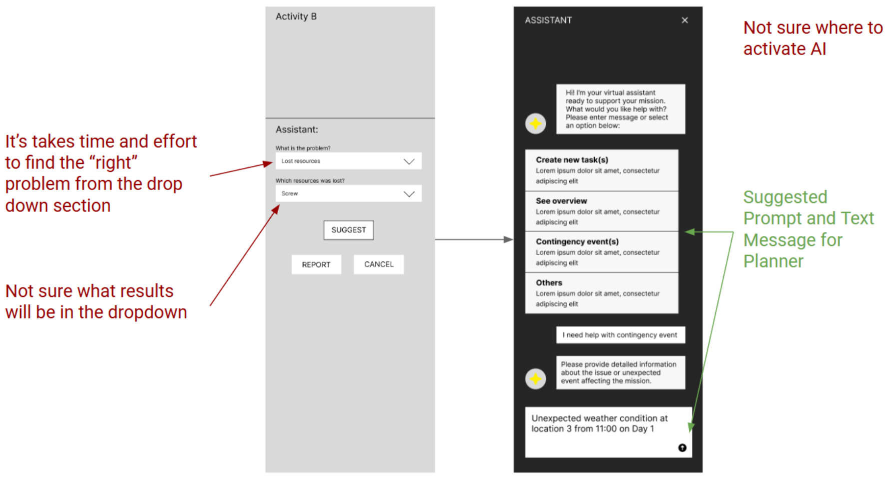

Figure 3.5: AI assistant

The AI Assistant feature was designed to provide decision-making support by offering suggestions and prompts to users during the re-planning process. Initially, a dropdown menu was implemented, allowing users to select a problem for AI to generate a solution. However, during low-fidelity testing, users reported frustration with the time-consuming nature of finding the "right" problem in the dropdown and uncertainty about the options available. To address this, we evolved the feature into a chatbox interface, targeting mission planners rather than both user types. The chatbox provides suggested prompts and text messages, enabling users to interact with the AI dynamically. Mid-fidelity testing revealed that the chatbox was intuitive and easy to use, though some users were unsure where to activate the assistance. This feedback highlighted the need for clearer entry points for accessing the AI Assistant in the interface.

3.4.2 Timeline & Activity Visualization

This feature was developed to simplify the visualization of activities and constraints on the mission timeline. The initial design relied on color-coding and numbered markers to represent constraints and dependencies. However, users found the **colour-coding** confusing and struggled to interpret the meaning of the numbers, leading to frustration during mid-fidelity testing. To address these issues, we refined the visualization by:

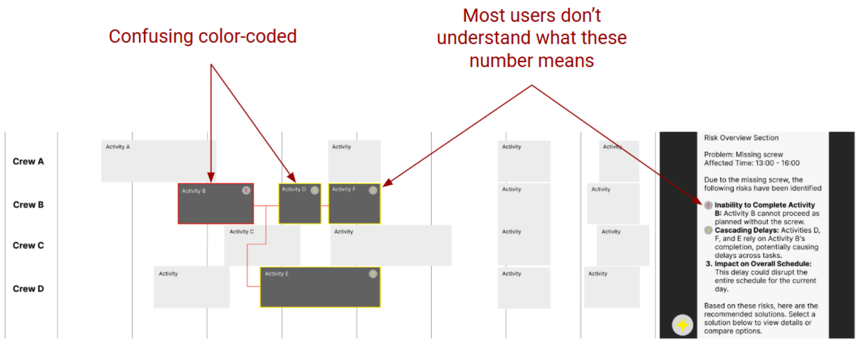

Figure 3.6: Timeline & Activity Visualization

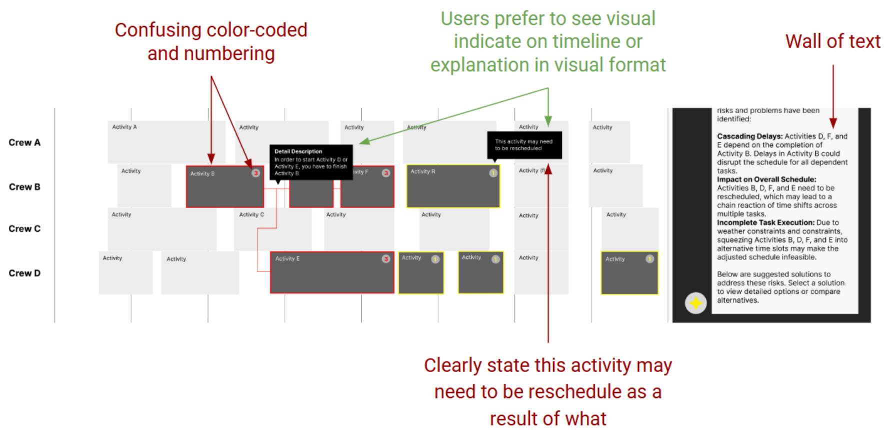

Figure 3.7: Timeline & Activity Visualization

- **Adding clear visual indicators:** These explicitly state when an activity may need to be rescheduled and why.

- **Providing concise explanations:** Contextual details are displayed in a visual format rather than as a wall of text, improving user comprehension.
- **Highlighting cascading effects:** The system visually illustrates how delays in one activity impact others, enabling users to anticipate and address scheduling conflicts.

The improved design made the timeline easier to interpret and more actionable for users.

3.4.3 Cascading Overview

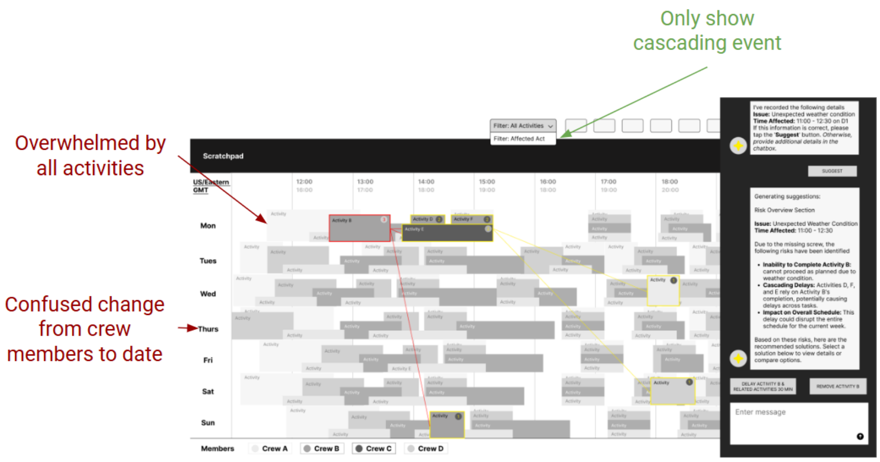

Figure 3.8: Cascading overview

Mission planners often need to understand how disruptions in one activity cascade across the mission schedule—the Cascading Overview concept aims to address this by presenting a comprehensive view of all affected activities.

