National Aeronautics and
Space Administration

Usability of pre-flight planning interfaces for Supplemental Data Service Provider tools to support Uncrewed Aircraft System Traffic Management

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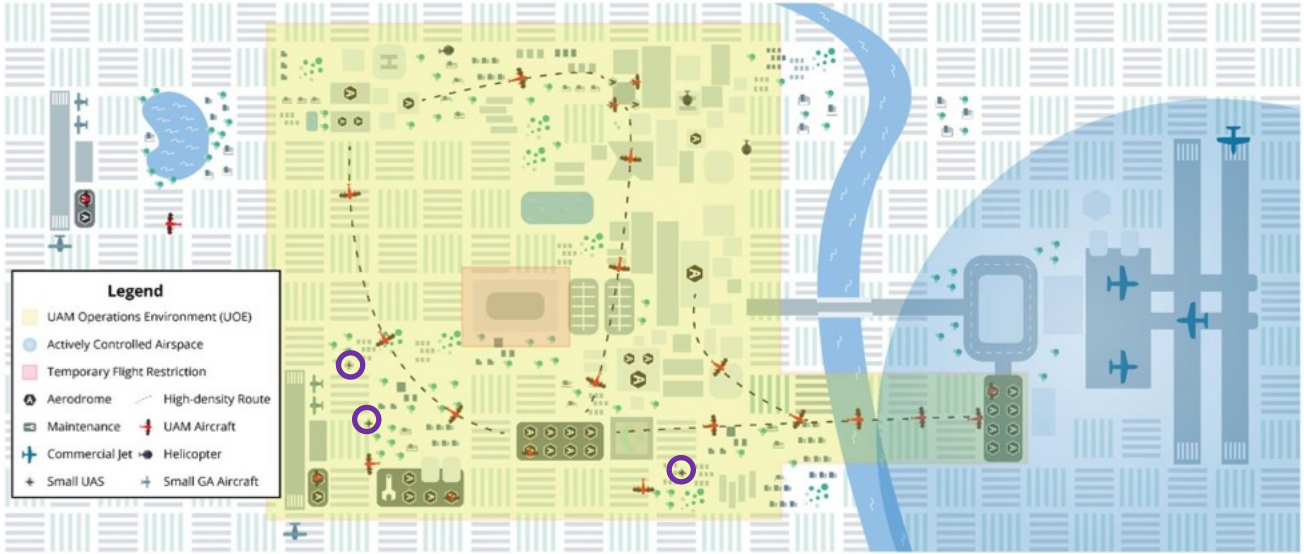
AHFE, December 4th-6th, 2023

System Wide Safety

Vision of future operations

- Emerging technologies for air transportation
- New opportunities/risks, and need for sustainability (environmental, economic, safety)
- Assure safety and efficiency of small Uncrewed Aircraft Systems (sUAS) operating in complex, urban, low altitude, uncontrolled airspace
- How do we do this? With risk and hazard prediction services and the tools to display them

Concept of Operations for Urban Air Mobility (UAM)



For illustrative purposes only - Artwork not drawn to scale

Image: UAM Operating Environment. Top-down view of UAM operation to illustrate routing of aircraft.

*"UAM aircraft at UAM Maturity Level-4 will utilize a network of **Providers of Service (PSUs)** that provide ATM services..." – minimal/no ATC assistance in operations, operators will be responsible*

Ref: Deloitte (UAM Vision Concept of Operations UAM Maturity Level (UML) 4. Version 1.0

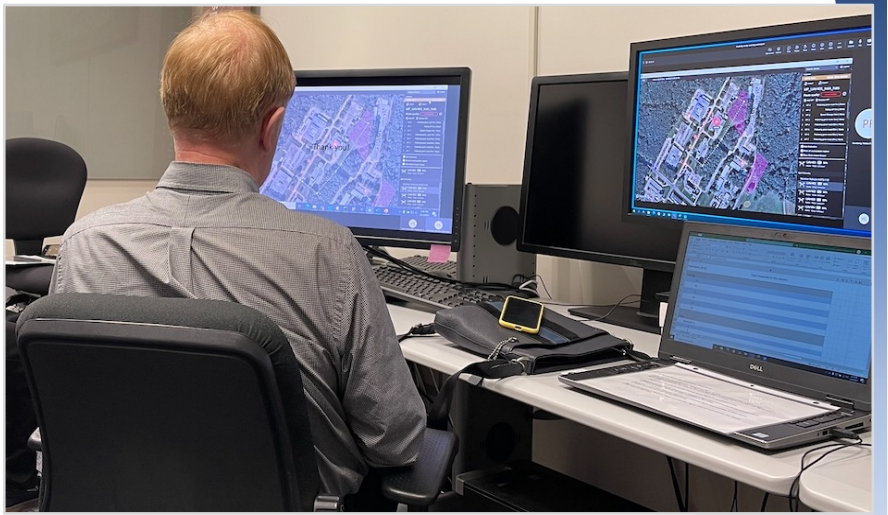
- ***Supplemental Data Service Providers (SDSPs)*** provide the means through which risks and hazards can be run and displayed on a graphical user interface (GUI) to operators
- Need to investigate interface requirements to display and organize these services, and report how operators might use these tools

