Progressive Development of Fleet Management Capabilities for a High Density Vertiplex Environment

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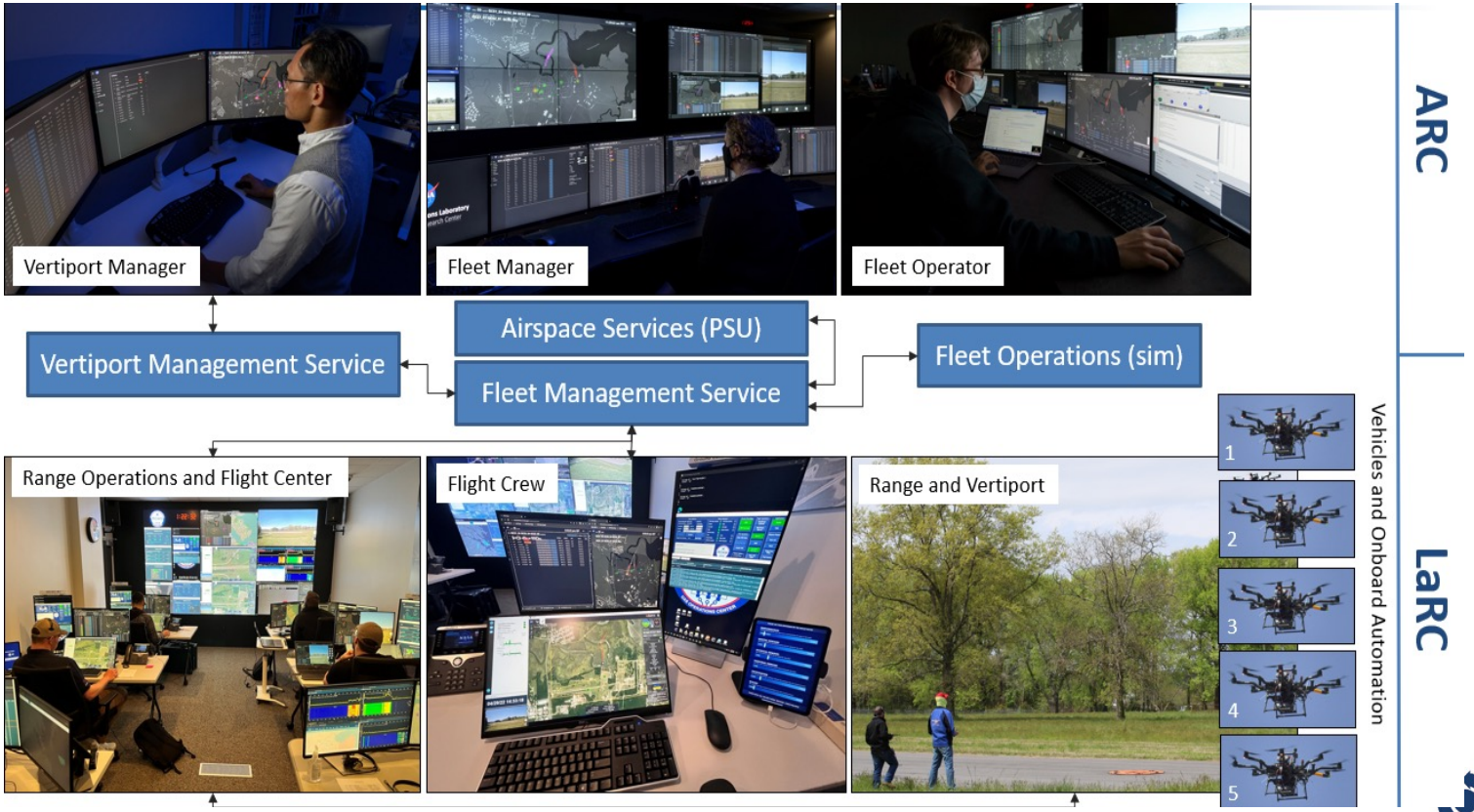
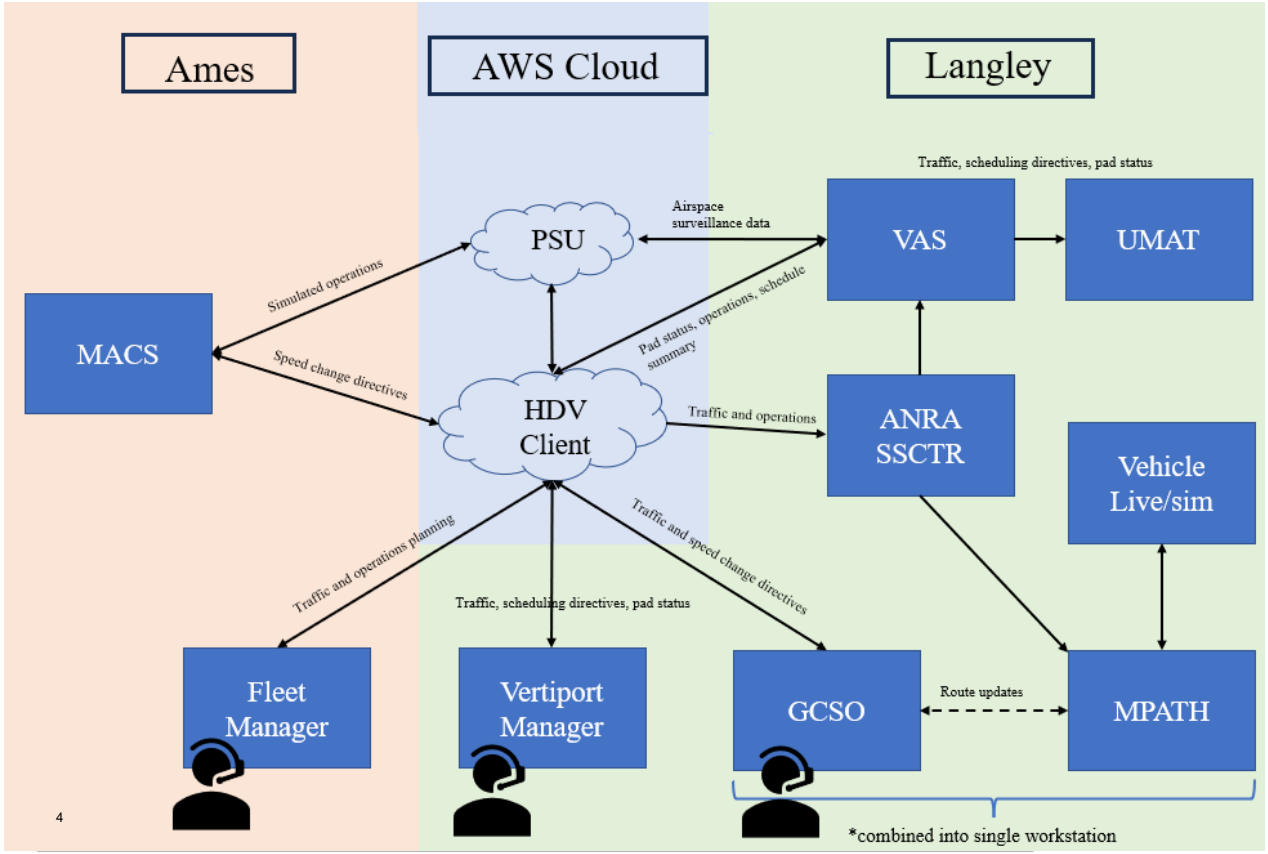
Introduction & Background

