National Aeronautics and Space Administration

NASA System-Wide Safety
TC-2 Closeout
Human-Machine Interface / User Interface (HMI/UI) Research

Wednesday April 23, 2025
Day 1

Jolene Feldman and Dr. Paul U. Lee
NASA Ames Research Center

System Wide Safety

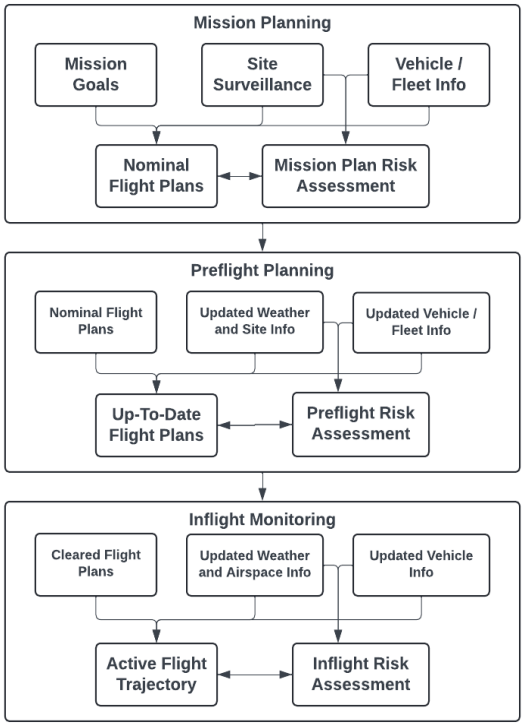
HMI/UI Research: Motivation and Goals

- The outlook: new emerging technologies present opportunities
- The challenges: airspace, low alt/urban/complex, # operators, new known/unknown risks to safety
- The purpose: *evaluate how users interpret & interact with different predicted risk & hazard information*
  - Developed a suite of data-driven tools that fuse data into hazard risk models for safety Services, Functions, and Capabilities (SFCs) that assist operators to *monitor, assess, and mitigate potential risks proactively* (IASMS)
  - However, it is not enough to develop the state-of-the-art hazard risk modeling capabilities.
  - These models CAN enhance safety IF this information is organized and presented in sensible ways for operators to understand, are relevant, timely, and used effectively.
  - Presenting salient and meaningful risk assessment information to operators is necessary to increase situation awareness and ultimately safety.

HMI/UI Research: Motivation and Goals

- Goals
  - Identify roles and responsibilities of operators to determine informational needs and develop user interaction requirements.
  - Integrate prognostic models and present predictive data through a graphical user interface (GUI) for clear and effective proactive risk assessment and mitigation.
  - Provide a tool interface to enable operators to access comprehensive information on a collection of hazard and risk services.

HMI/UI Research: Tasks, Operators and Roles



- Mission Planning (by Mission Planner)
  - Define the overall tasks based on the mission goals
  - Identify and select the mission sites and vehicles
  - Develop the nominal flights for the mission
- Preflight Planning (by Fleet Manager)
  - Update weather, site, and vehicle information
  - Update / modify flight plans if needed
- Inflight Monitoring (by UAS Remote Pilot)
  - Fly the UAS and monitor the actual state of the vehicle, weather, site constraints, and the active flight trajectory
- At each phase, different operators can monitor and assess potential risks that may occur based on the information available
- Our research and tool interface development focused on the Preflight Planning by the Fleet Manager
  - Identifying, assessing, and mitigating potential hazards during preflight can “buy down” and prevent hazards that may be more difficult to resolve during the inflight phase.