In early iterations, users reported feeling overwhelmed by the display of all activities and found the transition between viewing crew-specific schedules and date-specific timelines confusing. To simplify the experience:

- **The final design focuses solely on cascading events,** reducing clutter and highlighting only the most relevant information.
- **The interface provides clear visual links** between impacted activities, along with brief descriptions of how each event influences the overall schedule.

This approach ensures users can focus on managing disruptions without being overwhelmed by extraneous details.

3.4.4 Automated Timeline Suggestions

To assist users in quickly adapting plans during re-planning, the Automated Timeline Suggestions feature was designed to offer actionable solutions. In the low-fidelity prototype, the suggested timeline appeared as an overlapping view, making it difficult for users to differentiate the original plan from the suggested one. Additionally, comparing changes was challenging due to the lack of a clear side-by-side view.

The mid-fidelity design introduced several improvements:

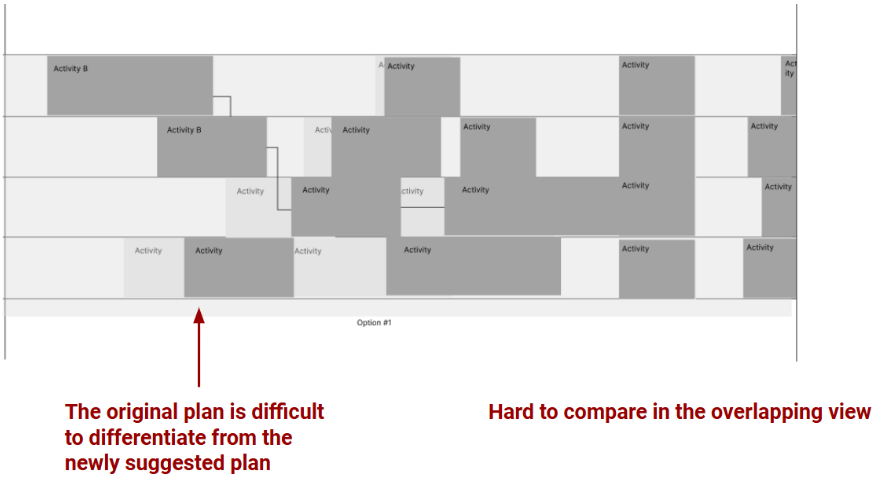

Figure 3.9: Automated timeline suggestions

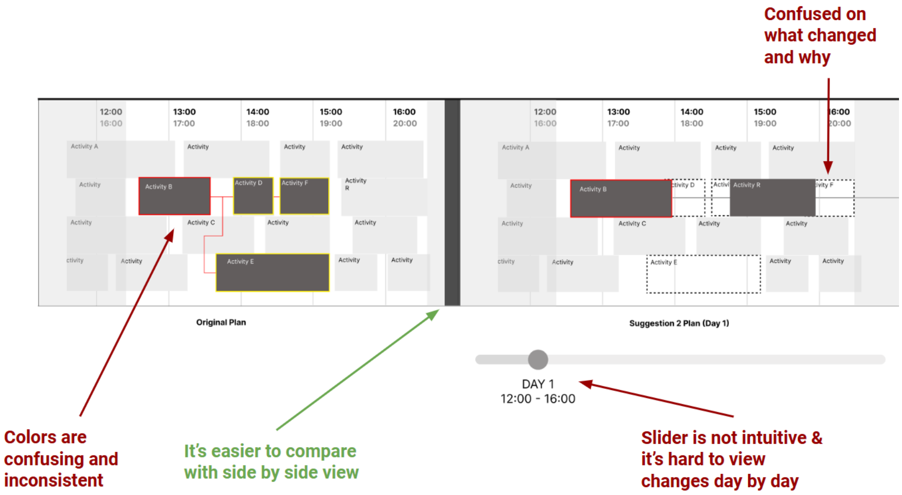

Figure 3.10: Automated timeline suggestions

- **Side-by-side comparison:** Users can easily toggle between the original plan and the suggested plan to compare changes.
- **Drag-and-drop functionality:** Activities can be rearranged within the suggested plan for customization without altering the original timeline.
- **Plan history and revision options:** Users can view the history of changes, revert to previous versions, and edit suggestions before finalizing.

These enhancements streamlined the process of reviewing and implementing timeline adjustments.

3.4.5 Multiple Suggestions

Recognizing the importance of flexibility in decision-making, the Multiple Suggestions concept allows users to explore alternative solutions for re-planning. The initial prototype provided only a single solution at a time, which lacked sufficient information for users to evaluate its feasibility. The refined mid-fidelity design offers:

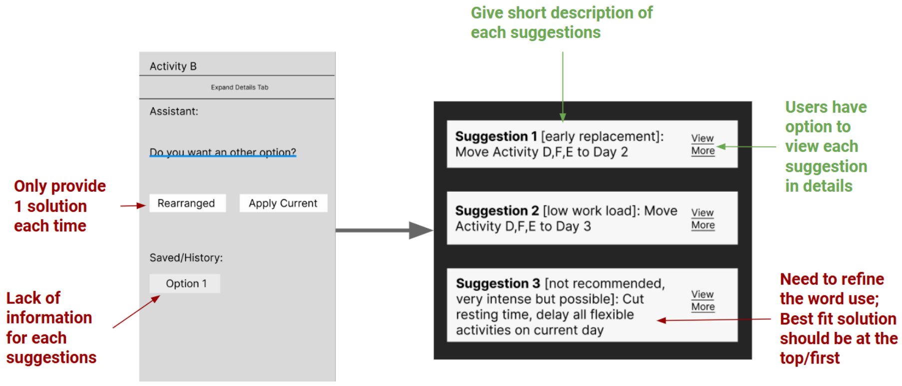

Figure 3.11: Multiple suggestions

- **Multiple options:** Users are presented with several suggestions ranked by suitability, with the best-fit solution displayed at the top.
- **Concise descriptions:** Each suggestion includes a brief summary and an option to expand for detailed steps and implications.
- **Enhanced usability:** The design enables users to quickly assess and compare options, supporting more informed decision-making.