- NASA has embarked upon a thrust of research in Advanced Air Mobility (AAM), in collaboration with industry and other government agencies.
- The High-Density Vertiplex (HDV) subproject focus area has been on developing a reference architecture for scalable, high-density operations in vertiport terminal areas
- This paper's focus is on fleet management capabilities to support multiple AAM operations from a supervisory fleet manager role.

Prototype demonstration



HDV System Architecture



- NASA Provider of Services for UAM (NPSU)
- Vertiport management
- Aircraft/onboard automation
- Operator user interfaces/HDV client
- Fleet management

Demonstration progression & assessment

Scalable Autonomous Operations

Advanced Onboard Automation

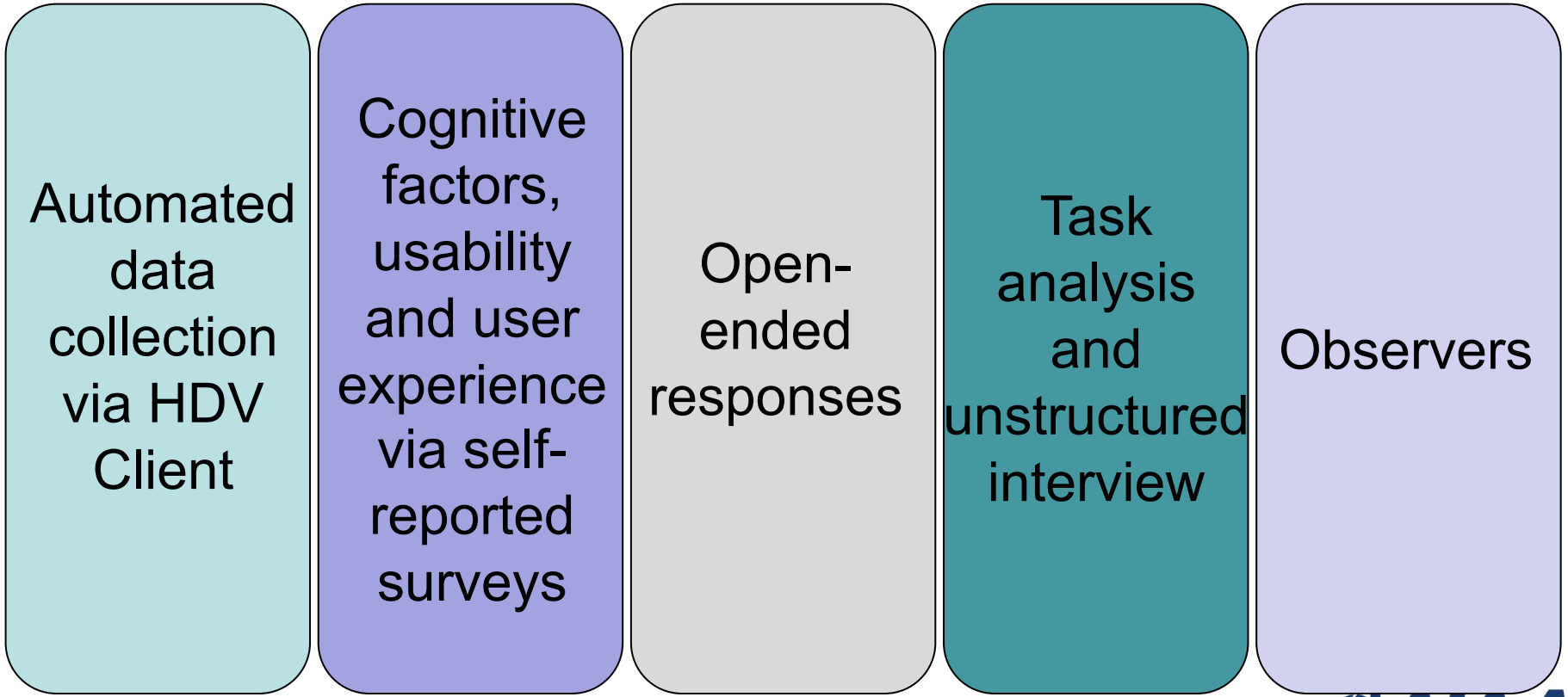
- Simulation & flight events
- Introduced FM with two scenarios
- lower traffic density @ 20 operations/hour

