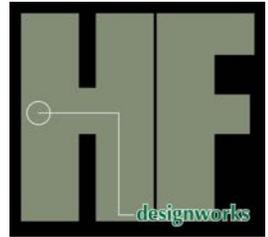
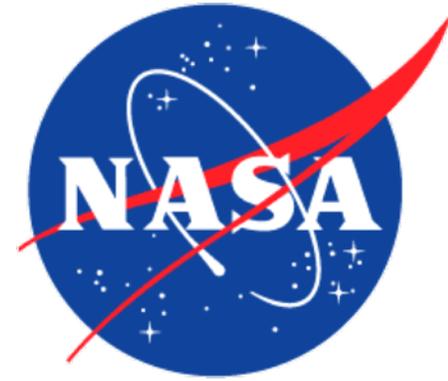


HAT m:N Cognitive Task Analysis (CTA)

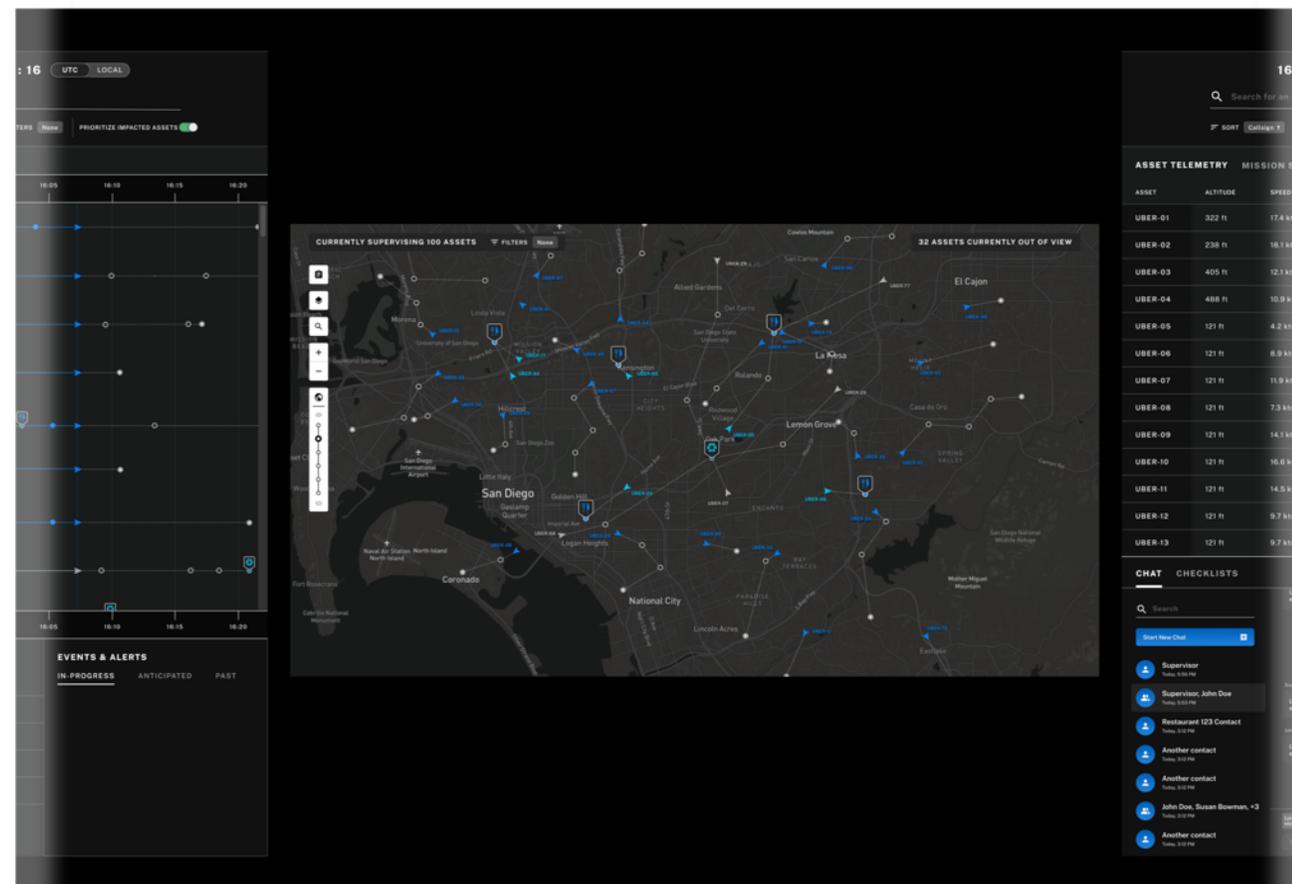
Scott Scheff

HF Designworks, Inc.

March 26, 2021



- **Goal** - understand the capability of the NASA-Jobym: N Tactical Operator (TO) interfaces to support TOs supervising up to 100 independent small unmanned aerial systems (sUAS)
- **Introduction** - Use incident-based cognitive task analysis methods with aviation SMEs who have served in analogous roles:
 - Examine cognitive support provided by m:N TO interface in simulations that included n=12 and n=100 scenarios
 - Elicit tacit aspects of expertise and complex mission settings related to command of multiple aircraft with relevance to the TO role and might require support from the m:N TO Interface