This approach empowers users to choose the most appropriate solution for their unique circumstances.

3.4.6 Real-Time Notification

Real-time notifications were introduced to reduce manual effort and provide timely alerts about unexpected events or delays. Early prototypes included a visual interface where crew members could manually report issues, such as missing or damaged tools. However, users found this process time-consuming, and the inclusion of images was deemed unhelpful. The final iteration shifts to a more streamlined and subtle notification system:

- **Subtle alerts:** Notifications appear at the bottom of the timeline screen, minimizing disruption and stress for crew members.
- **Actionable prompts:** Alerts include quick suggestions for resolving the issue, with the option to access more details or additional solutions.
- **Minimal steps:** The system reduces manual input by automating the detection of issues and suggesting resolutions.

This design ensures users are notified promptly without feeling overwhelmed or distracted during critical tasks.

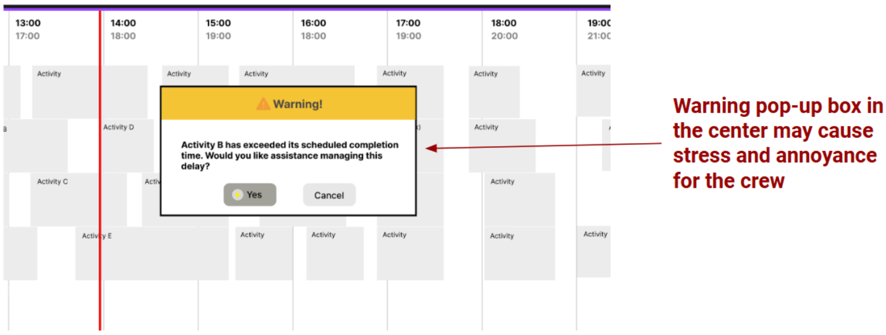

Figure 3.12: Real-Time notification

3.5 Testing

3.5.1 Usability Sessions

We conducted usability sessions with a diverse pool of participants to evaluate the effectiveness of our Lo-Fi, Mid-Fi, and Hi-Fi design concepts and ensure they addressed user needs. All participants were from NASA, representing a mix of those familiar with the Playbook software and those who lacked prior familiarity. This balanced participant pool allowed us to capture a wide range of perspectives and usability feedback from the crew as well as the planner's point of view.

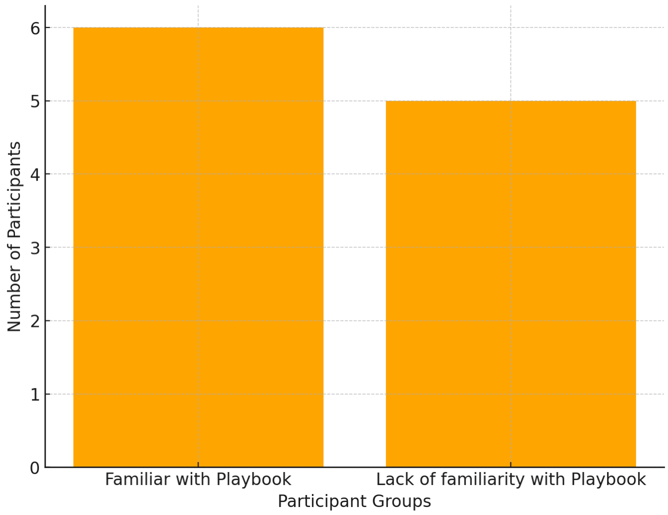

Figure 3.13: Participant pool

Participant Pool

The usability sessions included:

- **6 participants familiar with Playbook:** These participants provided insights into how the proposed designs integrated with existing workflows and tools.
- **5 participants unfamiliar with Playbook:** This group offered fresh perspectives, identifying challenges in understanding and using the designs without prior knowledge of the software.

This division helped us identify issues that could affect both experienced and new users, ensuring the designs were accessible and intuitive for all user types.

Session Details

- **Format:** All sessions were conducted online to accommodate the participants' schedules and locations.
- **Duration:** Each session lasted one hour, during which participants interacted with the designs and provided feedback.
- **Activities:** Participants were asked to:
  1. Perform tasks related to the proposed features (e.g., using the AI Assistant, reviewing timeline suggestions).
  2. Share their thoughts out loud and reactions during the interaction.
  3. Provide suggestions for improvement based on their experience.

Iterative Feedback and Design Refinement

The feedback gathered during these sessions played a critical role in shaping the designs:

- **Experienced Users:** Highlighted inefficiencies in workflows and provided detailed feedback on how to improve the integration of features like cascading overviews and timeline visualizations.
- **New Users:** Identified areas where the designs lacked clarity or introduced unnecessary complexity, helping us refine the user interface for better accessibility, especially from the crew's point of view.

After each round of usability testing, the designs were iterated to address the identified challenges. For example:

- **The AI Assistant:** Adjusted to include clearer activation points based on feedback that users were unsure where to access the feature.
- **The Timeline Visualization:** Simplified by refining color-coded elements and providing clearer explanations of cascading delays.
- **Real-Time Notifications:** Redesigned to appear less intrusive, following feedback that pop-up warnings caused unnecessary stress.

These continuous iterations ensured that our final designs were not only functional but also user-centered, addressing the practical needs of mission planners and crew members.

3.5.2 Quantitative results

To evaluate the effectiveness and usability of the designs, a quantitative analysis was conducted based on usability ratings collected across 11 testing sessions. Participants provided feedback on two key metrics, rated on a scale from 1 to 4: The following key aspects were analyzed across the usability tests:

1. **Usability from Crew Perspective:** How intuitive and user-friendly the designs were for crew members.

2. **Difficulty in Decision-Making:** The level of difficulty participants faced while making decisions using the tools (with 4 indicating very difficult and 1 being very easy).

The heatmap illustrates the variation in ratings across the 11 tests, highlighting trends and areas for improvement.

