



A Flight Replanning Tool for Terminal Area Urban Air Mobility Operations

Anne S. Suzuki

San Jose State University Research Foundation

Quang V. Dao

NASA

Research and Engineering Team: Ames and Langley



Purpose

- Introduce a tool for flight replanning decision-making research in UAM terminal area operations
- Report on the evaluation of version 1 of our trial planner



Overview

1. What is trial planning and why
2. Design strategy
3. UI and trial planning workflow
4. Evaluation
5. Results
6. Future work



What is trial planning?

Identify and evaluate new routes.

Trial planner: automated tool that computes and provides new route options

Purpose: Support decision-making research

Intended users:

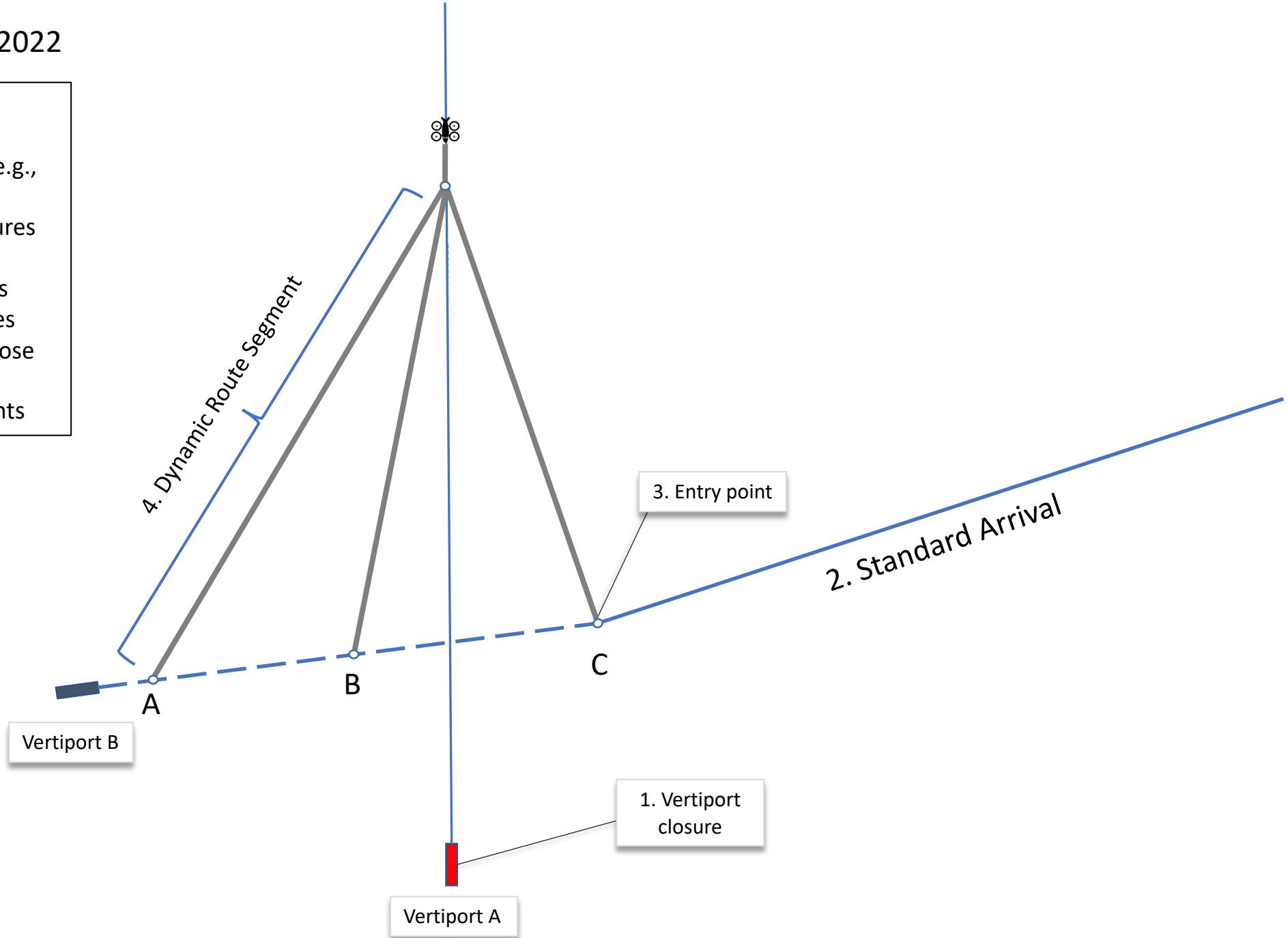
- ATC
- Airline Dispatchers
- Flight crew
- Fleet manager (Urban Air Mobility)

Why?