2021 - 2022

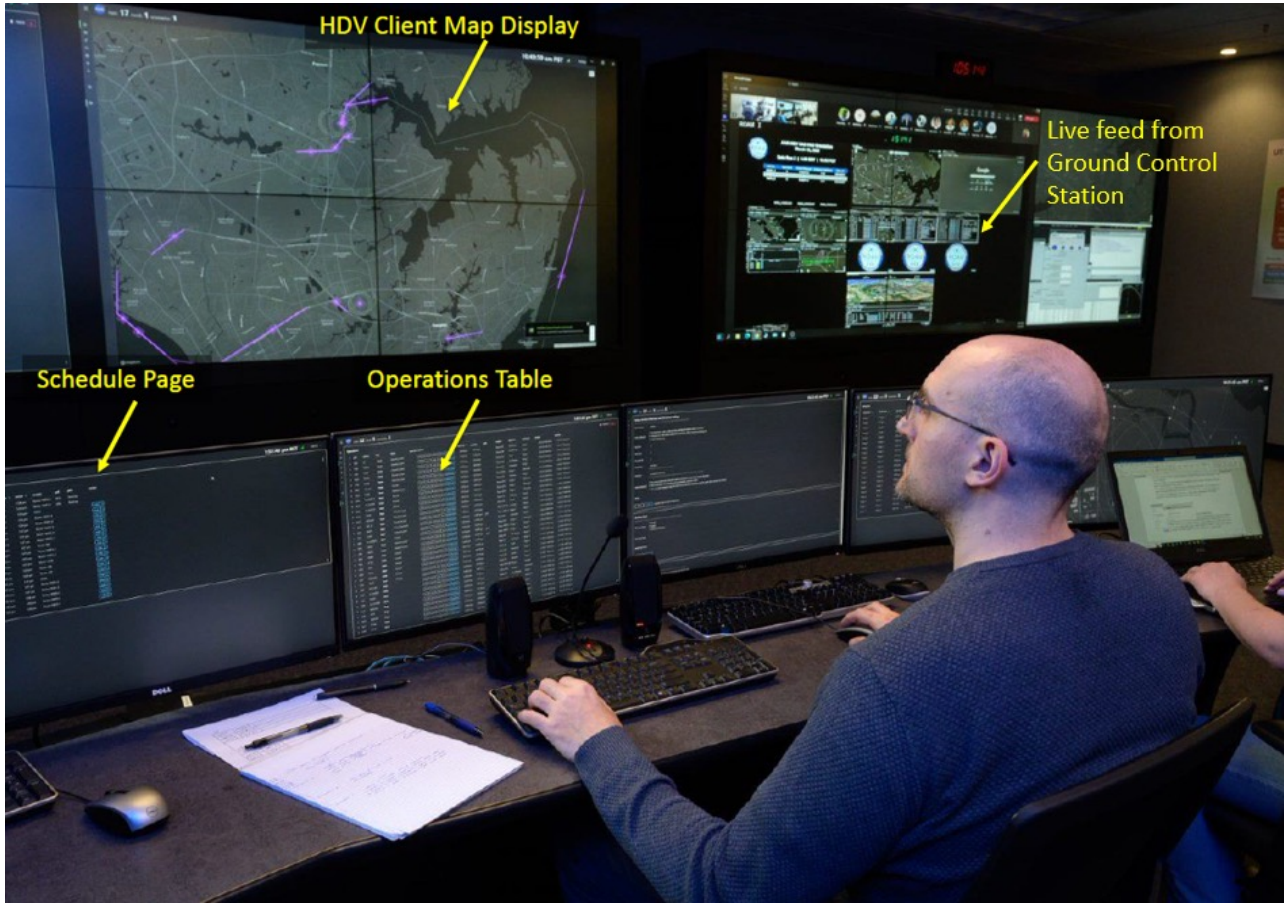
- Simulation & flight events
- Progressed interactions of FM to five scenarios
- higher traffic density @ 60 operations/hour

2023

Measures


Automated data collection via HDV Client
Cognitive factors, usability and user experience via self-reported surveys
Open-ended responses
Task analysis and unstructured interview
Observers

HDV Fleet Manager Workstation



- Map
- Operations Table
- Schedule Page

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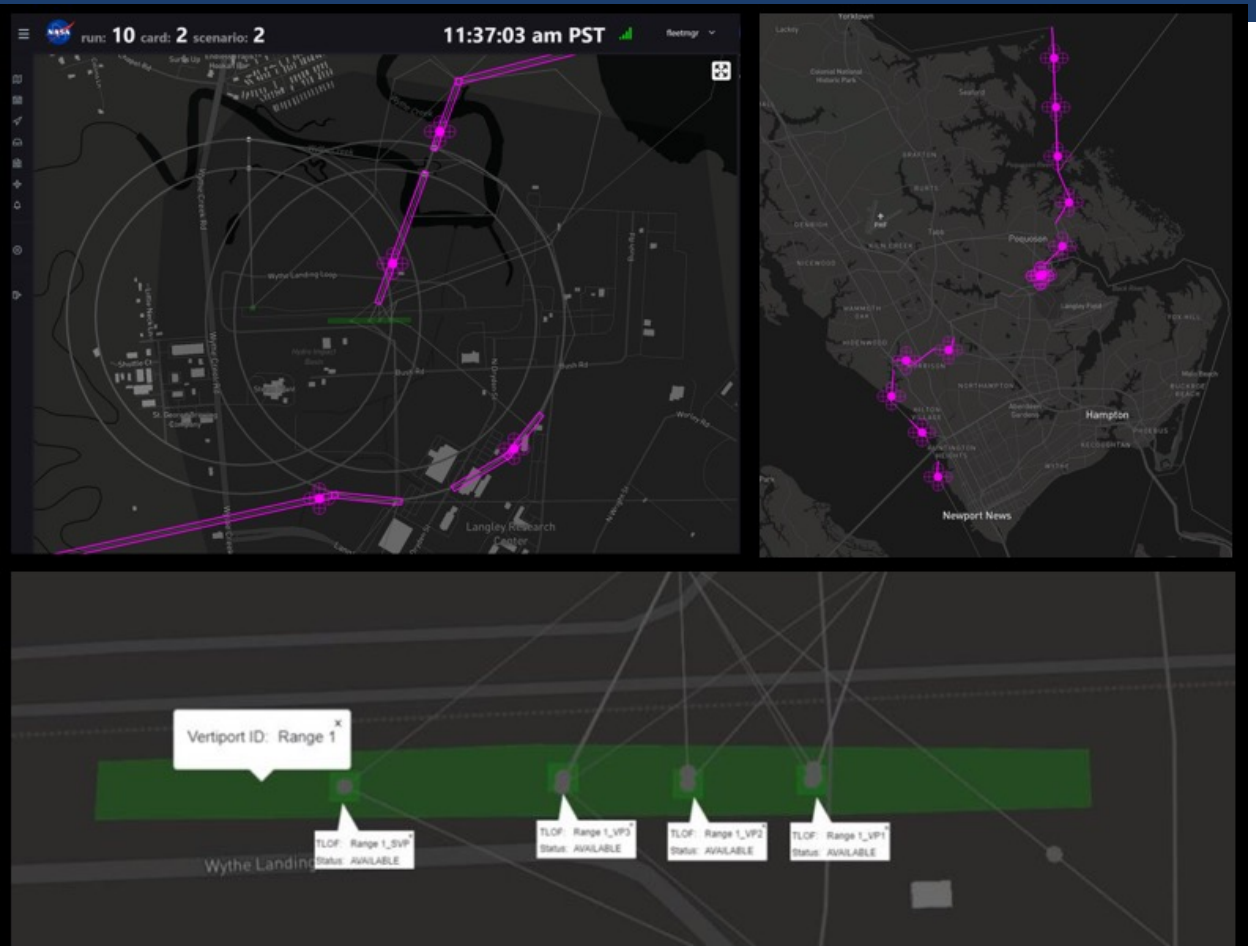
Map