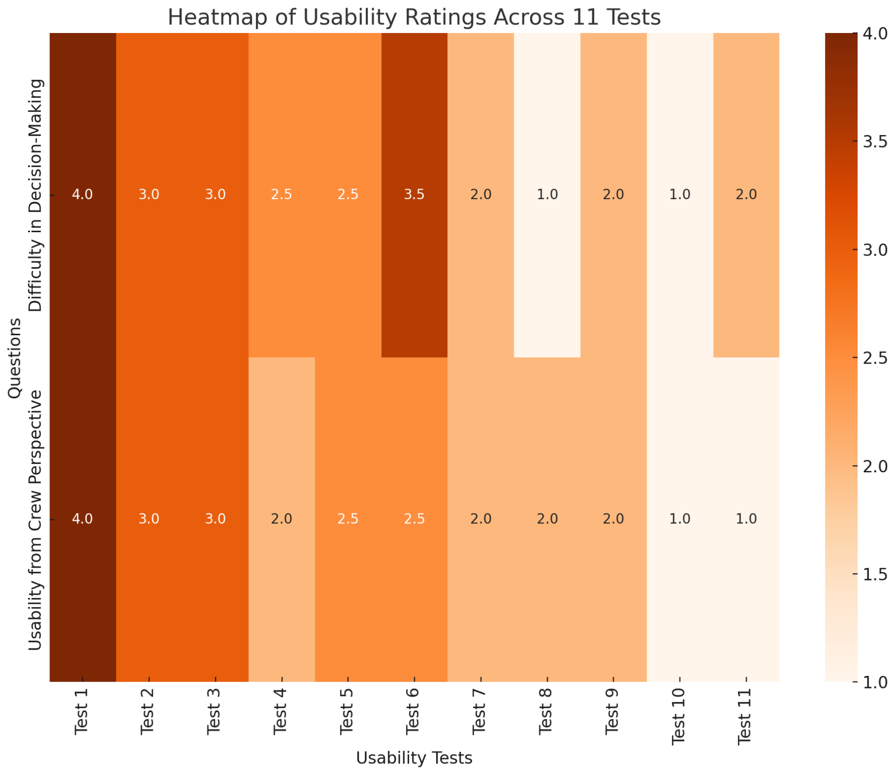

Figure 3.14: Participant pool

Findings

1. **Usability from Crew Perspective:**
   - **High Usability in Early Tests:** Usability ratings were high (4.0–3.0) during Tests 1–3, indicating that the designs were not intuitive for crew members and required significant effort to navigate.
   - **Reduced Usability in Later Tests:** Ratings dropped to 1.0 in Tests 10 and 11, reflecting substantial improvements in the designs' accessibility and user-friendliness after multiple iterations.
2. **Difficulty in Decision-Making:**
   - **Challenging Decision-Making in Initial Tests:** Early tests (Tests 1–6) recorded moderate to high difficulty ratings (2.5–3.5), revealing that participants struggled with the decision-making workflows and found certain tasks overly complex.
   - **Reduced Difficulty in Later Tests:** Tests 8 and 10 scored 1.0, demonstrating significant reductions in decision-making complexity, achieved by providing clearer guidance and simplifying workflows.

3.5.3 Insights

- **Early Iterations:** The initial designs posed significant usability challenges, particularly for crew members unfamiliar with the workflows. High ratings for difficulty and questions during these sessions highlighted the need for clearer instructions, intuitive navigation, and better decision-making support.
- **Improvements Through Iteration:** Mid-fidelity and late-stage iterations incorporated user feedback to streamline workflows, clarify features, and simplify decision-making tools. These adjustments led to steadily declining difficulty ratings and fewer questions over time.
- **Late-Stage Success:** By Tests 10 and 11, the designs had achieved high usability, as evidenced by the consistently low ratings across all metrics.

3.6 Qualitative Analysis of Usability Sessions

In addition to the quantitative evaluations, we conducted a qualitative analysis of participant transcripts to gain in-depth insights into user expectations, pain points, and overall confidence in interacting with the proposed designs. This analysis provided a richer understanding of user behaviors, preferences, and challenges that quantitative metrics alone could not capture.