- **Analysis**
 - Identify interface elements that were and were not supportive
 - Articulate cognitive requirements associated with command of multiple aircraft and mission contexts that increase complexity for the human operator



Adapted from Applied Cognitive Task Analysis (Militello & Hutton, 1998)

- Interviews occurred over two 1-hour sessions

Session 1

Demographics

Simulation 1: n=12 sUAS

Session 2

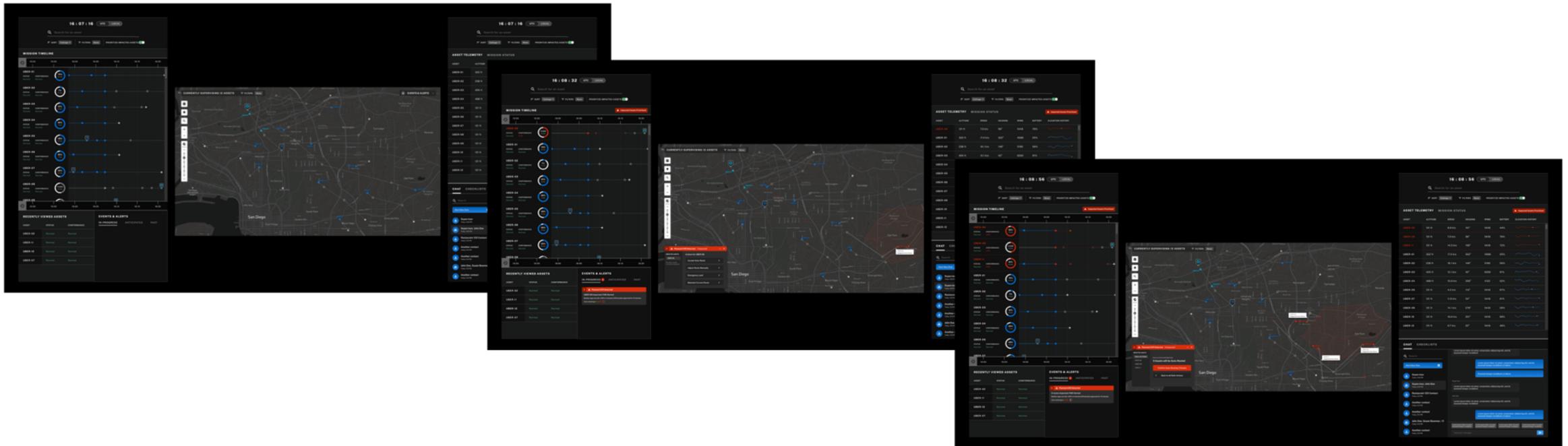
Simulation 2: n=100sUAS

Task Diagram

Knowledge Audit

- All interviews were conducted remotely using GoToMeeting with the interviewer, interviewee
 - Some interviews also included a note-taker and/or second interviewer
- Sessions were video-recorded and transcribed using an AI transcriber