- Display airspace/ associated structures like arrival/depart and divert routes, and vertiports/ vertipads, IAF and FAF
- Aircraft positions and intended trajectories
- Users reported the map was most used feature for SA
- Desired additional filtering and detailed info about vertiports

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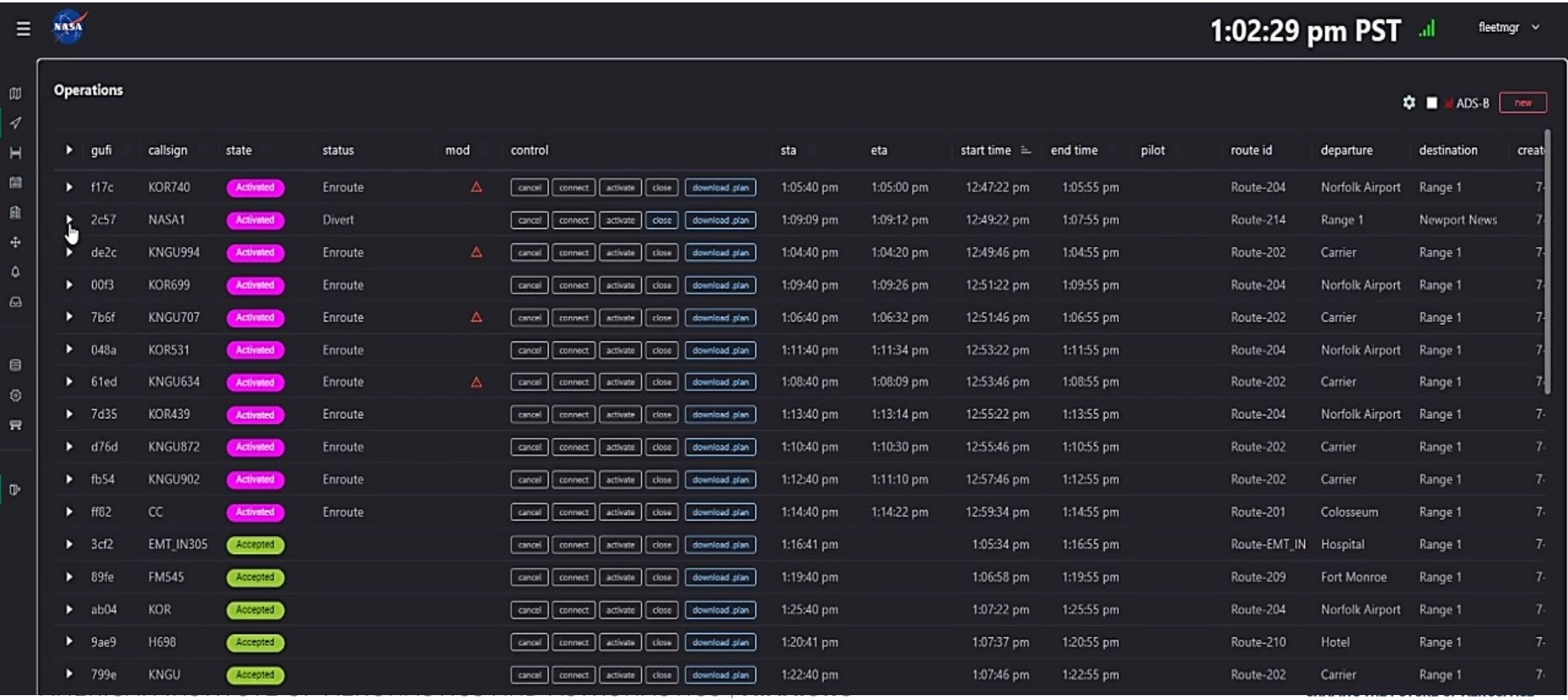
Operations Table