1. Resolve traffic conflicts
2. Avoid hazardous weather
3. **Divert to alternate landing location (may also involve 1 and 2)**
4. Recover from missed approach

Design strategy:

1. Automatic triggering, e.g., vertiport closure
2. Model airspace structures to support replanning
3. Determine entry points along predefined routes
4. Compute route from nose of aircraft to alternate vertiport via entry points

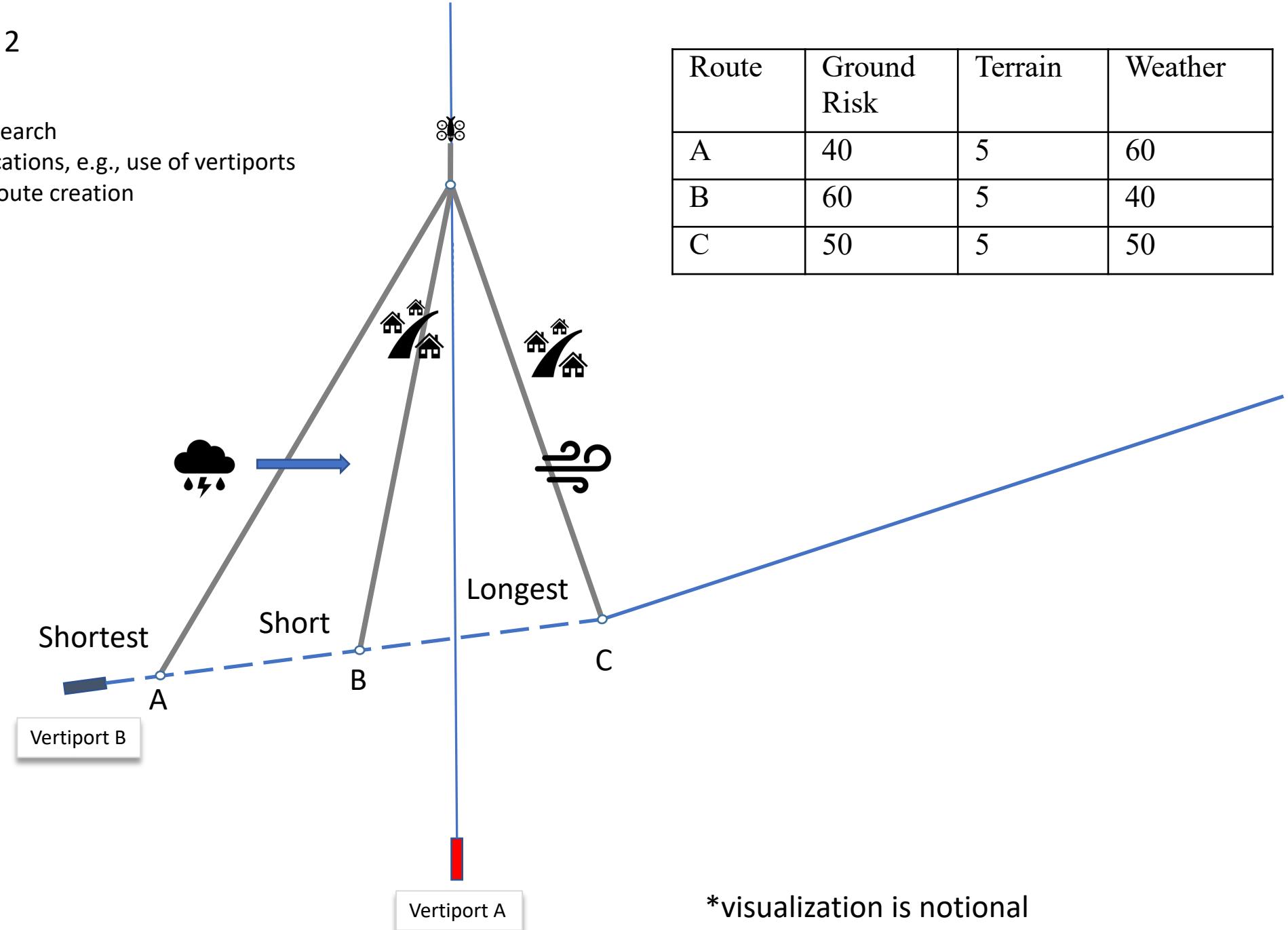




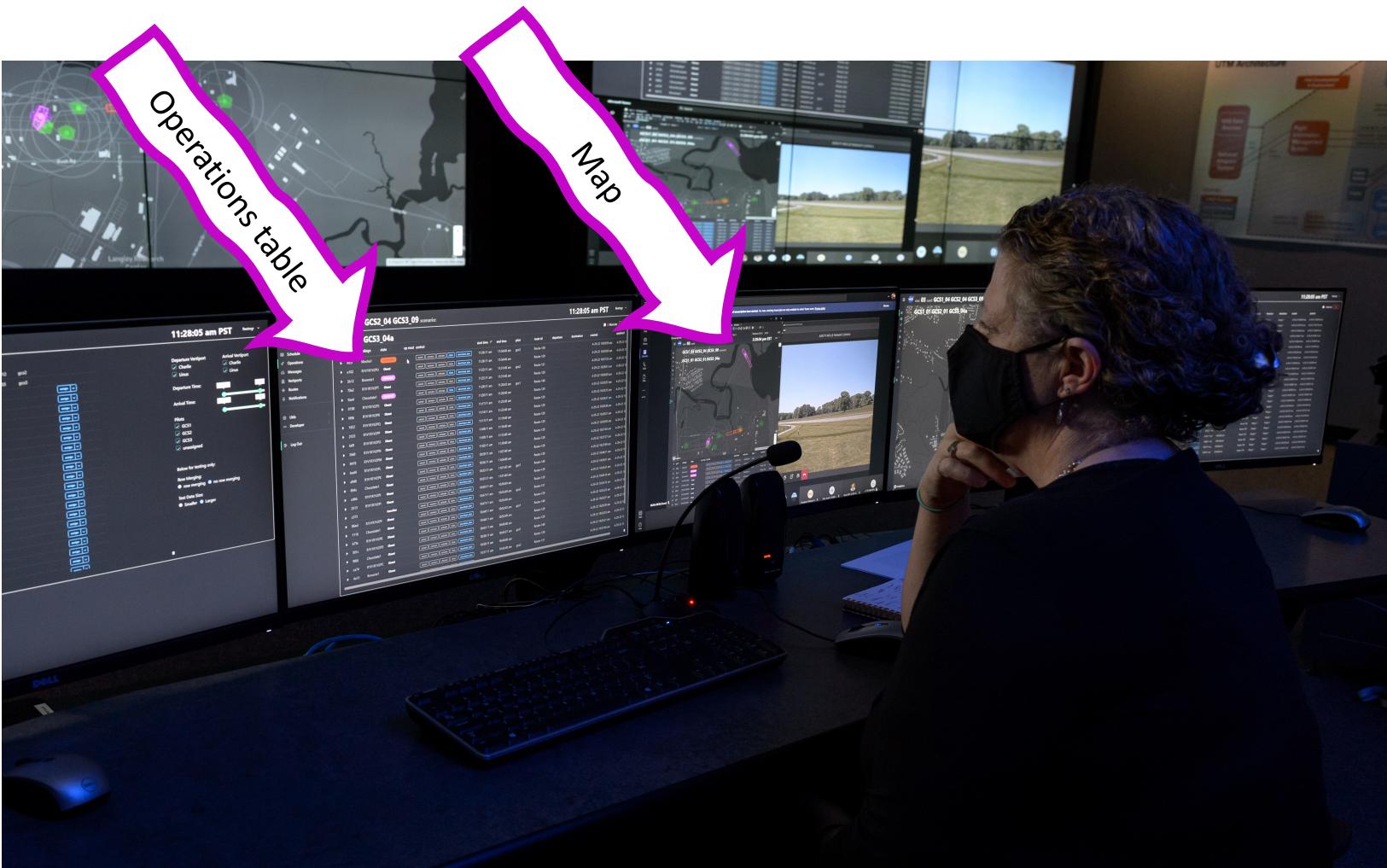
Trial Planner Version 2

Our goals with trial planning:

- Support decision-making research
- Demonstrate for UAM applications, e.g., use of vertiports and airspace structures for route creation



Fleet Manager Workstation





1. Create and submit an operation

10:35:11 am PST fleetmgr

Map Schedule Operations Messages Vertiports Routes Notifications 1

Log Out

gufi	callsign	state	op mod	control	start time	end time	pilot	route id	departure	destination	created	updated
f93b	R1V1R1V2PG	Activated		cancel connect activate close download plan	10:34:53 am	10:43:22 am		Route-129	Range 1	Range 1	8-05-22 10:32:52 am	8-05-22 10:
9129	R1V1R1V2PH	Accepted		cancel connect activate close download plan	10:37:53 am	10:46:22 am		Route-129	Range 1	Range 1	8-05-22 10:33:09 am	8-05-22 10:
0aa5	R1V1R1V2PA	Closed		cancel connect activate close download plan	10:40:53 am	10:49:22 am		Route-129	Range 1	Range 1	8-05-22 10:33:28 am	8-05-22 10:
3310	Chocolate1	Accepted		cancel connect activate close download plan	10:40:53 am	10:49:22 am	gcs1	Route-130	Range 1	Range 1	8-05-22 10:35:04 am	8-05-22 10:
7a8e	R1V1R1V2PB	Accepted		cancel connect activate close download plan	10:43:53 am	10:52:22 am		Route-129	Range 1	Range 1	8-05-22 10:33:45 am	8-05-22 10:
6a44	R1V1R1V2PC	Accepted		cancel connect activate close download plan	10:46:53 am	10:55:22 am		Route-129	Range 1	Range 1	8-05-22 10:34:03 am	8-05-22 10:
4683	R1V1R1V2PD	Accepted		cancel connect activate close download plan	10:49:53 am	10:58:22 am		Route-129	Range 1	Range 1	8-05-22 10:34:21 am	8-05-22 10:
89d0	R1V1R1V2PE	Accepted		cancel connect activate close download plan	10:52:53 am	11:01:22 am		Route-129	Range 1	Range 1	8-05-22 10:34:40 am	8-05-22 10:
1f1e	R1V1R1V2PF	Accepted		cancel connect activate close download plan	10:55:53 am	11:04:22 am		Route-129	Range 1	Range 1	8-05-22 10:34:57 am	8-05-22 10:



2. Load flight plan and take off

Map

Schedule

Operations

Messages

Vertiports

Routes

Notifications 1

Utils

Developer

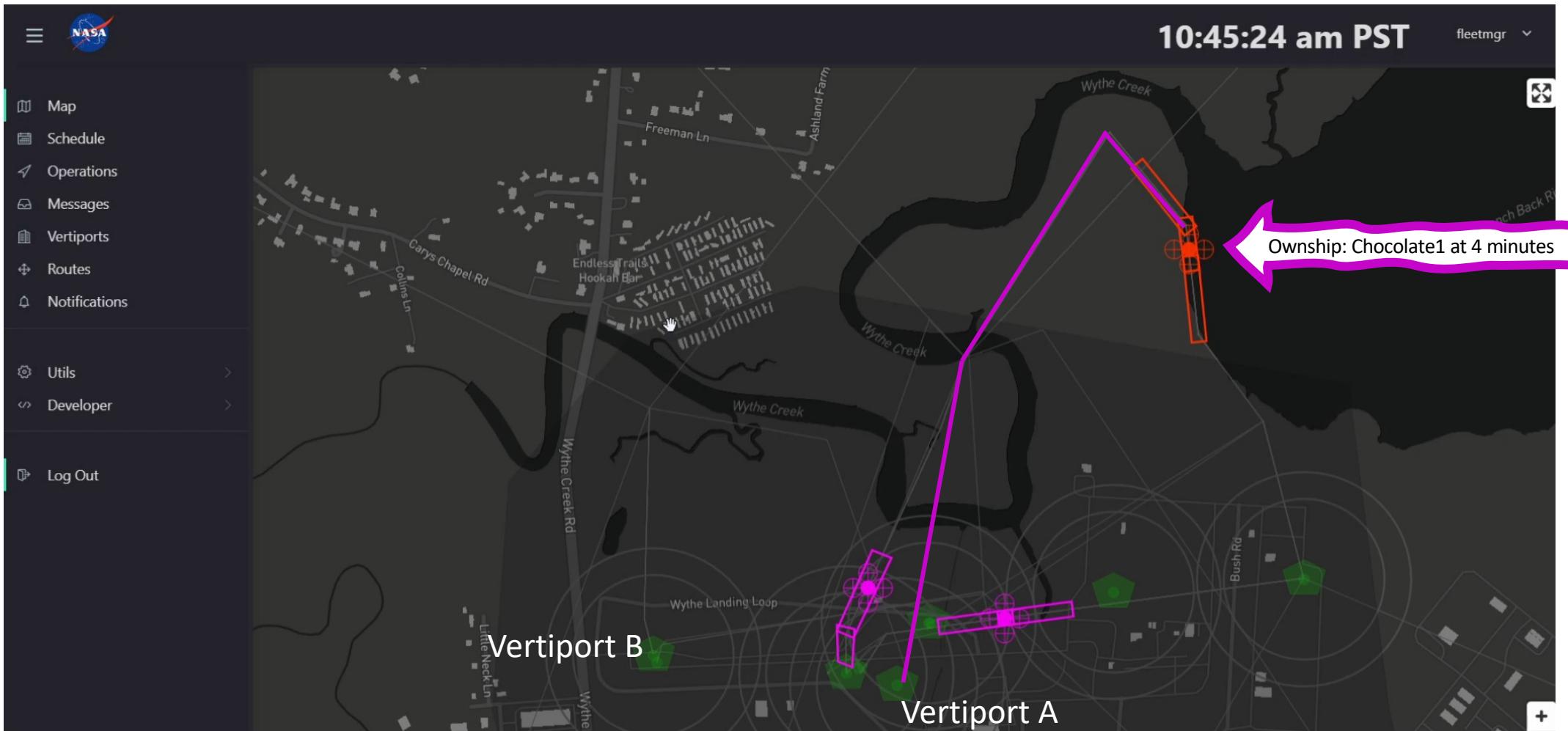
Log Out

Operations

gufi	callsign	state	op mod	control	start time	end time	pilot
f93b	R1V1R1V2PG	Activated			10:34:53 am	10:43:22 am	
9129	R1V1R1V2PH	Activated			10:37:53 am	10:46:22 am	
0aa5	R1V1R1V2PA	Closed			10:40:53 am	10:49:22 am	
3310	Chocolate1	NonConforming			10:40:53 am	10:49:22 am	gcs1
7a8e	R1V1R1V2PB	Accepted			10:43:53 am	10:52:22 am	
6a44	R1V1R1V2PC	Accepted			10:46:53 am	10:55:22 am	
4683	R1V1R1V2PD	Accepted			10:49:53 am	10:58:22 am	
89d0	R1V1R1V2PE	Accepted			10:52:53 am	11:01:22 am	
1f1e	R1V1R1V2PF	Accepted			10:55:53 am	11:04:22 am	
d5c0	R1V1R1V2PI	Accepted			10:58:53 am	11:07:22 am	
f080	R1V1R1V2PJ	Accepted			11:01:53 am	11:10:22 am	
8285	R1V1R1V2PK	Accepted			11:04:53 am	11:13:22 am	
306b	R1V1R1V2PL	Accepted			11:07:53 am	11:16:22 am	
0594	R1V1R1V2PM	Accepted			11:10:53 am	11:19:22 am	
ee0a	R1V1R1V2PN	Accepted			11:13:53 am	11:22:22 am	
a75e	R1V1R1V2PO	Accepted			11:16:53 am	11:25:22 am	
3278	R1V1R1V2PP	Accepted			11:19:53 am	11:28:22 am	
d3d4	R1V1R1V2PQ	Accepted			11:22:53 am	11:31:22 am	
c5ee	R1V1R1V2PR	Accepted			11:25:53 am	11:34:22 am	
6d35	R1V1R1V2PS	Accepted			11:28:53 am	11:37:22 am	
d4c9	R1V1R1V2PT	Accepted			11:31:53 am	11:40:22 am	