- Each simulation included three events: nominal start, caution/warning event, and complex caution/warning event



- Events were followed by a series of questions to understand the interviewees assessment of the situation, potential actions, alternatives, communication needs

- Each scenario included follow-on questions based on hypotheses about how the user would be supported by the interface
- Hypotheses
 - Interviewees would be able to supervise 100 assets – **True**
 - Interviewees would understand alerts and know what steps to take – **False**
 - Interviewees would choose to drop the payload – **False**
 - Interviewees would want to customize displays – **False**
 - Interviewees would want to handoff off-nominal assets – **True**
 - Interviewees would accept system recommendations – **Mixed**
 - Interviewees would use the Recently Viewed Assets table – **False**

Task Diagram

- Interviewee asked to reflect on role where they had control of other aircraft and react to unexpected events
- Decompose task into three to six subtasks
- Identify subtasks that required most expertise

Knowledge Audit

- Reflecting on that same role, asked to provide an example for each of three cognitive probes about an aspect of expertise
 - Noticing
 - Big Picture
 - Job Smarts
- Follow on questions regarding what made this task hard, and cues and strategies

- Aviation subject matter experts in analogous roles: experience commanding or directing multiple aircraft simultaneously

Role	N
Part 107 Certified UAS operator	2*
Pilot (military, commercial, or private)	3
MQ-1 senior mission intelligence coordinator	1
Air Traffic Controller	3**

*Note: one participant had both experience as a Part 107 Certified UAS operator and a military/commercial pilot

**Note: one participant had both experience as an air traffic controller and a pilot

- Data set: 16 video recordings, transcripts, 8 task diagrams, 8 knowledge audit tables
- Qualitative data analysis tool: Dedoose Version 8.0.35
 - Transcripts uploaded to Dedoose for qualitative data analysis
 - Fixed coding scheme to identify content about specific interface elements
 - Flexible coding scheme to identify other content relative to CTA objectives
 - Example codes: Alerts, Asset Telemetry, Locate Uber Driver, Management by exception, Desired Feature, Map filters/layers

The screenshot displays the Dedoose web interface for a project named "NASA_Uber M:N CTA". The interface is divided into several panels:

- Project Summary:** Shows counts for Users (2), Media (23), Descriptors (16), Excerpts (271), Codes (45), and Code Applications (764). It includes buttons for "Import Data" and "Export Data".
- Media Table:** A table with columns for Type, Title, and Added. It lists several transcripts with dates ranging from 10/20/2020 to 11/09/2020.
- Codes:** A sidebar menu listing various codes such as Alerts, Altitude, Asset Telemetry, Automation, Battery, Bulk Actions, Central Display, Icons, Routes, Waypoints, and Widgets.
- Excerpts:** A section showing 271 excerpts, with sample text from transcripts.
- Codes x Descriptor:** A panel showing bar charts for "Alerts" and "Altitude" across different roles (ATC, Mission Coordinator, Pilot). For Alerts, ATC is 13.4%, Mission Coordinator is 66.4%, and Pilot is 20.2%. For Altitude, ATC is 36.0%, Mission Coordinator is 27.0%, and Pilot is 37.1%.
- Descriptor Ratios Multi:** A pie chart showing the distribution of roles across descriptors: Pilot (largest), ATC, and Mission.