Initial Lo-fi and Midfi Test/ Analysis			
Red: Unsure/Not-Confident	Blue: User Expectations	Green: User Confidence	Quantitative assessments
Lack of Clarity in AI Suggestions: Participants felt unsure about the options presented by the AI assistant. The absence of descriptions or context for each option led to random, uninformed decision-making. The interface labeled options as "Option 1" or "Option 2" without providing sufficient explanation.	**Proactive Assistance:** Users expected the assistant to be more proactive. They wanted the AI to recognize problems and provide possible solutions on its own, rather than requiring them to initiate each step.	**Familiarity with Chat-Like Interface:** Users expressed confidence in interacting with the AI assistant's chat-like interface, as it felt familiar and approachable. **However, later on this confidence lacks due to the lack of visual clarity, suggestions and reliance(doubtful) while decision making.**	Easiness in the decision making: **4**
Difficulty in Understanding Visual Connections: Participant was confused by the visualization of activity dependencies. Dashed lines and arrows in the timeline weren't intuitive, leading to confusion about their meaning and the overall impact of rescheduling.	**Meaningful Visualization:** Users expected the assistant to present rescheduling options in a simple, meaningful way that made changes easy to understand. They wanted high-level summaries or context for each options and suggestions rather than generic labels.	**Initial Confidence in Resolving Issues:** When provided with adequate context, users indicated that they could make decisions effectively. **However, confidence was lacking when the AI assistant lacked sufficient contextual information.**	Ability to complete the rescheduling process: **4**
The complexity of Risk Overview and Timeline Navigation: The risk overview feature was described as visually cluttered and hard to interpret, which reduced its usefulness. Participants struggled to navigate the timeline and understand the changes between old and new schedules.	**Effective Risk Communication:** Users hoped for a clearer explanation of risks, with visualization that made it easy to see the severity of delays and their potential impact on the timeline.		Measure of difficulty in using feature to complete task: **3**
Confusing Comparison Feature: Users found it difficult to understand the difference between the original and updated plans, with unclear visual differentiation.	**Simplified User Experience:** Expectations included a more seamless(less no. of clicks for the simple tasks) and context-aware user interface, where the assistant infers details like current activities or relevant issues.		Effectiveness of design from the crew perspective: **3**
Intuitiveness in Rescheduling Process: Users faced challenges in rescheduling due to the complexity(too much information) and number of steps involved. They were required to input too much information manually, which the assistant could have inferred automatically.			
Terminology Confusion: Participant found the terminology used by the assistant and design.			
Mid-fi test Analysis			
Red: Unsure/Not-Confident	**Blue: User Expectations**	**Green: User Confidence**	**Quantitative assessments**
The risk overview could be useful, but it wasn't communicated clearly. The information about risks felt buried within the assistant's responses rather than being readily accessible or intuitive. The numbering system used to indicate risks was also confusing—it wasn't clear without hovering over it what those numbers represented.	**Proactive Assistance:** Participant expected the assistant to proactively recognize issues, such as weather-related problems, and offer potential solutions instead of waiting for user initiation.	Participant expressed comfort with certain features, like the **chat-like interface**, which felt familiar. **They also liked the sliding bar feature for additional information.**	how difficult was it for the assistant to guide you through rescheduling? ----**3**
Terminology Confusion: Participant found the terminology used by the assistant (e.g., "contingency event") confusing and not matching their expectations. This led to initial uncertainty about how to proceed.	**Simplified Overview and Visualization:** The expectation was for the overview to provide relevant and focused information. **Participant wanted a more simplified view that highlighted only directly impacted activities.**	Participant felt confident in completing simple task, **but noted that the system made tasks like shifting activites from 30 minutes unnecessarily complex.**	Usability rating of the design from the crew point of view-----**3**
Complexity in Visual Representation: The color-coding and numbering system intended to show the connection between activities added complexity rather than aiding understanding. User did not fully grasp the cascading effects and the relationships represented by numbers and colors.	**Streamlined Processes:** Participant wanted a quicker, more intuitive workflow for making simple changes like delaying activities. **The expectation was for fewer steps and a reduction in manual input requirements.**		how difficult was this feature to use? ----2.5
Overwhelming Overview Feature: The weekly overview of activities was described as overwhelming and visually cluttered. User found it challenging to focus on the relevant information, making it hard to understand its utility.	**More Contextual Visualization**: Participant expected the visualization to effectively communicate the impact of changes, **ideally with contrasting colors or clearer labels to show original vs. proposed schedules.**		Usability rating of the design from the crew point of view-----2
Unclear Visualization of Changes: The visualization of the timeline after rescheduling activities was unclear. Participant had difficulty understanding how their actions affected the overall schedule.			How difficult or easy was this feature to use?------2 to 3/**we can assume 2.5**
Initial Information: Initially, I received a lot of information, and it took me a moment to process it. It wasn't immediately clear how to start assessing the weather impact on Activity B.	**I expected to click on Activity B and get details,** but instead, an AI virtual assistant appeared, which was unexpected and added to my confusion.	**Comparison view is relevant and interesting.**	how difficult was this feature to use? ----**3.5**
Initial Impression of AI assistant: The assistant presented suggestions like "create a contingency event" without clearly explaining what each option would involve. The lack of explanation made it difficult to understand why I should select one option over another.	The **user felt a lack of explanation** in Task 1, they are expecting that each option should explain the **underlying impacts.**	**Second concept was leading the participant towards more informed decision making.**	Usability rating of the design from the crew point of view-----**2.5**

Figure 3.15: Usability analysis

3.6.1 Methodology

The qualitative analysis involved systematically coding participant feedback during usability sessions. Insights were categorized into three main themes:

- **Red: User Uncertainty or Lack of Confidence**
- **Blue: User Expectations**
- **Green: User Confidence**

Each theme was analyzed to identify recurring patterns and specific areas for improvement in the designs. The findings were further supported by relevant examples and contextual details from user interactions.

3.6.2 Findings

User Uncertainty or Lack of Confidence (Red)

Participants frequently expressed uncertainty and confusion during early iterations of the designs. Key issues included:

- **Terminology Confusion:** The use of terms such as *"contingency event"* and *"assistant prompts"* did not align with user expectations, leading to hesitation and difficulty in proceeding with tasks.
- **Complex Visualizations:** Features like the timeline visualization were described as overwhelming due to unclear color-coding and numbering systems, making it difficult to interpret cascading impacts or identify dependencies.
- **Risk Overview Challenges:** The risk overview feature was perceived as cluttered and lacking clarity, with participants struggling to locate actionable information quickly.

For example, one participant noted:

> *"The numbering system used in the assistant's response was confusing—it wasn't clear without hovering over it what those numbers represented."*

These findings highlighted the need for simplification and better contextual explanations in the designs.

User Expectations (Blue)

Participants provided valuable insights into what they expected from the features to make them more effective and user-friendly:

- **Proactive Assistance:** Users desired a more proactive AI assistant that could recognize potential issues (e.g., weather-related problems) and suggest solutions without requiring user initiation.
- **Simplified Overview and Visualization:** Participants expressed a need for clean and focused visual representations that highlighted only directly relevant activities or cascading effects.
- **Streamlined Processes:** Many users expected quicker workflows with fewer steps for common tasks like rescheduling or adjusting timelines.

For instance, a participant mentioned:

> *"I want to see a simplified view that shows only the directly impacted activities and how they connect to others. Too much information makes it harder to focus."*

These expectations informed several iterative improvements to the design, such as reducing manual input requirements and highlighting essential details.

User Confidence (Green)

The qualitative feedback also revealed areas where users demonstrated confidence and ease of interaction, particularly in later iterations:

- **Chat-Like Interface for AI Assistance:** Participants found the chat-based AI assistant intuitive and approachable, providing familiarity and reducing cognitive load. However, confidence decreased when the assistant lacked contextual clarity or generated generic suggestions.
- **Improved Comparison Features:** The side-by-side timeline comparison was well-received, as it enabled users to evaluate original and suggested plans more effectively.
- **Refined Sliding Bar for Suggestions:** Users appreciated features like the sliding bar for accessing additional details, which made it easier to navigate through options without overwhelming the interface.

One participant remarked:

> *"The comparison view was relevant and interesting—it allowed me to see the changes clearly and understand how they might impact the overall schedule."*

These findings validated many of the refinements made during the iterative design process.

3.6.3 Insights and Implications

The qualitative analysis provided several actionable insights:

- **Simplify and Contextualize Features:** Terminology, visualizations, and risk overviews need to be more intuitive and directly aligned with user expectations.
- **Enhance Proactivity of AI Assistance:** The assistant should be designed to identify and address potential issues independently, reducing user effort and building trust in its capabilities.
- **Focus on Role-Specific Needs:** Tailoring features to the distinct requirements of mission planners and crew members can enhance usability and confidence across user types.

3.6.4 Conclusion

The qualitative analysis was instrumental in identifying nuanced user challenges and expectations that informed the iterative refinement of the designs. By addressing the themes of user uncertainty, expectations, and confidence, the final designs were able to achieve greater clarity, usability, and effectiveness in meeting the needs of mission planners and crew members.