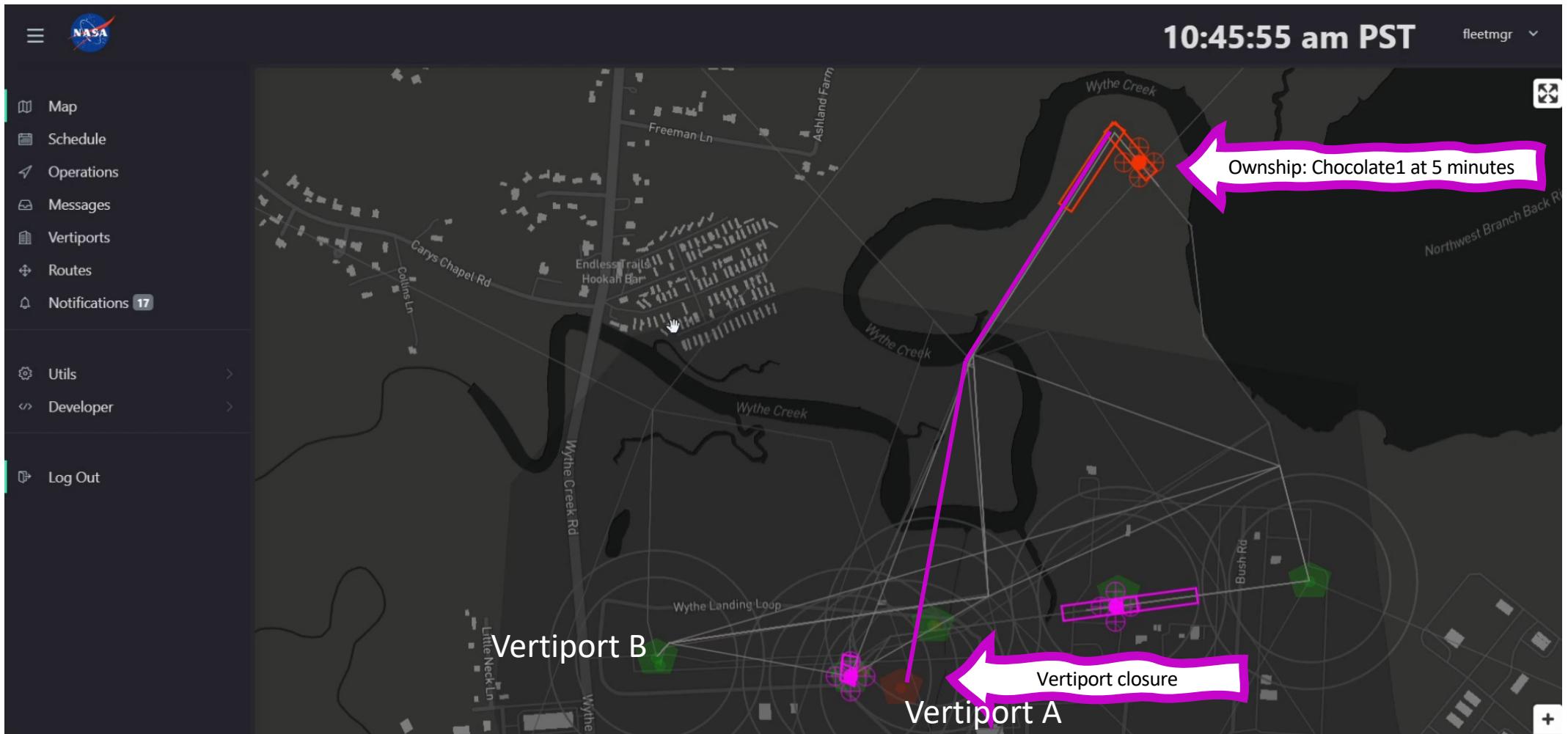


3. GCSO and FMI monitor the airspace





4. Vertiport Closure





5. Trial Planner is activated, and route options were presented

10:46:20 am PST fleetmgr

Operations

#	id	created	updated	expires	destination	status	duration	distance	casualty	terrain	weather	control
3	758f	10:45:47 am	10:45:47 am	10:47:16 am	Linus	Proposed	3:15	1.72 km	40	5	60	submit reject
2	5450	10:45:47 am	10:45:47 am	10:47:16 am	Linus	Proposed	** 3:15	1.71 km	50	5	50	submit reject
1	0649	10:45:47 am	10:45:47 am	10:47:16 am	Linus	Proposed	3:22	** 1.71 km	60	5	40	submit reject