- Cognitive requirements table (see excerpt below) draws primarily from
 - Task diagram and knowledge audit tables
 - Interviewee statements on past role during simulation interview

Name	What makes this hard?	Cues	Strategies	Vignette
Predicting mission flow over time (on time, late)	Mission flow is affected by independent mission attributes such as the amount of cargo, or potential bottlenecks in the system from outside forces that are unaware of their impact.	Visually inspecting the size of the luggage cart, the amount of ground traffic, the orientation of aircraft and how aircraft are lined up to land or takeoff. Understanding weather impacts.	Early on, get stopwatch estimates of task times to understand normal variation and abnormal. Understanding the steps in the workflow. Knowing typical events or flow specific to area of responsibility. Widening the field of view on displays to see what coming into sector to affect your operations	There is a certain pattern and pace to getting an aircraft loaded on time. ...seeing how close they were going to put an arrival and departure together, especially at the start. I think that expertise to pull those arrivals and departures apart by a good extra five minutes to give ourselves some time to kind of get through the process the first time.

- Mission or context-specific examples that increase task complexity
- Drawn from complexities described by interviewees during the simulation or specific lived experiences
- Examples:
 - Aircraft controlled landing in uncontrolled area
 - Payload too heavy for airframe
 - Battery status inaccurate
 - Automation failure undetected and unrepresented to the TO
 - Congested intersection point



Dedoose Code Cloud

- Depicts frequency of codes representing features, tasks and concerns
- Guided organization of findings

Desired Features

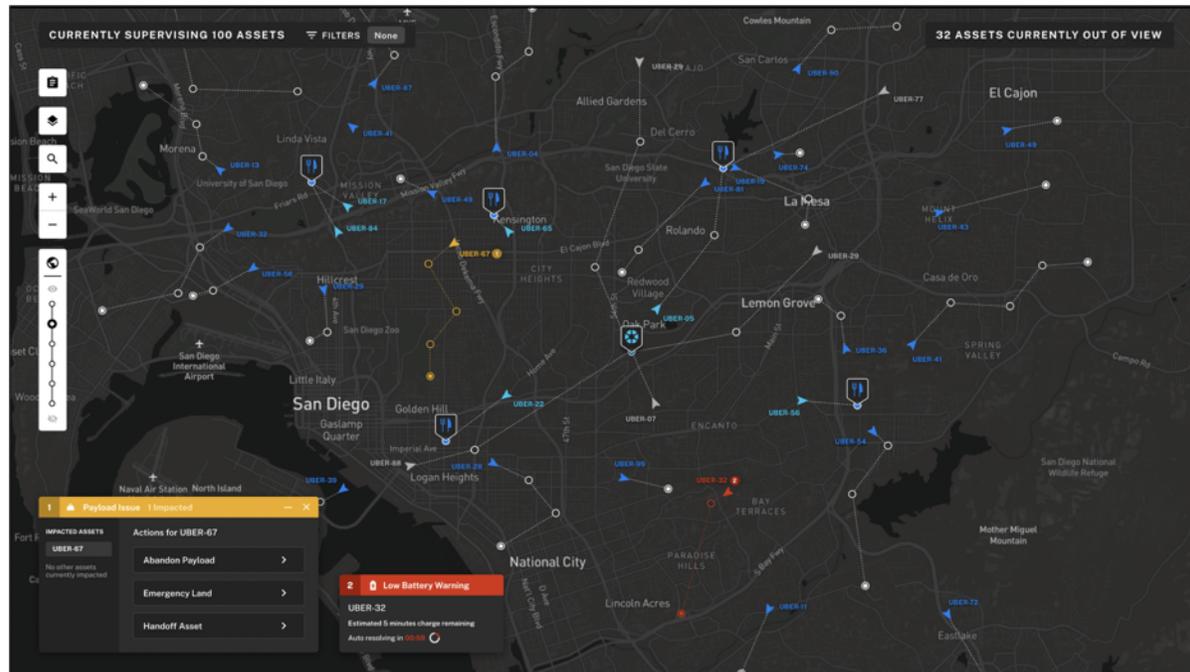
- Screen within a screen
- Micro/macro view
- Safe landing locations with real time video of the area
- Excess payload weight
- Amount of delay
- Representation of vehicle connectivity
- Phase of flight on mission timeline
- Resize chat and asset telemetry as needed
- Auto resolve actions
- Select sUAS on map and see additional information including telemetry
- At a glance representation of recently off-nominal sUAS
- TSD new chat notification
- Battery information
- Sparklines for planned and actual altitude