4

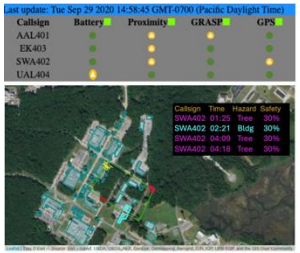
HMI/UI Research: Approach

Build, Evaluate, Iterate

- Build
  - 2021: Two panel design with four SFCs integrated (Four SFCs – Battery, Proximity, Population and GPS)
  - 2022: Supplemental Data Service Provider-Consolidated Dashboard (SDSP-CD) with multiple section of SFC functions
  - 2023: Two interfaces evaluated – SDSP-CD & Human Automation Teaming Interface System (HATIS); Radio Frequency Interference (RFI) SFC added
  - 2024: Vertiport Congestion Service added
  - 2025: Wind and Trajectory Generation Service added
- Evaluate
  - User evaluation conducted after each build
    - Both formal and informal evaluations were conducted at various development stages
    - UI improvement feedback received from Part 107 UAS pilots and human factors researchers
    - Compare the UI with another similar tool (HATIS) to identify strengths and weaknesses of each tool
- Iterate
  - After each build and evaluation of the UI, the feedback were compiled and used to improve on the next iteration of the UI design, in addition to integrating new SFCs

Iterative Design, Development, and Evaluation OF SDSP-CD

2021



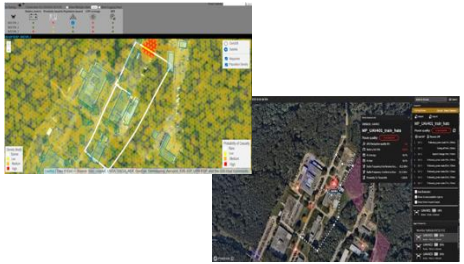
Introduction of Two-Panel Design included a first panel presenting four services – Battery, Proximity, GRASP (Population), GPS – with a status indicator next to each service and displaying a map with detailed alert information

2022



Introduction of Consolidated Dashboard with user-selectable parameters, adjusted color scale, legends simplified, navigation streamlined, and added "Select Multiple Alert" feature

2023



Tested the Consolidated Dashboard and the Human Automation Team Interface System (HATIS). RFI service was integrated and UI was improved based on feedback from previous evaluation.

2024



Integration of Congestion service into SDSP-CD and more feedback incorporated

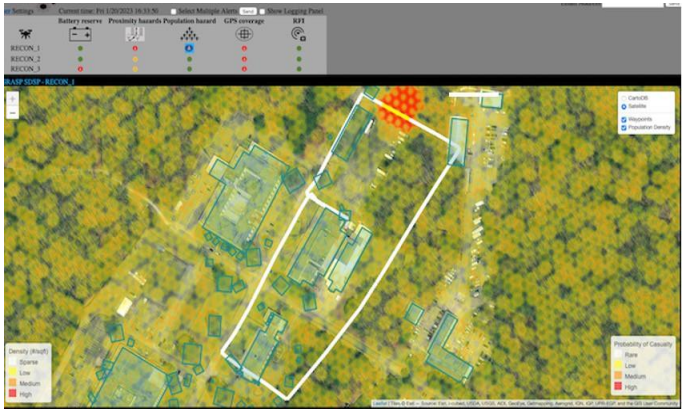
2025 – Current Design



User feedback and performance metrics from each version were used to refine and enhance the next iteration.

Development and Evaluation of UI Variations

Image of SDSP-CD display interface with Pop hazard alert selected for RECON_1. Pop density and probability of casualty heat map shown.



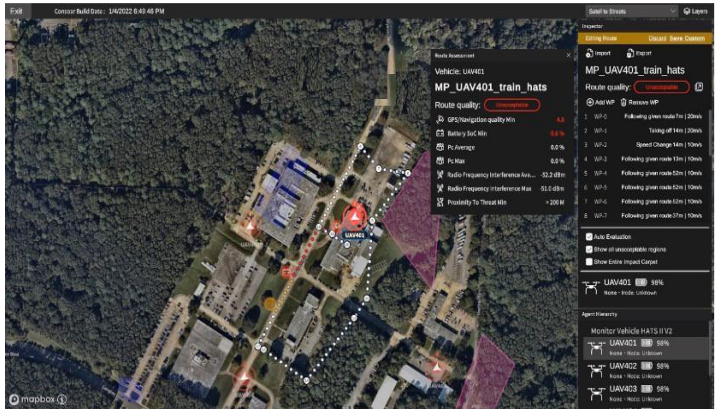


Image of HATIS display interface with route assessment selected for UAV401.