Chapter 4

Results

4.1 Results

The results of our research and iterative design process culminated in a set of robust features aimed at addressing the critical challenges of mission planning and execution. These features were developed based on user feedback, usability testing, and qualitative insights, ensuring a user-centered approach. Below is a brief overview of the key features integrated into the toolkit:

4.1.1 AI Assistance (for Planners)

The AI Assistance feature provides mission planners with decision-making support through pre-built prompts, chat-based interaction, and voice input. This tool allows planners to handle unexpected contingencies and generate new tasks efficiently. Key highlights include:

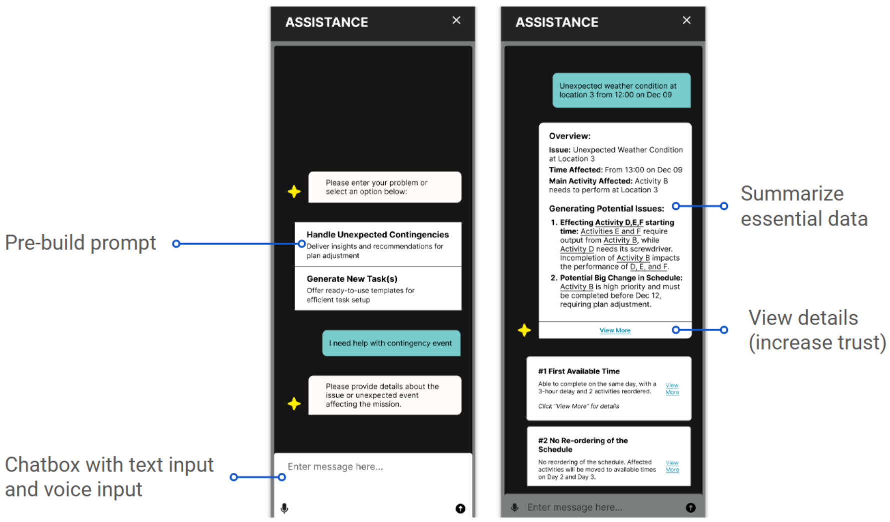

Figure 4.1: AI Assistance (for Planners)

- **Pre-Built Prompts:** Enables quick access to issue-specific prompts, reducing cognitive load.
- **Data Summarization and Details:** Summarizes essential information while offering the option to dive deeper into the context, increasing user trust in the system.

- **Metrics Comparison View:** Provides a visual summary of suggestions, allowing users to evaluate each option based on key performance metrics such as efficiency, flexibility, and safety.

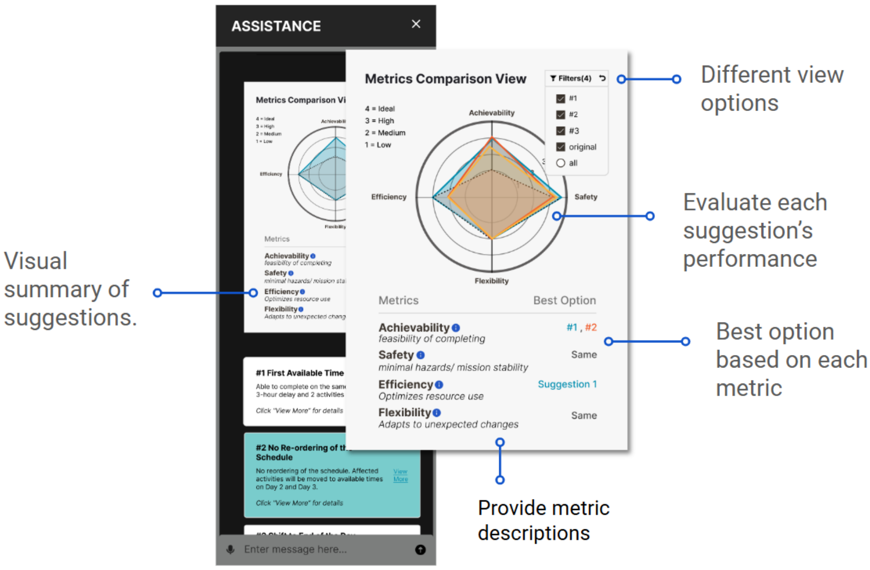

Figure 4.2: AI Assistance (for Planners)

4.1.2 AI Assistance (for Crew)

Designed to assist crew members during mission execution, this feature provides real-time assistance through:

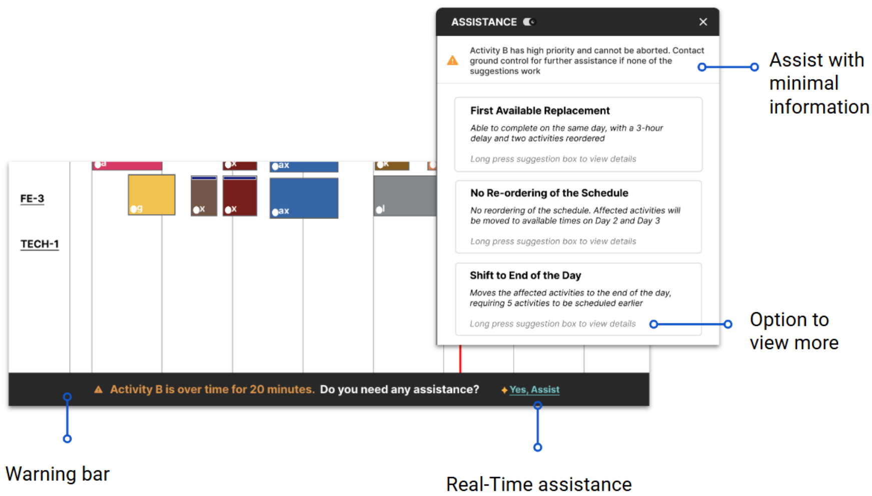

Figure 4.3: AI Assistance (Crew)

- **Warning Bar:** Alerts crew members when tasks exceed their allocated time, ensuring timely interventions.
- **Minimal Assistance with Options to Expand:** Offers concise suggestions for resolving issues, with the ability to view more detailed information if required.