- Screen within a screen (so users can see the full map but when desired zoom in on a specific grid or map tile to get a better view of a particular sUAS).
- Micro/Macro view (helpful when trying to see all assets, including those that might be out of the current view).



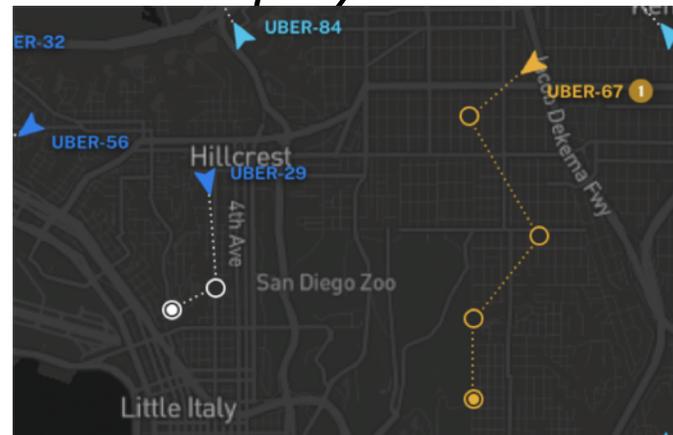
Screen Design Mockup to Illustrate a Micro/Macro View Concept

- The central display, also known as the TSD, was considered by all but one interviewee to be the cornerstone of the interface. Users stated they spent between 60-80% of their time looking at this display followed by the Telemetry screen, Chat screen, and then the Timeline screen.
 - Percentage of time working with the TSD did reduce as more assets (and more assets in off-nominal states) were added to the map and management by exemption came into play
 - Participants still looked at the TSD the majority of the time however



- There was some concern over the colors used in the coding scheme as well as the use of dark colors over a dark map
- While interviewees could easily ascertain that red signaled a warning and yellow a caution, they were less sure of the dark blue vs. lighter blue for sUAS icons and routes. White routes over grey streets was also a complaint

“The thing that immediately jumps out to me is, it's a little hard for my eyes to deal with the blue, with the black. I would want to make the targets more salient. So whatever the options were, my goal would be making sure that the background didn't mask the targets and the information display.” – Interviewee 8, ATC



- Interviewees wanted access to weather information, either as part of a brief, and/or as part of a map filter. Weather especially came up with the payload scenario when interviewees were trying to troubleshoot why an asset could not reach its designated altitude.
 - **Consider incorporating weather patterns, wind speed and heading, and barometric pressure as a map layer.**



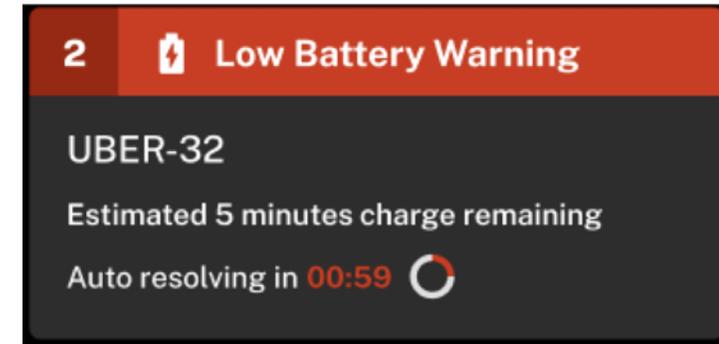
“I’m thinking that wind measurements should be on the screen so that I can know what’s going on with wind and weather.” - Interviewee 6, ATC