Usability study

Objective: Determine whether candidate interfaces provide enough information for users to understand the GUIs capabilities and functions while using them to complete various risk and hazard assessment tasks successfully in simulated scenarios.

Method:

- 16 participants (HF SMEs & pilots with range of sUAS experience)
- 2 prototype GUIs for *pre-flight* planning:
  - Supplemental Data Service Provider – Consolidated Dashboard (**SDSP-CD**)
  - Human Automation Teaming Interface System (**HATIS**)
- 5 services: [Battery] [Proximity to Threat] [Population] [GPS] [Radio Frequency Interference]
- 4 scenarios developed (training, testing), counterbalanced, participant role
- Multiple measures collected (System Usability Scale, simple tasks, risk assessment, open-ended feedback, *workload ratings, *response times)



User receiving training on the HATIS interface in the Airspace Operations Lab at NASA Ames.

Reference: Feldman, J., Martin, L., Gujral, V., Walter, C., Billman, D., Revolinsky, P., & Costedoat, G. (2023). Developing and testing two interfaces for Supplemental Data Service Provider (SDSP) tools to support UAS Traffic Management (UTM), *Proceedings of the AIAA Aviation 2023 Forum, San Diego, CA and Online*.

SDSP-CD Interface

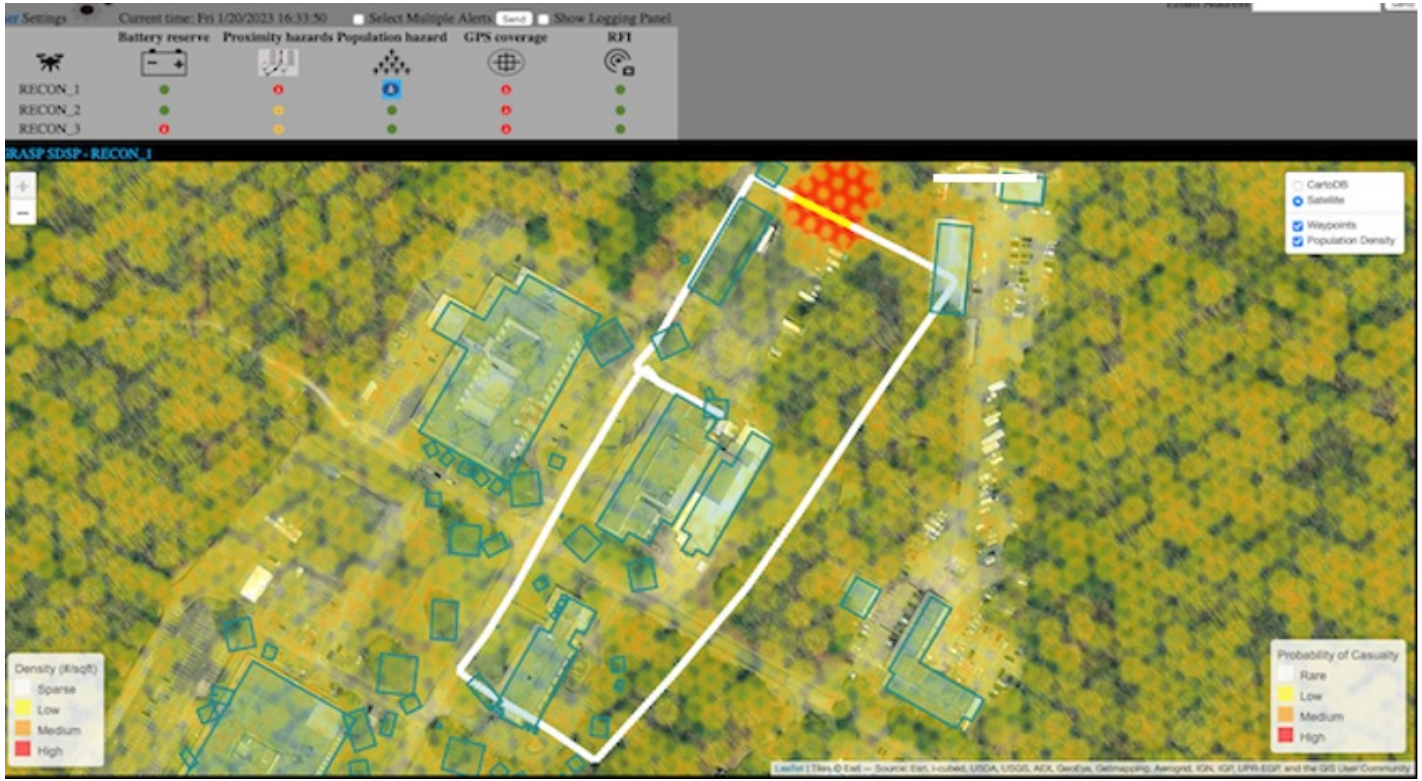


Image of SDSP-CD display interface with Population hazard alert selected for the UAS with the callsign "RECON_1". Population density and probability of casualty heat map show dense population along the flight route. (NASA image)

HATIS Interface

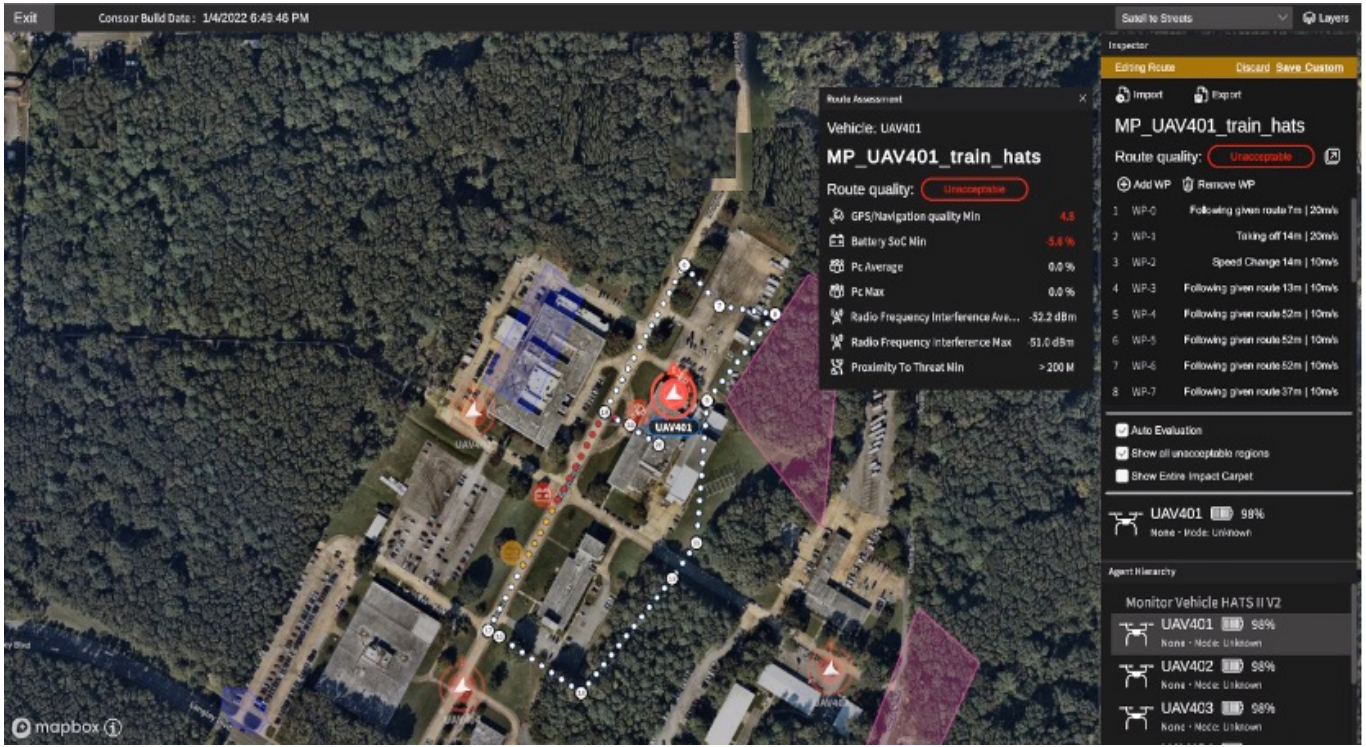
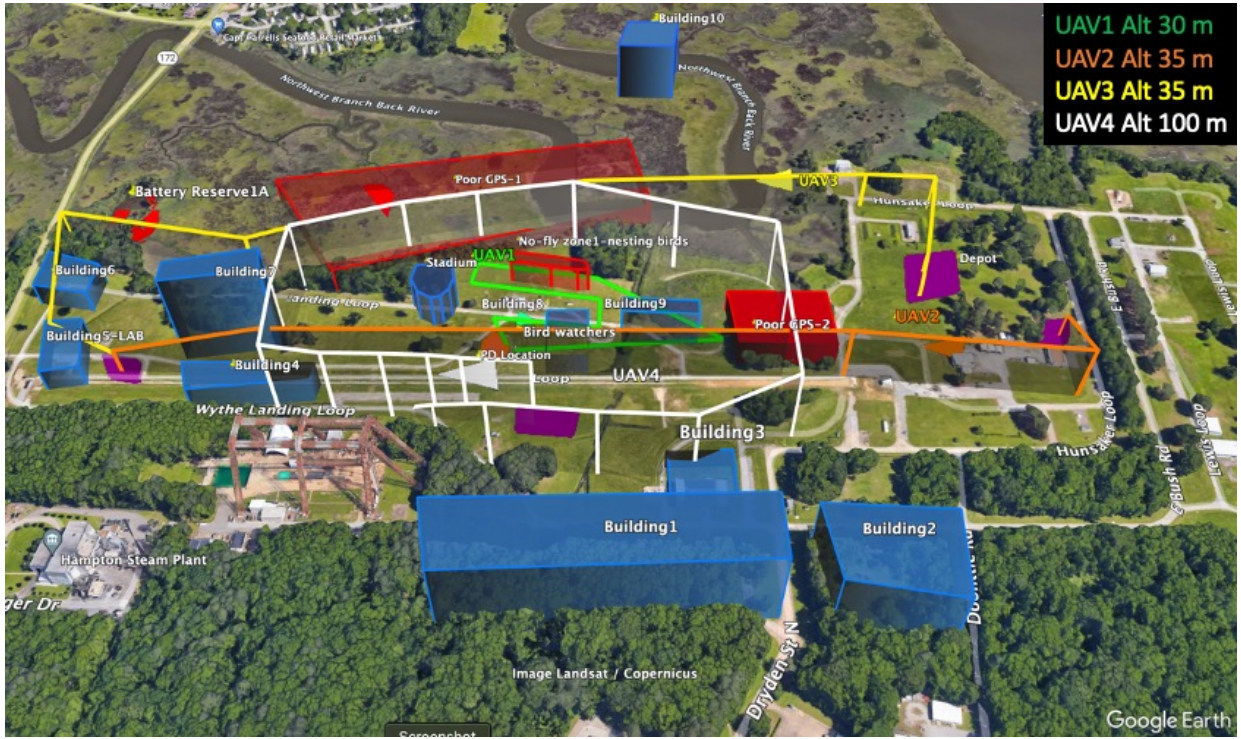