4.1.3 Multi-Suggestions/Insightful Suggestions

The multi-suggestions feature empowers users to explore multiple options for solving a problem. Each suggestion is ranked and accompanied by detailed information about constraints, impacts, and resolution steps:

- **First Available Time:** Presents the earliest viable replacement for activities while preserving the existing schedule.
- **No Reordering of Schedule:** Highlights non-disruptive alternatives to minimize changes.
- **Detailed Constraints and Steps:** Offers a comprehensive view of how each suggestion impacts the schedule and other activities.

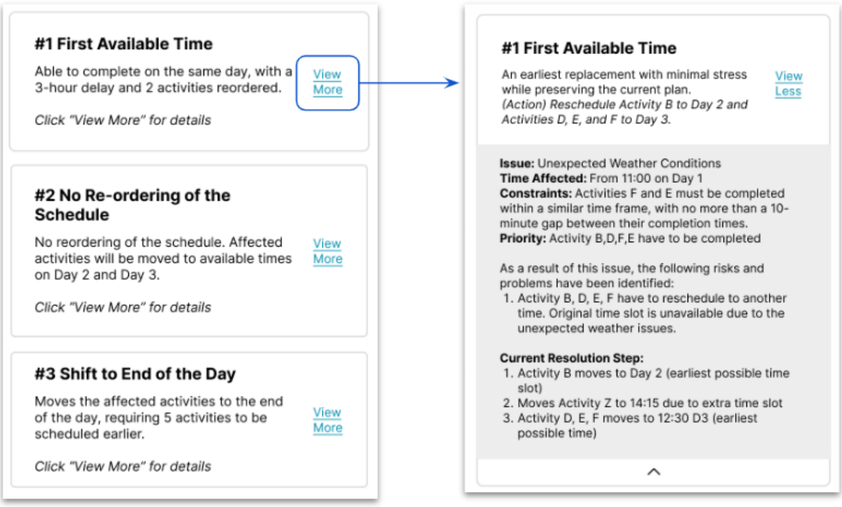

Figure 4.4: Multi-Suggestions/Insightful Suggestions

4.1.4 Timeline Visualization (Hints Features)

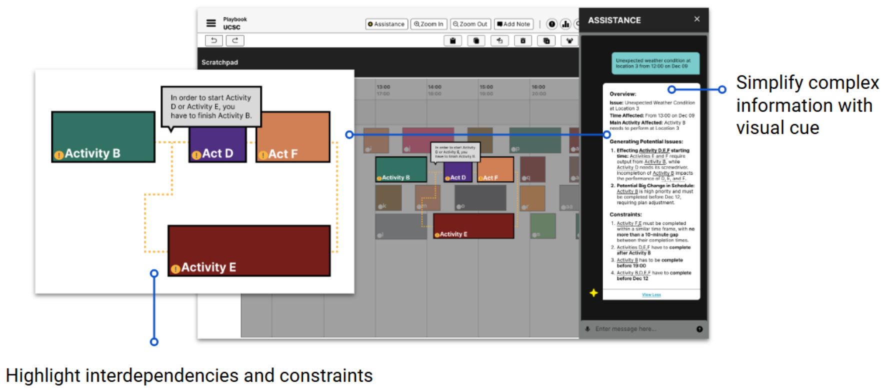

Figure 4.5: Timeline Visualization (Hints Features)

This feature simplifies complex dependencies and constraints through intuitive visual cues:

- **Highlighting Interdependencies:** Displays relationships between activities, helping users understand cascading impacts.
- **Simplifying Information:** Provides clear and concise explanations to improve decision-making during re-planning.

4.1.5 Timeline Visualization - Comparison View

The comparison tool enables users to evaluate the differences between the original plan and suggested changes:

- **Plan vs. Suggestion:** Offers side-by-side visualizations, making it easier to assess the impact of proposed adjustments.
- **Detailing Suggestions:** Provides detailed information about the suggested placement of activities.

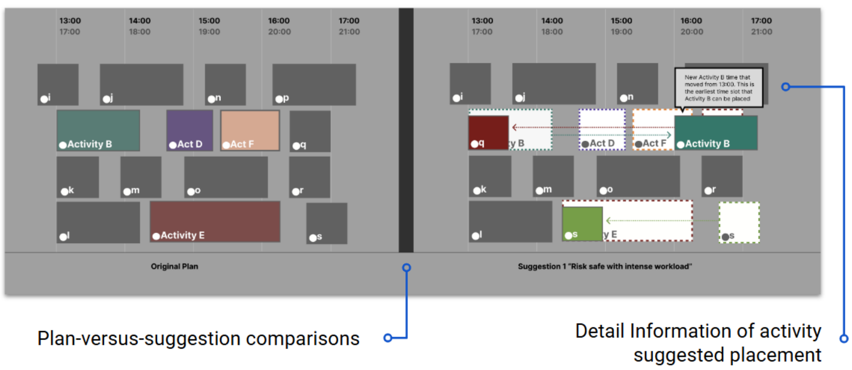

Figure 4.6: Timeline Visualization - Comparison View

4.1.6 Timeline Visualization - Cascading Overview

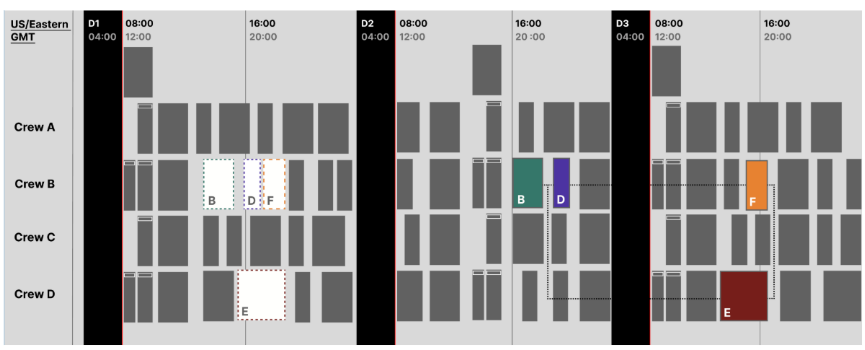

Figure 4.7: Timeline Visualization - Cascading Overview

This feature provides a comprehensive view of cascading effects caused by activity delays or changes:

- **Multi-Day Overview:** Displays how changes on one day impact subsequent days and activities.
- **Simplified Navigation:** Highlights critical changes to reduce cognitive load and improve understanding.

