



Evaluation of Initial and Mid-Term Air Traffic Procedures for Urban Air Mobility

Savvy Verma, Jillian Keeler, Richard Mogford, Megan Shyr, Gabriela Rosado, Rania Ghatas (NASA)

Amir Farrahi (USRA), Robert Wood (SimLabs)

Eric Mueller, Thomas Prevot, Christabelle Bosson (Joby Aviation)

Presented by Jillian Keeler

Integrate initial UAM operations into the current airspace and evolve the airspace environment for future scale

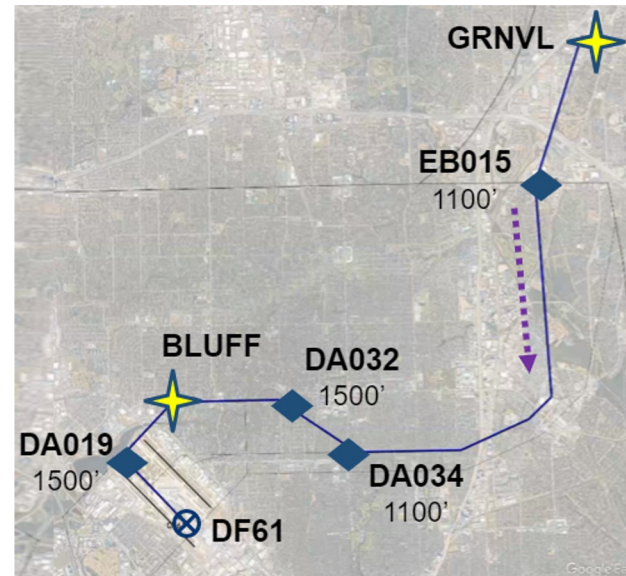
Challenge



Potential Solutions

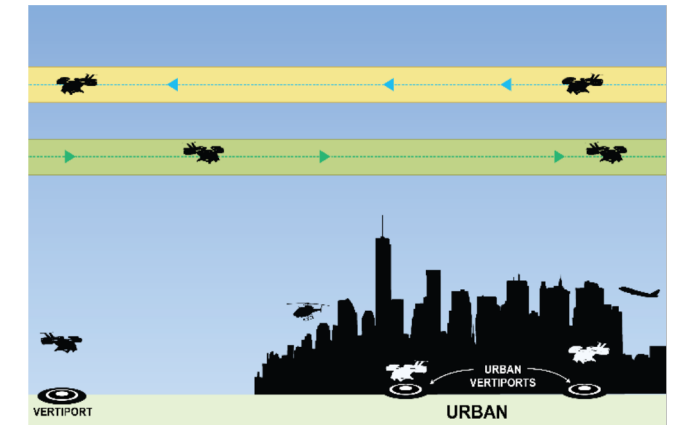


Current Day



Defined Routes that Streamline Communications

Mid-Term to Long-Term



Corridors with Third-Party Service Providers

- Early work focused on investigating the potential of airspace around Dallas-Fort Worth (DFW) for initial UAM operations
 - Included modified set of procedures defined in a Letter of Agreement (LOA)
 - Allowed for higher level of throughput than current day procedures and reduced communications workload
- Continued analysis of airspace to develop corridor designs in DFW area



- Develop and evaluate notional air traffic controller (ATC) and UAM pilot procedures for Initial and Mid-term UAM operations in the Dallas area
 - Communications (voice and digital)
 - Scalability and feasibility (throughput and workload)
 - Information requirements



APPROACH

Dallas Love Field Tower



Facility Model



Dallas Fort-Worth Tower



Pilots



Air Traffic Controllers (Participants)



Pilots



Air Traffic Control Subject Matter Experts



NASA Researchers



NASA Simulation Engineers



Joby Airspace Operations





UAM Traffic Density	Experimental Conditions	
	Initial Operations	Mid-Term Operations
Low	A	C
High	B	D

*40 min scenarios



Approach: Experimental Assumptions



	UAM Operations	
	Initial Operations	Mid-Term Operations
Crew	On board pilot	
Operating Conditions	VFR operations in VMC	
Airport Configuration	DFW and DAL in South Flow	
Operations	Nominal Operations and Unconstrained vertiport capacity	
Separation	ATC/Pilot	Operator/Pilot inside new airspace structures
Radar Acquisition	Pre-Assigned Beacon codes as per the LOA	Pre-Programmed ADS-B
Airspace Structure	Current-Day	New Airspace Structure (e.g., Corridors)
Automation	Current-Day	Automation Functions Assumed (Strategic and Tactical)
Procedures	LOA-defined Procedures	No verbal clearance from ATC to enter corridor