SDSP-CD/+	HATIS/+	Both UIs/+	Feedback/-
One comprehensive view – alerts/aircraft	Flight path route editing	Rated positively	Guidance on how to resolve, route suggestions
Heat maps	Exceedances clearly shown	Useful for preflight	Information hidden in layers (e.g., alert severity)
Manage multiple aircraft together	Route analysis	"Good" SUS scores	Excessive clicking, and in multiple places
Correspondence between the dashboard and the flight paths on the map	Path color change due to hazard threshold	Able to identify risks and hazards, and along a flight path	More information requested (e.g., altitude)

Able to identify and integrate the advantageous capabilities of each UI.

HMI/UI Research: Hazard Risks in the UI

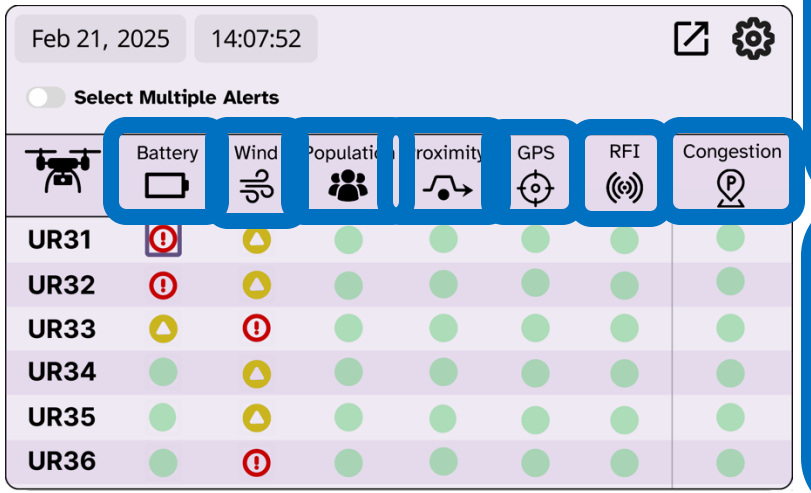
Battery (2021-24)



Wind (2025)



Consolidated Dashboard (2025)



Vertiport Congestion (2024)

Callsign	Prop ETD	Prop ETA	Cleared ETA	Delay	Congestion
UAV5		6:00	6:00	0:00	
UAV6		7:00	7:00	0:00	
UAV1		8:00	8:00	0:00	
UAV7		9:00	12:00	3:00	
UAV2		10:00	14:00	4:00	
UAV8		11:00	18:00	7:00	
UAV9	11:00				
UAV10	13:00				
UAV11	15:00				

RFI (2023-24)



Population (2021-24)



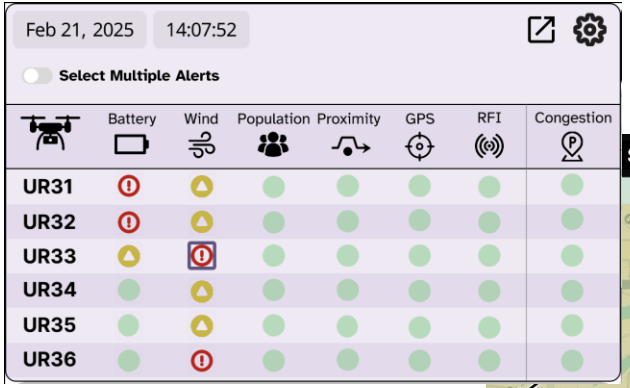
Proximity (2021-24)