“Weather observations should be given to me in my brief.” - Interviewee 6, ATC

“If I saw an anomaly I might flip on the weather and see if there was a non-loss event that just happened with the weather.” - Interviewee 1, Mission Coordinator

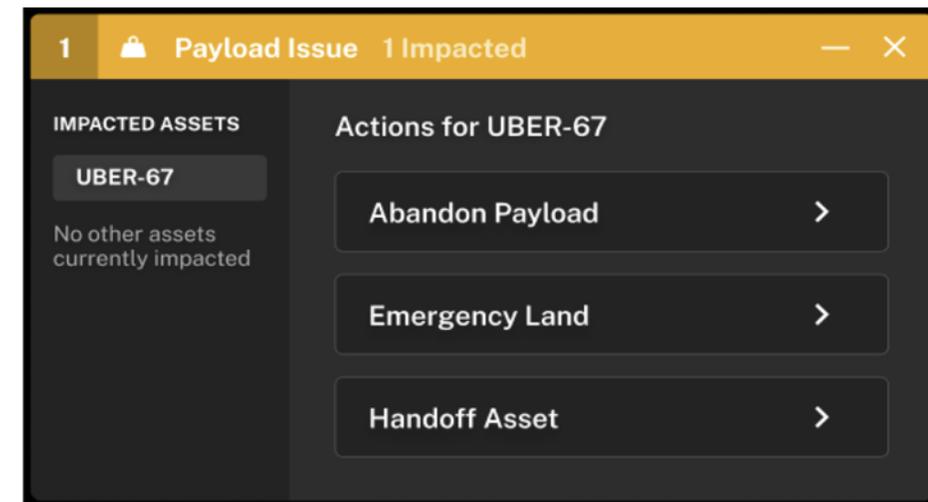
“I’d usually use just general forecasts from like Accuweather, and then we had a local weather station as well that was showing wind speed and barometric pressure.” - Interviewee 3, Pilot

- Interviewees were challenged with understanding some of the terminology used in the alerts, understanding what steps the auto resolver was going to make, how to get more information on an alert, and how to take next steps to dealing with the alert.
- The prioritization of options in the alert was not always liked. For the payload issue for example, the first option of abandoning (releasing) the payload was either the last resort or would not be considered by most interviewees and as such interviewees felt that option should be listed at the bottom of the message, or not at all.



“I need additional information to interpret, to start augmenting my decision making.” - Interviewee 8, ATC

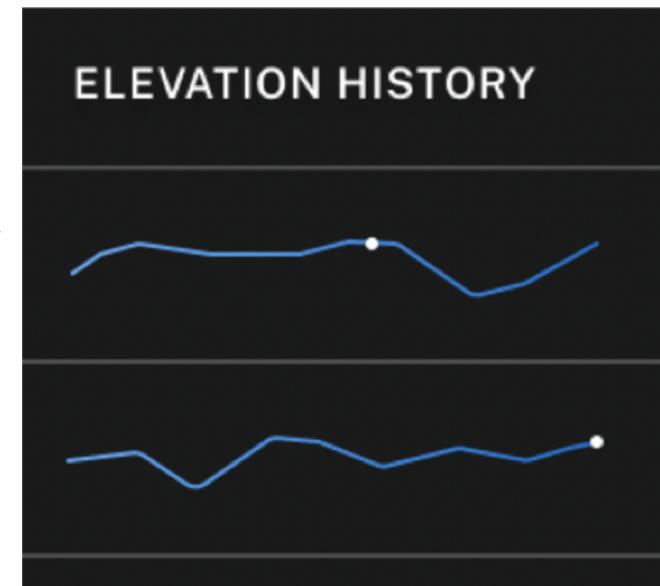
“It says auto resolving and asset and timeline, which is super unsatisfactory for me because I don't know what auto resolving means. I'm not getting any additional information about this. There's too many aircraft for me to have an idea of what everyone's flight plan is. When something like this pops up, I would like the information so I know, OK, payload, issue. Maybe, you don't have more information on the issue but I would certainly want as much as there was. Hopefully it's more than auto resolving and a timeline. That's nice, but maybe some checklist tailored to the issue, especially if this is a thing that comes up often, so at least I have some reference to it.” - Interviewee 8, ATC



- Interviewees found the altitude sparkline very important but also felt it wasn't enough. The dot representing where the asset was, was just a single snapshot in time. Interviewees wanted to see trends.