[Stop Trial Planning](#) [Invoke Trial Planning](#)

Messages

Volume Info

Trial Planning

Json Tree

Raw Json

Map

Schedule

Operations

Messages

Vertiports

Routes

Notifications 18

Utils

Developer

Log Out



Route options

*not actually displayed on map





Route	Ground Risk	Terrain	Weather
A	40	5	60
B	60	5	40
C	50	5	50

*Factor values were notional



Route Decision Factors: Distance, Ground Risk (Casualty), Terrain, Weather

10:46:20 am PST fleetmgr

Operations

#	id	created	updated	expires	destination	status	duration	distance	casualty	terrain	weather	control
3	758f	10:45:47 am	10:45:47 am	10:47:16 am	Linus	Proposed	3:15	1.72 km	40	5	60	submit reject
2	5450	10:45:47 am	10:45:47 am	10:47:16 am	Linus	Proposed	** 3:15	1.71 km	50	5	50	submit reject
1	0649	10:45:47 am	10:45:47 am	10:47:16 am	Linus	Proposed	3:22	** 1.71 km	60	5	40	submit reject

Stop Trial Planning [Invoke Trial Planning](#)

Messages **Volume Info** **Trial Planning** **Json Tree** **Raw Json**

Operations

#	gufi	callsign	state	op mod	control	start time	end time	pilot	route id	departure	destination	created	updated	
▶	f93b	R1V1R1V2PG	Closed			cancel connect activate close download plan	10:34:53 am	10:43:22 am		Route-129	Range 1	Range 1	8-05-22 10:32:52 am	8-05-22 10
▶	9129	R1V1R1V2PH	Activated	⚠		cancel connect activate close download plan	10:37:53 am	10:46:22 am		Route-129	Range 1	Range 1	8-05-22 10:33:09 am	8-05-22 10
▶	0aa5	R1V1R1V2PA	Closed			cancel connect activate close download plan	10:40:53 am	10:49:22 am		Route-129	Range 1	Range 1	8-05-22 10:33:28 am	8-05-22 10
▼	3310	Chocolate1	Contingent	⚠		cancel connect activate close download plan	10:40:53 am	10:49:22 am	gcs1	Route-130	Range 1	Range 1	8-05-22 10:35:04 am	8-05-22 10
▶	7a8e	R1V1R1V2PB	Activated	⚠		cancel connect activate close download plan	10:43:53 am	10:52:22 am		Route-129	Range 1	Range 1	8-05-22 10:33:45 am	8-05-22 10
▶	6a44	R1V1R1V2PC	Accepted			cancel connect activate close download plan	10:46:53 am	10:55:22 am		Route-129	Range 1	Range 1	8-05-22 10:34:03 am	8-05-22 10
▶	4683	R1V1R1V2PD	Accepted			cancel connect activate close download plan	10:49:53 am	10:58:22 am		Route-129	Range 1	Range 1	8-05-22 10:34:21 am	8-05-22 10
▶	89d0	R1V1R1V2PE	Accepted			cancel connect activate close download plan	10:52:53 am	11:01:22 am		Route-129	Range 1	Range 1	8-05-22 10:34:40 am	8-05-22 10
▶	1f1e	R1V1R1V2PF	Accepted			cancel connect activate close download plan	10:55:53 am	11:04:22 am		Route-129	Range 1	Range 1	8-05-22 10:34:57 am	8-05-22 10
▶	d5c0	R1V1R1V2PI	Accepted			cancel connect activate close download plan	10:58:53 am	11:07:22 am		Route-129	Range 1	Range 1	8-05-22 10:35:15 am	8-05-22 10
▶	f080	R1V1R1V2PJ	Accepted			cancel connect activate close download plan	11:01:53 am	11:10:22 am		Route-129	Range 1	Range 1	8-05-22 10:35:33 am	8-05-22 10
▶	8285	R1V1R1V2PK	Accepted			cancel connect activate close download plan	11:04:53 am	11:13:22 am		Route-129	Range 1	Range 1	8-05-22 10:35:51 am	8-05-22 10
▶	306b	R1V1R1V2PL	Accepted			cancel connect activate close download plan	11:07:53 am	11:16:22 am		Route-129	Range 1	Range 1	8-05-22 10:36:09 am	8-05-22 10