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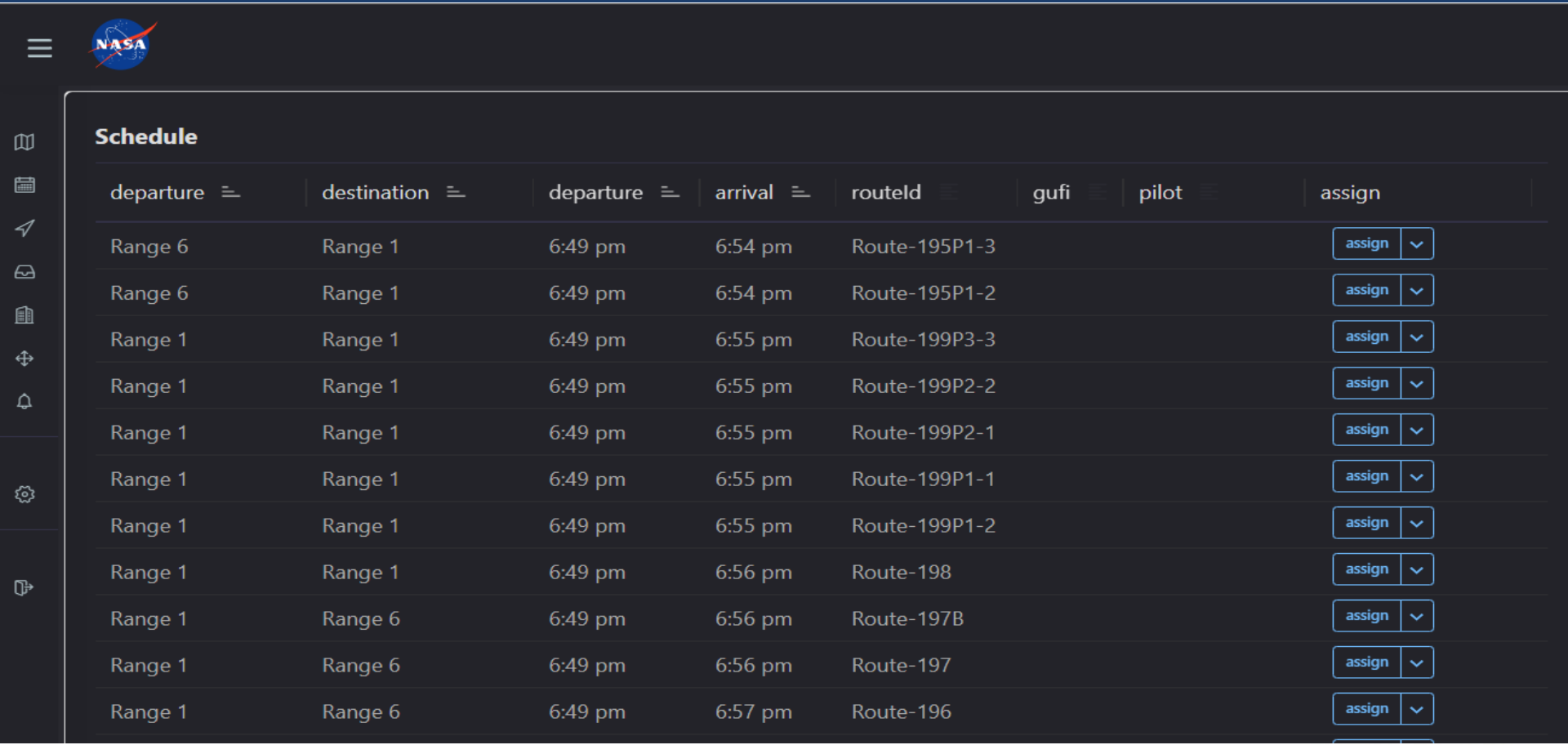
f17c	KOR740	Activated	Enroute	⚠	cancel connect activate close download plan	1:05:40 pm	1:05:00 pm	12:47:22 pm	1:05:55 pm		Route-204	Norfolk Airport	Range 1	7
2c57	NASA1	Activated	Divert		cancel connect activate close download plan	1:09:09 pm	1:09:12 pm	12:49:22 pm	1:07:55 pm		Route-214	Range 1	Newport News	7
de2c	KNGU994	Activated	Enroute	⚠	cancel connect activate close download plan	1:04:40 pm	1:04:20 pm	12:49:46 pm	1:04:55 pm		Route-202	Carrier	Range 1	7
00f3	KOR699	Activated	Enroute		cancel connect activate close download plan	1:09:40 pm	1:09:26 pm	12:51:22 pm	1:09:55 pm		Route-204	Norfolk Airport	Range 1	7
7b6f	KNGU707	Activated	Enroute	⚠	cancel connect activate close download plan	1:06:40 pm	1:06:32 pm	12:51:46 pm	1:06:55 pm		Route-202	Carrier	Range 1	7
048a	KOR531	Activated	Enroute		cancel connect activate close download plan	1:11:40 pm	1:11:34 pm	12:53:22 pm	1:11:55 pm		Route-204	Norfolk Airport	Range 1	7
61ed	KNGU634	Activated	Enroute	⚠	cancel connect activate close download plan	1:08:40 pm	1:08:09 pm	12:53:46 pm	1:08:55 pm		Route-202	Carrier	Range 1	7
7d35	KOR439	Activated	Enroute		cancel connect activate close download plan	1:13:40 pm	1:13:14 pm	12:55:22 pm	1:13:55 pm		Route-204	Norfolk Airport	Range 1	7
d76d	KNGU872	Activated	Enroute		cancel connect activate close download plan	1:10:40 pm	1:10:30 pm	12:55:46 pm	1:10:55 pm		Route-202	Carrier	Range 1	7
fb54	KNGU902	Activated	Enroute		cancel connect activate close download plan	1:12:40 pm	1:11:10 pm	12:57:46 pm	1:12:55 pm		Route-202	Carrier	Range 1	7
ff82	CC	Activated	Enroute		cancel connect activate close download plan	1:14:40 pm	1:14:22 pm	12:59:34 pm	1:14:55 pm		Route-201	Colosseum	Range 1	7
3cf2	EMT_IN305	Accepted			cancel connect activate close download plan	1:16:41 pm		1:05:34 pm	1:16:55 pm		Route-EMT_IN	Hospital	Range 1	7
89fe	FM545	Accepted			cancel connect activate close download plan	1:19:40 pm		1:06:58 pm	1:19:55 pm		Route-209	Fort Monroe	Range 1	7
ab04	KOR	Accepted			cancel connect activate close download plan	1:25:40 pm		1:07:22 pm	1:25:55 pm		Route-204	Norfolk Airport	Range 1	7
9ae9	H698	Accepted			cancel connect activate close download plan	1:20:41 pm		1:07:37 pm	1:20:55 pm		Route-210	Hotel	Range 1	7
799e	KNGU	Accepted			cancel connect activate close download plan	1:22:40 pm		1:07:46 pm	1:22:55 pm		Route-202	Carrier	Range 1	7