“If there was a planned elevation, then maybe I would understand that here's the path, and here's where they are, and if they're deviating higher or lower.” - Interviewee 1, Mission Commander

ASSET TELEMETRY		MISSION STATUS					▲ Impacted Assets Prioritized
ASSET	ALTITUDE	SPEED	HEADING	RPMS	BATTERY	ELEVATION HISTORY	
UBER-67	112 ft	4.4 kts	101°	8199	46%		
UBER-32	456 ft	10.9 kts	167°	5418	6%		
UBER-01	322 ft	17.4 kts	322°	4566	25%		
UBER-02	238 ft	18.1 kts	148°	5190	56%		
UBER-03	405 ft	12.1 kts	42°	6200	91%		
UBER-04	488 ft	10.9 kts	356°	4122	22%		
UBER-05	121 ft	4.2 kts	113°	5418	67%		
UBER-06	121 ft	8.9 kts	101°	5418	44%		
UBER-07	121 ft	11.9 kts	34°	5418	81%		
UBER-08	121 ft	7.3 kts	56°	5418	76%		
UBER-09	121 ft	14.1 kts	278°	5418	29%		
UBER-10	121 ft	16.6 kts	201°	5418	99%		
UBER-11	121 ft	14.5 kts	156°	5418	72%		

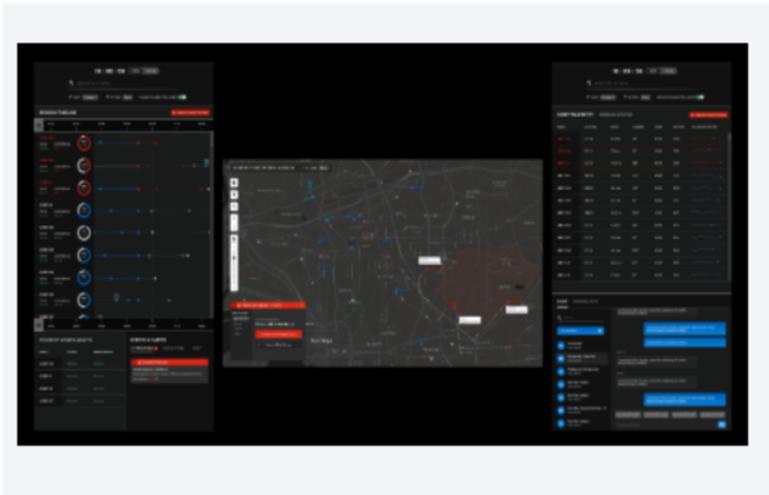


- Facilitating mission flow
 - Recognize and foresee potential bottlenecks, conflicts, and barriers to mission flow
 - Importance of weather
 - Known set of abnormal events
 - Initiate corrective actions early
- Predicting automation in context
 - Robust mental model of sUAS operations even when interface is not transparent
 - Calibrating trust in automation
- Maintaining big picture perspective
 - Use knowledge of aircraft type and capabilities, weather, mission, location, adjacent aircraft
 - Understand second and third order effects
 - Operators force themselves to maintain scan even during emergency/off-nominal

Non-exhaustive categorized examples of complexities, useful for hypothesis testing and scenario design:

- sUAS air vehicle and payload – controlled and uncontrolled landings (injury, property damage), battery state, in-flight automation failure
- Environmental conditions - fixed and mobile vertical obstructions, weather
- Food delivery service - arising from the nature of food delivery
- sUAS/Driver infrastructure - arising from n sUAS operations, necessary interface between sUAS and driver, or sUAS and ground personnel
- TO personnel - TO behaviors or support to the TO