7. Trial Planner is activated, and a new reroute is selected

10:46:20 am PST

fleetmgr

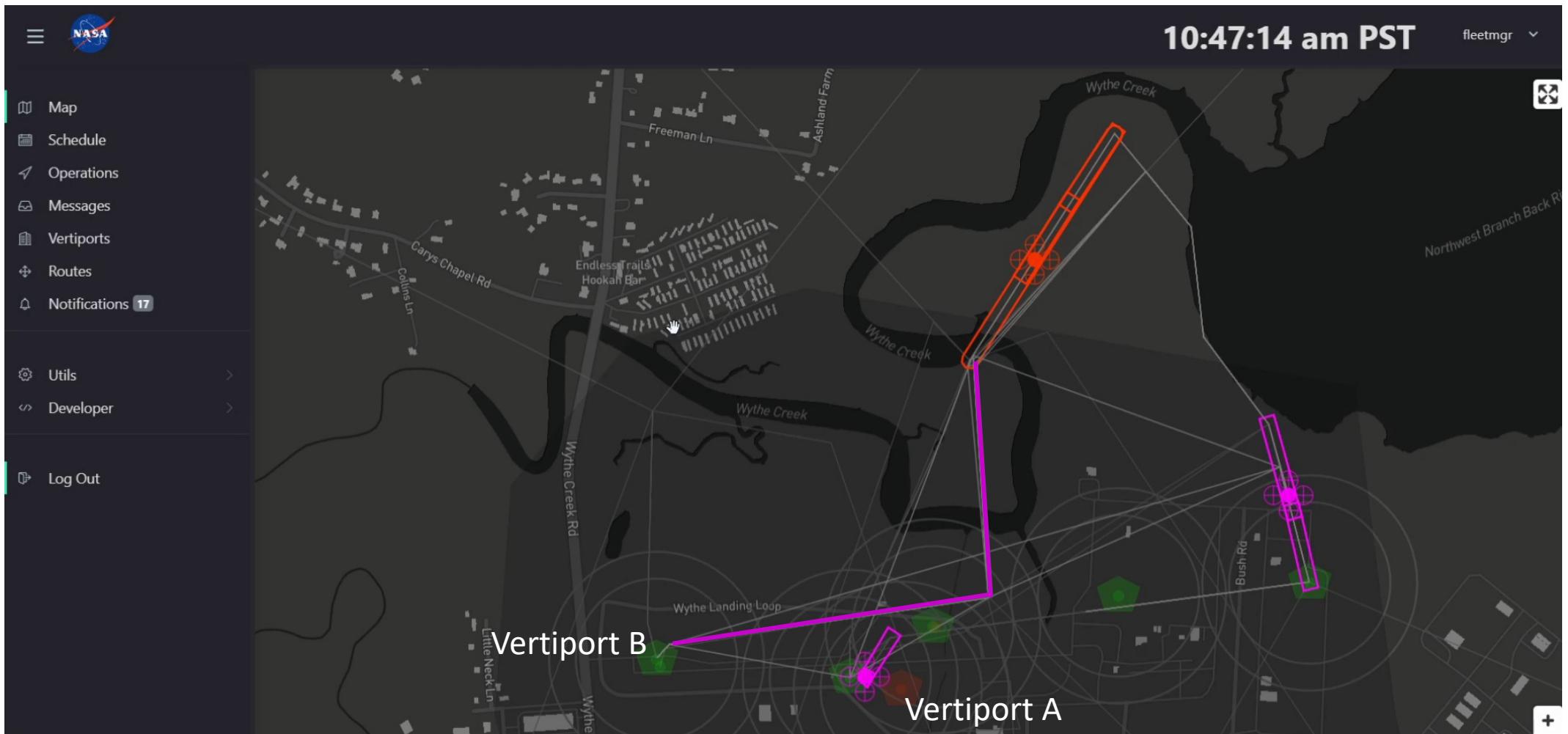
Operations

#	id	created	updated	expires	destination	status	duration	distance	casualty	terrain	weather	control
3	758f	10:45:47 am	10:45:47 am	10:47:16 am	Linus	Proposed	3:15	1.72 km	40	5	60	submit reject
2	5450	10:45:47 am	10:45:47 am	10:47:16 am	Linus	Proposed	** 3:15	1.71 km	50	5	50	submit reject
1	0649	10:45:47 am	10:45:47 am	10:47:16 am	Linus	Proposed	3:22	** 1.71 km	60	5	40	submit reject

Route selection button



8. Flight crew reviewed and executed new route



Evaluation

Purpose: Evaluate the quality of the interaction with the trial planner

Goals:

- Collect human factors data on workload, situation awareness, and trust in automation
- Improve the FMI software through usability data collected

Participants:

- 3 air traffic control SMEs at NASA Ames
- 6 pilots at NASA Langley





Testing Schedule

- 1 hour training session with the fleet manager workstation
- 3 FM participants ran 3, 30 minute runs every day for 4 days, for a total of 12 runs
- 20 minutes for the scenario, 10 minutes for the questionnaire
- Run example:
 1. Pilot performs preflight checklist
 2. FM confirms FMI connectivity
 3. Pilot commands takeoff
 4. Pilot and fleet manager monitored the airspace
 5. Scenario Types:
 - A. Scenario 1: Nominal automated landing occurred at scheduled vertiport
 - B. Scenario 2: Original vertiport closes, and diverted route created through use of the trial planner and automated landing at an unscheduled alternate vertiport