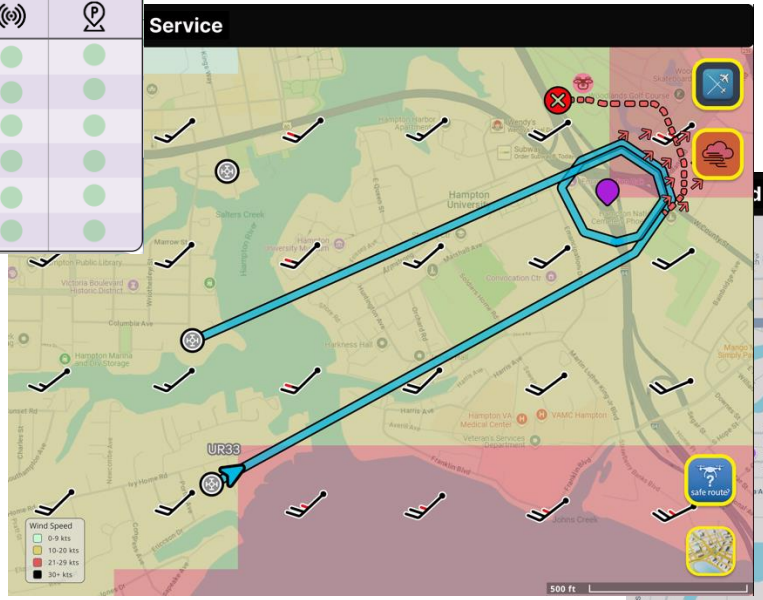
GPS (2021-24)



HMI/UI Research: Current UI w/ Wind Service

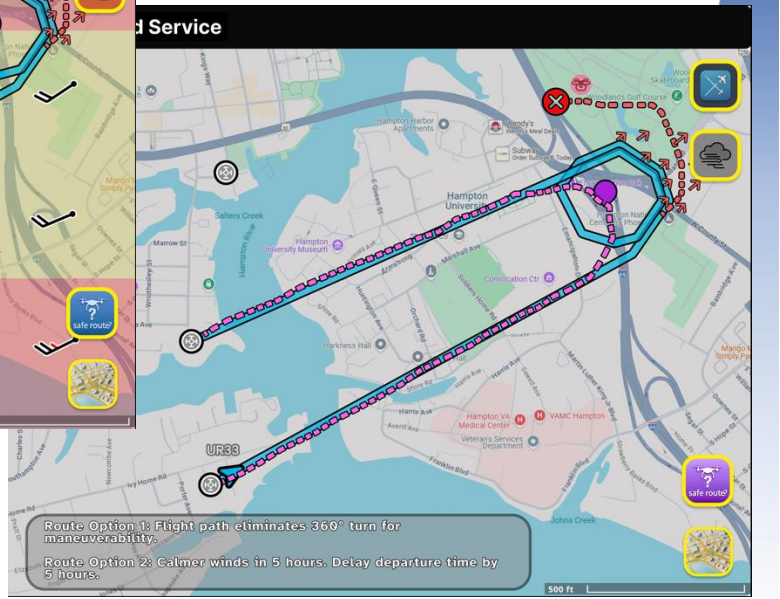


On the Dashboard, UR33 shows Wind Service Alert, indicating that the flight plan is severely impacted by the predicted winds, resulting in "unsafe" flight trajectory.



Clicking on the UR33 Wind alert on the Dashboard, shows its planned flight path and the wind-deviated path that indicates that the flight plan cannot be completed as designed. The display can also show wind direction and strength using wind barbs and heat map.

Operator can query the Trajectory Generation capability to offer potential alternate wind-safe routes. The purple path below shows that the route can be completed if it eliminates the 360 degree turn.



HMI/UI Research: User Evaluation Results

- Overwhelming support for the tool interface and the Hazard Risk Dashboard design concept
  - Highly effective for operators to assess potential risks at a quick glance
- Broad consensus on the tool's effectiveness in reducing potential safety hazards during preflight planning
- Each iteration of the UI design based on the user feedback improved upon the earlier designs

HMI/UI Research: Summary Accomplishments

- SWS team has built a number of state-of-the-art hazard risk models to use for safe UAS operations
- Our team tested prototypes and built a Consolidated Dashboard tool interface to integrate multiple hazard risk models into an easy-to-understand UI.
- User feedback from multiple evaluation studies throughout the project showed positive feedback on the usefulness and usability of preflight risk assessment and mitigation tool.
  - Their feedback allowed us to identify and refine the operators' roles, their interactions with the tool, and how to improve the UI in the next iterations.
- Numerous papers were written and presented at various conferences and meetings to disseminate the findings to the aviation research community