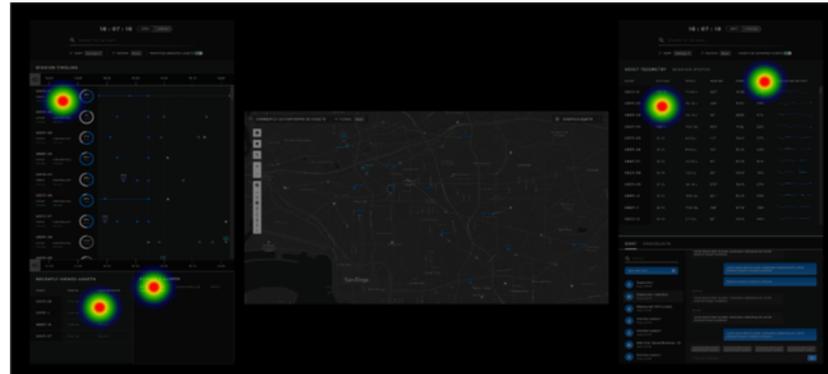
- Iterate future designs and user feedback, including more in-depth navigation and asset handoff exploration
- Google Forms for a deeper dive on Handoffs
- UsabilityHub.com survey to capture user interactions and feedback



7. The interface provides me with useful options and choices

- Strongly disagree
- disagree
- neither disagree nor agree
- agree
- strongly agree

Pass



Hypothetical

You are a Tactical Operator (TO) supervising 6 nominal food delivery small unmanned aerial systems (sUAS) in a downtown urban environment. You have just received the following notification from your supervisor.

Using the notification below, what is the important information pertinent to the supervisor's request?

ALERTS

1 Handoff Request

Requested by: Jonathan Smith via FHM

Auto-assigning to: []

ALERT DETAILS

Handoff Request

Operator workload levels

Auto-assigning to: []

REQUESTED OPERATOR

REQUESTED BY	SUPERVISORS	WCA	LAST BREAK
Jonathan Smith	42 Assets	3 0 0	4h 30m ago

REQUEST

Handoff of 3 Assets requested

ACCEPT HANDOFF OF 3 ASSETS ACCEPT PARTIAL HANDOFF SELECT HANDOFF OF 2 ASSETS

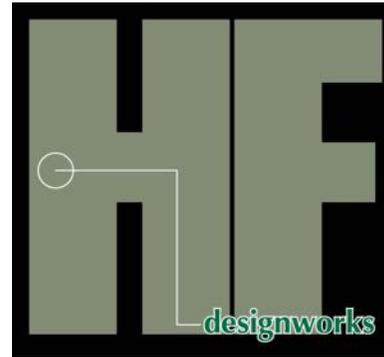
Your answer

Under what circumstances would you be willing to accept a handoff with this information?

- You are receiving 6 nominal sUAS from a TO taking a 30 min lunch break
- You are receiving 6 nominal sUAS from a TO taking a 5 min bio break
- You are receiving 6 nominal sUAS from a TO who is also currently managing 3 other sUAS with warnings, cautions, or advisories (WCA)
- You are receiving 6 nominal sUAS from a *novice* TO who is also currently managing 3 other sUAS with warnings, cautions, or advisories (WCA)
- You are receiving 6 nominal sUAS from an *experienced* TO who is also currently managing 3 other sUAS with warnings, cautions, or advisories (WCA)
- You are receiving 2 off-nominal sUAS from an *experienced* TO who is also currently managing 4 other sUAS (1 with warning, caution, or advisory (WCA), and 3 nominal)

Would you ever accept an asset without knowing its:

	Yes	No
Location	<input type="checkbox"/>	<input type="checkbox"/>



Questions or Comments?

scottscheff@hfdesignworks.com