Schedule Page



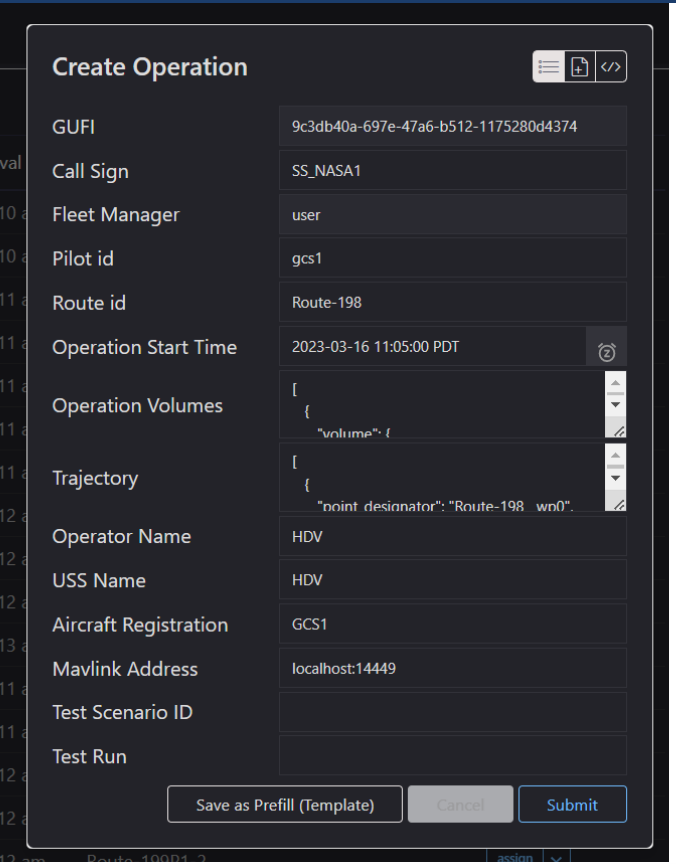
Scenario based tools & feedback

- (All scenarios) Exchanging voice and digital communications with other operators
- (All scenarios) Scheduling operations
- Performing a nominal mission
- Performing a missed approach procedure
- Performing a speed change procedure
- Performing a divert procedure

Comms

- Exchanging voice and digital comms with GCSOs and Vertiport Managers
- FMs reported higher SA than VMs & GCSOs when it came to knowing what other operators were doing – possible artifact of how role was designed – mediated info between VM & GCSOs, had two-way comms with both
- FMs experienced lower levels of workload on scenarios that required verbal comms vs digital comms. Unfamiliar interface, button clicks, visual searching and interpreting messages with incomplete info could be a source of frustration.
- Designers of interface-based comms must ensure notifications are salient, persist long enough for operators to respond, and contain relevant info about specific task to be completed.

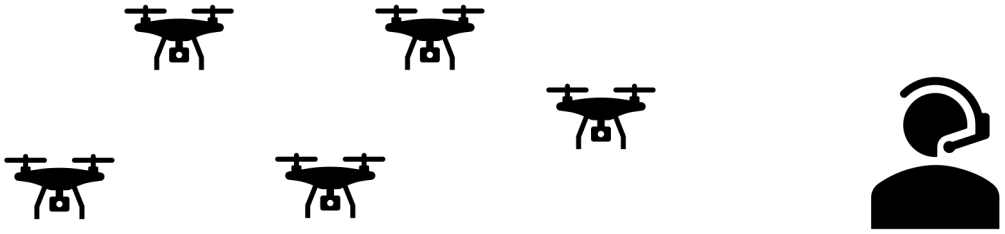
Scheduling an Operation



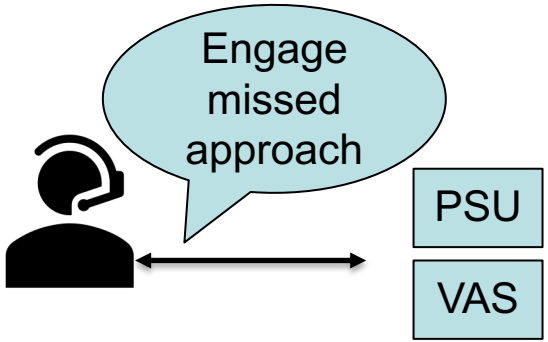
- To schedule an operation, the flight crew used voice communication to call the FM and announce their callsign, requested route and requested takeoff time. FM used the Create Operation window on the Schedule page to manually input the callsign, then confirm the operation details were correct.
- Then transmitted to NPSU for acceptance, then sent to flight crew for execution.
- Highest user error because of the manual editing
- Suggested improvements – remove irrelevant fields or pre-fill form and send to FM to approve with a single button click