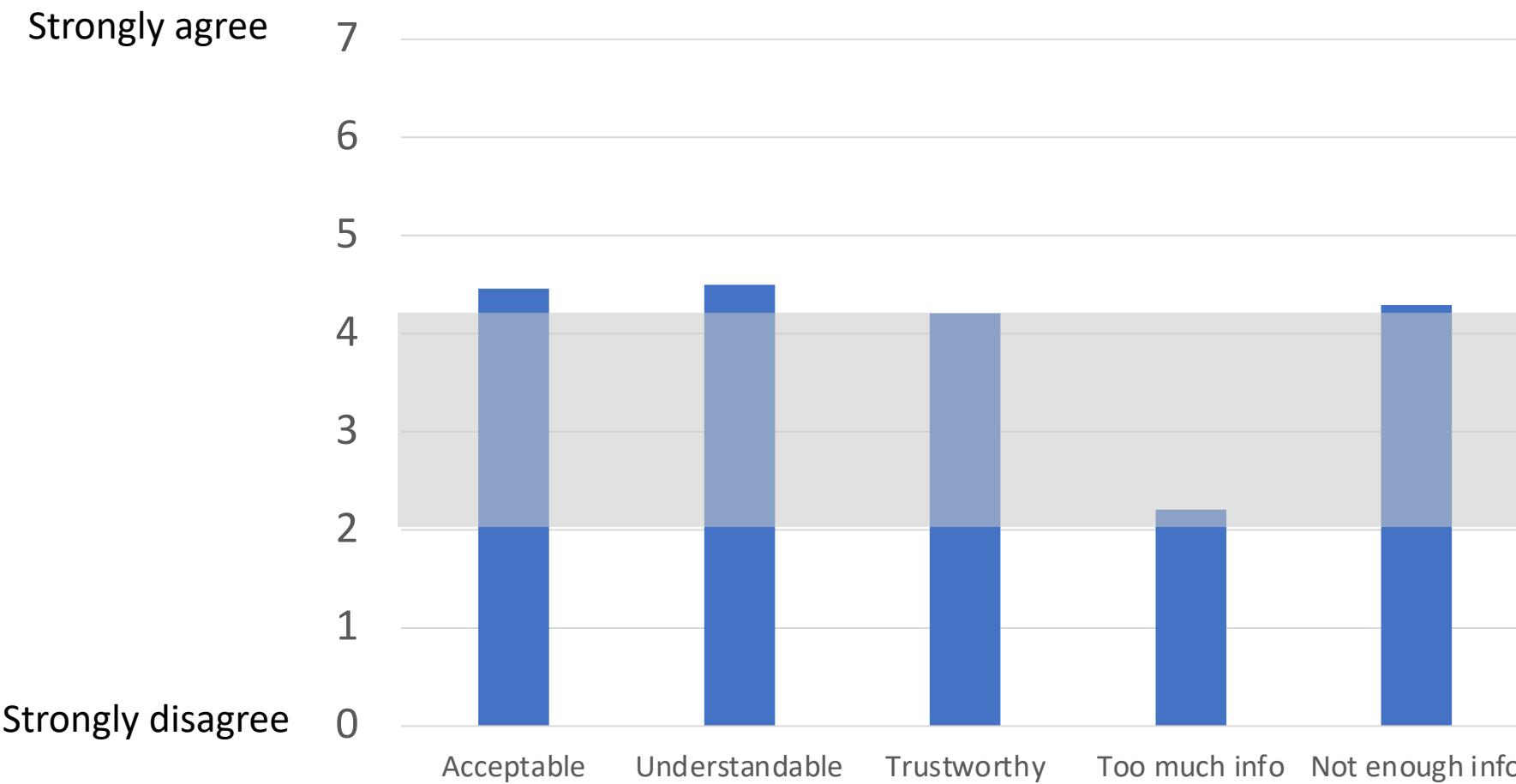


Metrics

1. The trial-planner solutions were acceptable.
2. The trial-planner solutions were understandable.
3. The trial-planner solutions were trustworthy.
4. The trial-planner displayed too much information.
5. The trial-planner did not display enough information.



Results: Average Ratings Evaluation Scales





Limitations

- Route selection was mandated
- Not enough time to select and execute routes
- Selected routes were not displayed visually
- Route selection factors were not visually displayed
- Quality of decision-making was not evaluated



Future Work: Trial Planner Version 2023

- Engage trial planner over a map display
- Highlight route selections over the map
- Show relevant decision factors over the map
- Employ decision making metrics in evaluation
- Explore different scenarios
 - Longer operations over SF/Bay Area and Norfolk, VA *to add variation to the decision factors
 - Missed approach routes



Backup

Methods (Continued)

- Video and audio recordings
- 9 unique subjective questionnaires across 12 runs
 - NASA-TLX [7]
 - Situation Awareness Rating Technique (SART) [10]
 - Perceived Risk [12]
 - Human-Automation Trust [8]
 - Trial Planner UX Survey
 - Post-Scenario review

END OF DAY

- Human-Automation Trust [8] (again)
- Post Study System Usability Questionnaire [9]
- Safety and Risk Perceptions of Automation [3]
- FMI Usability Questionnaire