4.2 Discussion

Figure 4.8: UI for Crew

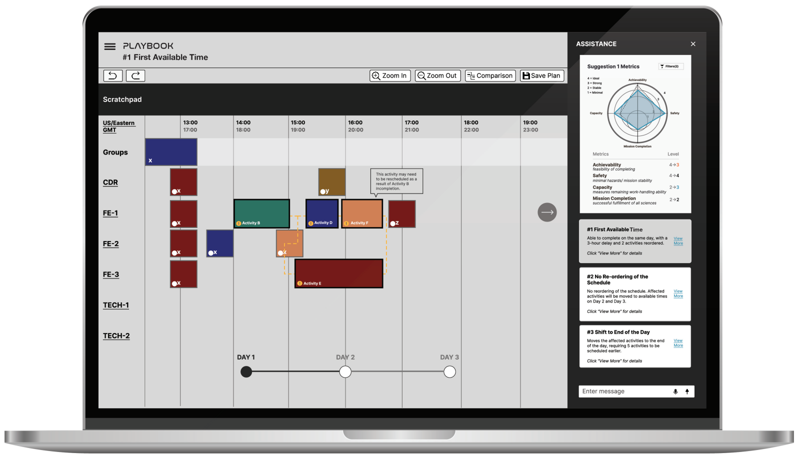

Figure 4.9: UI for Planner

The features developed in this AI-driven mission planning and execution toolkit signify a transformative shift in managing complex and high-stakes operations. By leveraging user-centered design principles and iterative usability feedback, the toolkit addresses critical challenges faced by planners and crew members under contingency scenarios. Traditional mission planning often relies on highly manual workflows, leading to delays and potential errors in decision-making during crises. This toolkit overcomes those limitations by introducing AI-driven solutions that enhance the adaptability, efficiency, and clarity of planning processes. Features such as AI Assistance, multi-suggestions, and timeline visualizations ensure that users are equipped with actionable insights tailored to their roles and the situational demands of the mission.

For mission planners, the AI Assistance feature represents a proactive partner in decision-making. The tool not only identifies potential disruptions but also offers ranked alternatives based on predefined metrics like efficiency, flexibility, and safety. This level of transparency fosters trust in the AI's recommendations, enabling planners to make informed decisions with confidence. By reducing the cognitive load required to interpret and evaluate cascading impacts of delays, features like the cascading overview and metrics comparison view ensure that even the most complex scenarios can be navigated with ease. Additionally, multi-suggestion functionality provides flexibility, allowing planners to choose the most suitable resolution based on mission priorities and constraints. These features collectively redefine how planners engage with uncertainty, empowering them to focus on strategic goals rather than operational bottlenecks.

For crew members, the toolkit introduces real-time assistance designed to deliver timely and concise support. Features such as the warning bar and minimal intervention prompts ensure that the crew can respond effectively to time-sensitive disruptions without being overwhelmed by excessive details. By offering quick resolutions and the option to explore more detailed suggestions when needed, the system strikes a balance between simplicity and depth. This is particularly valuable in environments where crew members are isolated and must make autonomous decisions with limited support from ground control. The seamless integration of AI-driven insights into their workflows bridges the gap between planning and execution, ensuring that contingency scenarios are managed with minimal disruption to mission objectives.

The visualization tools in the toolkit serve as a cornerstone for enhancing situational awareness and collaboration between planners and crew members. The timeline visualization features, including the hints, comparison, and cascading overview functionalities, simplify the complexity of task dependencies and constraints. For instance, the ability to visually compare the original plan with suggested changes allows users to evaluate the trade-offs of each adjustment, ensuring alignment with mission goals while minimizing unnecessary disruptions. The cascading overview, on the other hand, highlights the ripple effects of task delays across multiple days, providing a comprehensive understanding of how a single decision can impact the broader mission timeline. These tools not only streamline decision-making but also enhance collaboration by ensuring that both planners and crew members operate with a shared understanding of mission priorities and constraints.

Looking ahead, the features developed in this toolkit are poised to have far-reaching implications beyond space exploration. In an era where operational complexity continues to grow across various industries, the ability to integrate AI-driven tools for adaptive planning and decision-making is becoming increasingly essential. The principles of this toolkit can be applied to fields such as disaster management, healthcare operations, and military logistics, where the stakes are high and timely interventions are critical. By fostering a collaborative relationship between humans and AI, this toolkit exemplifies how technology can augment human capabilities, ensuring that planning and execution processes are not only efficient but also resilient in the face of uncertainty.

Chapter 5

Limitations and Future Work

5.1 Limitations

While this project introduced a robust AI-driven toolkit for mission planning and execution, certain limitations impacted the development process and final outcomes. These include:

1. **Limited Access to the Playbook Tool:**
   As Playbook served as the primary platform for this project, restricted access to its full functionality and capabilities posed challenges in integrating and testing the proposed features seamlessly. This limitation constrained our ability to simulate real-world mission planning scenarios fully.

2. **Restricted Access to End-Users:**
   Direct interaction with end-users, such as astronauts and mission controllers, was not feasible during this project. Consequently, the feedback relied heavily on indirect stakeholders, which may not fully capture the specific needs and preferences of the primary users.

3. **Assumed AI Capabilities:**
   The design process treated AI capabilities as assumptions, excluding considerations of current technical limitations. While this approach allowed for conceptual exploration of features, it may require significant adaptation when aligning with actual AI performance and technical feasibility.

These limitations underscore areas for improvement in future iterations, particularly in engaging with end-users and aligning designs with real-world constraints.

5.2 Future Work

The outcomes of this project open several avenues for future exploration and refinement. Key directions for future work include:

1. **Conducting Usability Testing with Crew:**
   Engaging astronauts and mission controllers in usability testing will provide first-hand feedback, enabling the refinement of features based on real-world use cases. This will help bridge the gap between conceptual designs and practical applications.

2. **Evaluating Features Across Devices:**
   Testing the toolkit on various devices, such as mobile phones, tablets, and other small-form-factor devices, will ensure that the features remain accessible and functional across different platforms. This is particularly important for scenarios where users may not have access to full desktop interfaces.

3. **Investigating Alternative Approaches to Metrics:**
   Exploring alternative methods for calculating and presenting relevant metrics, such as efficiency and safety, will improve the clarity and usability of the Metrics Comparison View. This could include experimenting with visual representations or simplifying complex data into actionable insights.

4. **Understanding AI Capabilities and Refining Designs:**
   As AI technologies continue to evolve, revisiting the designs to align with current capabilities will be crucial. This includes refining features like multi-suggestions and real-time assistance to leverage advancements in AI-driven prediction, decision-making, and adaptability.