Nominal Mission

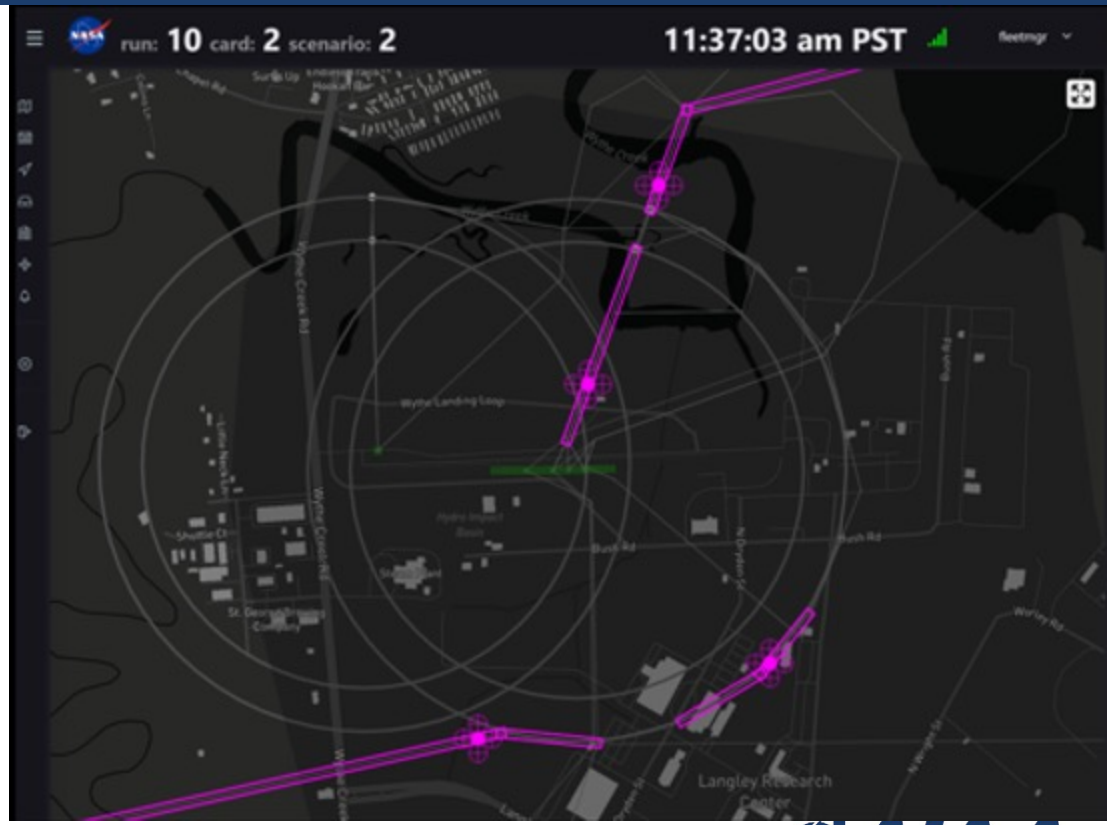
- FM performed steps to schedule an operation for between 1-5 vehicles, who then flew their originally filed plan with no changes
- The FM continuously monitored the flight missions from takeoff to landing, looking for status updates such as 1) activated, 2) enroute, 3) cleared to land, and 4) landed. FMs could monitor flight status from the operations page, and flight positions from the map page.
- FMs ultimately preferred the map page as their primary tool for flight monitoring.



Missed Approach



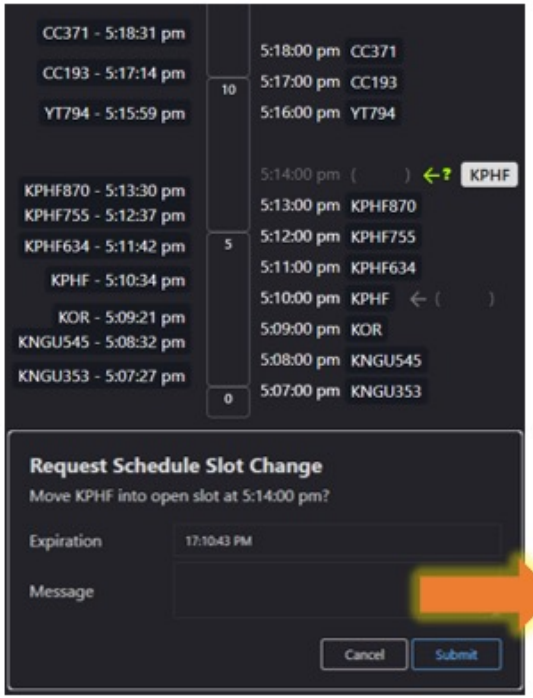
- Users reported MA tool was easy to use, high level of understanding but wondered why it was a task for FM. Preference for GCSO to coordinate with VM directly
- Good candidate for automation



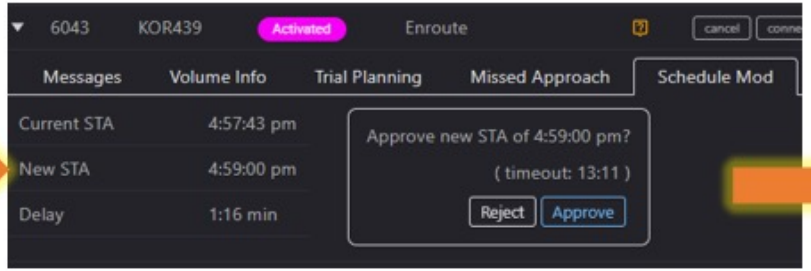
Speed Change

- Users reacted positively to viewing and modifying schedule via a timeline
- FM would like more insight into how one schedule change affects overall fleet/flow
- Solution: add timeline for FM to see ownship