Image of HATIS display interface with route assessment selected for a UAS with the callsign "UAV401". An unacceptable route quality is shown due to hazards: a risk due to poor GPS quality and a low battery risk. (NASA image)

Example scenario: Wildlife management



Wildlife Management Scenario. (Maps Data: Google, Image ©2023 Landsat / Copernicus)

Workload ratings

- **To explore workload, we used a modified version of the NASA TLX** for subjective workload ratings, participants mark responses "Low/High" for each of 5 ratings

- **Two blocks of similar discriminative tasks constructed for each GUI, TLX administered post each D task**
  - D1, e.g., asked about power management, handling risks around insufficient battery
  - D2, e.g., asked to resolve issues with a population hazard, adjust path to avoid hazard (rubber-banding or draw on map)

- **Results (raw/unweighted data)**
  - Mean workload scores were similar within blocks and were *not significantly different* between GUI ($p > .05$)
  - Mean ratings for subscales - Mental demand, Effort, and Frustration were higher using the HATIS than the SPSD-CD, with Temporal being higher for SDSP-CD than the HATIS. *No significant differences* between GUIs within the task blocks ($p > .05$).

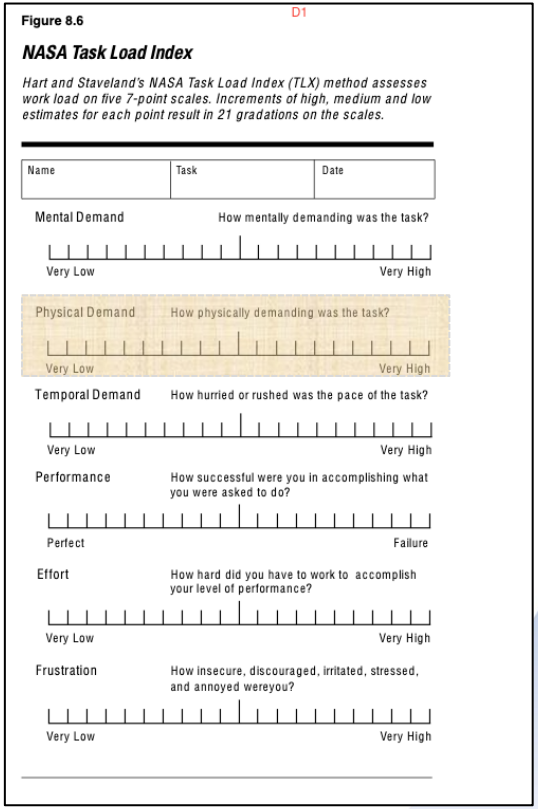


Figure 8.6

D1

NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?
Very Low — Very High

Physical Demand — How physically demanding was the task?
Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?
Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?
Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?
Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?
Very Low — Very High

Response time and risk assessment

- Response time – to explore the possible effect of display design on efficiency and timeliness of operations
  - Participants asked to **identify total number of hazards** across all vehicles (Response Time Question-1, RTQ-1)
  - Report **frequency of a specific hazard** type (e.g, # of GPS hazard alerts, Response Time Question-2, RTQ-2)
- Results (correct responses only)
  - Time needed was *significantly less* when using the SDSP-CD interface compared to the HATIS (RTQ-1), $p < .01$; SDSP-CD interface ($M = 13.89$ s, $SD = 11.91$ s), compared to HATIS ($M = 25.33$, $SD = 12.36$), $t(8) = 8.20$, $p < .001$.
  - Time needed was *significantly less* using the SDSP-CD interface compared to the HATIS (RTQ-2), $p < .01$, SDSP-CD ($M = 4.00$ s, $SD = 1.84$ s) than when using HATIS ($M = 25.82$ s, $SD = 18.35$ s), $t(10) = 4.09$, $p < .01$.

- Risk assessment – to query about hazard/risk assessment and rationale
  - Low battery risk and nearby population hazard were perceived to be *high-priority risks* to address (Package scenario)
  - Participants had more difficulty identifying low-battery risk than other types of risks/hazards
  - When altering flight paths to avoid hazards, most chose to *alter routes laterally*, rather than vertically or to make no changes (GPS hazard); shorten the route (low-battery risk)

Summary

- **Workload ratings**
  - No significant differences found between GUIs
  - Variations in vehicle information access, multi- vs single-view, additional clicking
  - TLX Interpretation – tasks were not too demanding nor too simple, but indicate low-average workload levels

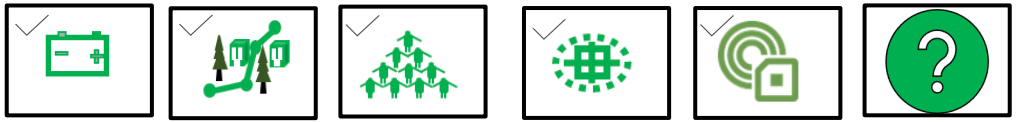
- **Response time**
  - Significant differences found between GUIs
  - RT interpretation – Risk and hazard visibility of scenario and quicker access to information with high level overview of SDSP-CD compared to more detailed HATIS interface

- **Risk assessment & participant feedback**
  - Largely positive comments about both GUIs for flight planning and hazard awareness (e.g., efficient, could reduce workload)
  - Suggestions include level of guidance for alternate flight paths, heat maps, preventing hidden alerts and/or waypoints
  - Note: Some flight path adjustments were not most efficient, compromised mission, not consider constraints or effect on other services

Conclusion and future work

- Based on workload ratings, consider level of difficulty for tasks (> difficulty?)
- Based on response time tasks, consider more operationally representative and relevant questions
- Consider feedback from participants (e.g., visibility of alerts, unexpected hazards)

- Re-run usability study with updated scenarios and tasks
  - Implement key items from participant feedback for the SDSP-CD and HATIS GUIs
  - Improve study design, e.g., reduce TLX ratings variability – reduce number of tasks in the D1/D2 blocks
  - Develop pre-flight planning of sUASs for natural disaster relief and recovery scenarios
  - Explore use of other Services, Functions, and Capabilities (SFCs)...



Thank you!

For any additional questions or comments, please contact:

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