Vertiport Manager

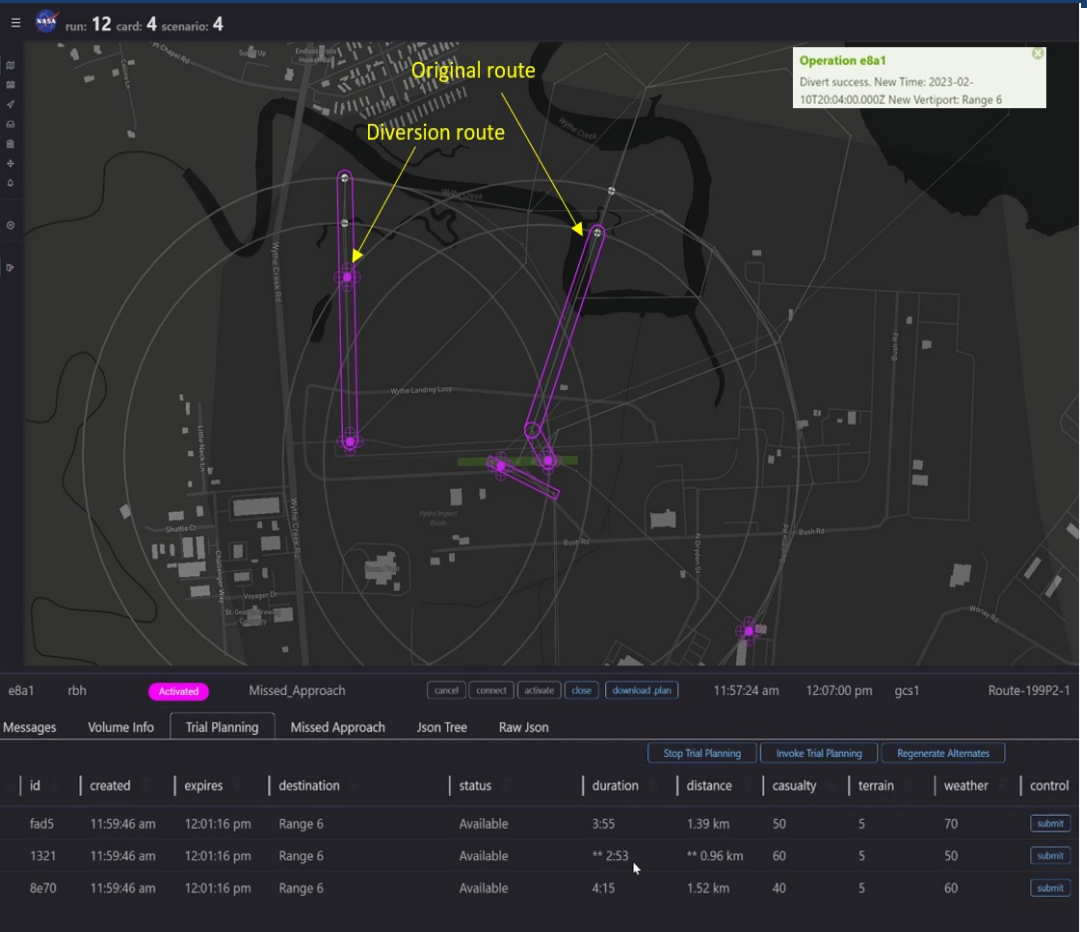


Fleet Manager



GCSO

Divert (version 1)



- Relative short routes and planning horizons, forced a quick response from FM.
- Information available had loosely defined numerical factors, causing varied interpretation
- Room to improve - longer time horizons & more salient trade-off factors.

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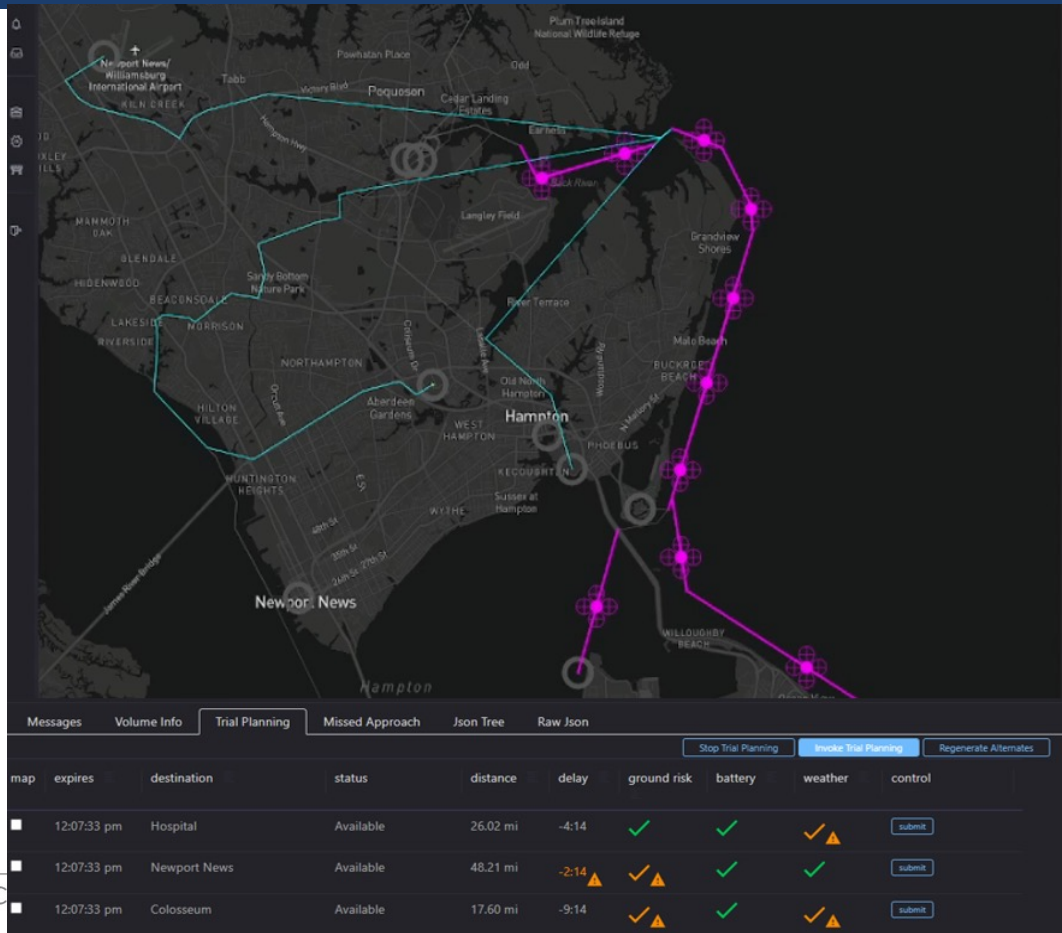
Divert (version 2)

- Design changes helped address previous issues
- User reported favorable view of new TP tool. Increased confidence and decision-making power with longer planning time
- Q's arose about who should do the reroute for a single flight (FM vs GCSO), leading to discussion on situation where group of flights need to divert – candidate for multi-trial plan tool and automation



Discussion

- Who is a Fleet Manager? What do their roles and responsibilities look like?
- HDV subproject defined FM as an operator who will manage multiple departure/arrivals at vertiport and indeed accomplish this to a certain extent but remaining close to 1:1 operator to aircraft paradigm.
- The impact of off-nominal situations on air carrier customers is not well understood by the current instantiation of the HDV ecosystem. When a flight is diverted away from the original destination it is presumed that the air taxi company will still be responsible for getting the passenger to the desired destination. Therefore, more info would be needed for FM planning.
- What will the specific responsibilities of the FM be over different phases of flight? Possibly a specialized FM for each phase of flight or route/corridor

Conclusion

- The present studies of fleet management for HDV have only scratched the surface of the FMs potential
- Over the course of studying the Fleet Manager interface, we learned a great deal about how users interacted with the partially automated systems while they communicated with us the information requirements for more advanced automation. There is a lot left to explore, but there is great value in expanding our knowledge of the FM role within a reference UAM automation architecture

Thanks for listening!

Questions? Email Ashley.n.Gomez@nasa.gov or gita.s.hodell@nasa.gov

Backup Slides

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