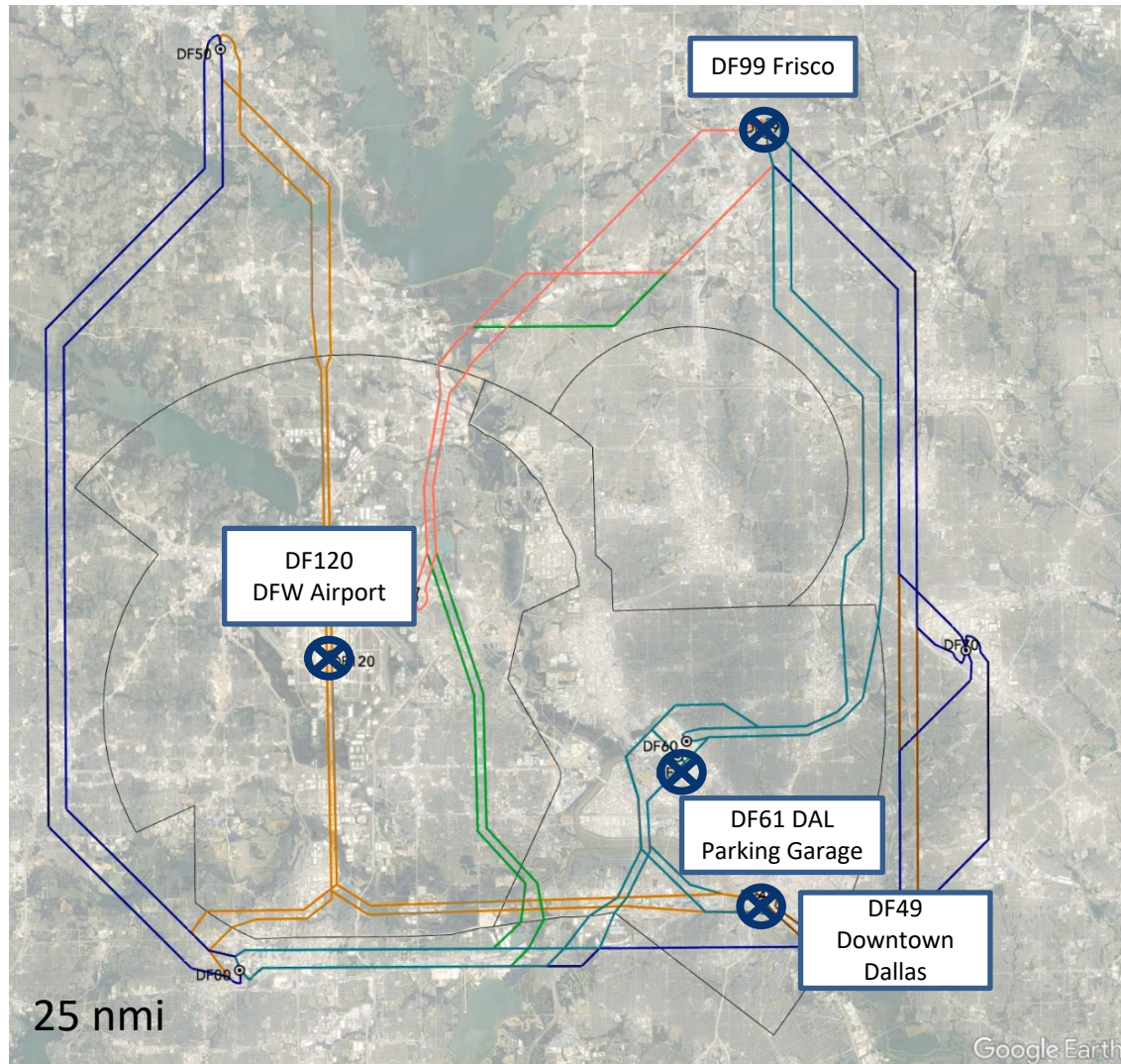
Approach: Controller Positions



Rotate positions	DAL	Traffic Handled
	Local controller (DAL)*	13L and 13R
	Helo (DAL)*	UAM traffic / helicopter traffic (VFR)
Rotate positions	DFW	Traffic Handled
	Local East-1 (DFW) *	17C and 17R
	DFW Helo (DFW) *	UAM traffic / helicopter traffic (VFR)
	Local East-3 (confederate)	17L traffic

VFR = Visual Flight Rules

* Data collected for these positions



Initial Operations: Routes



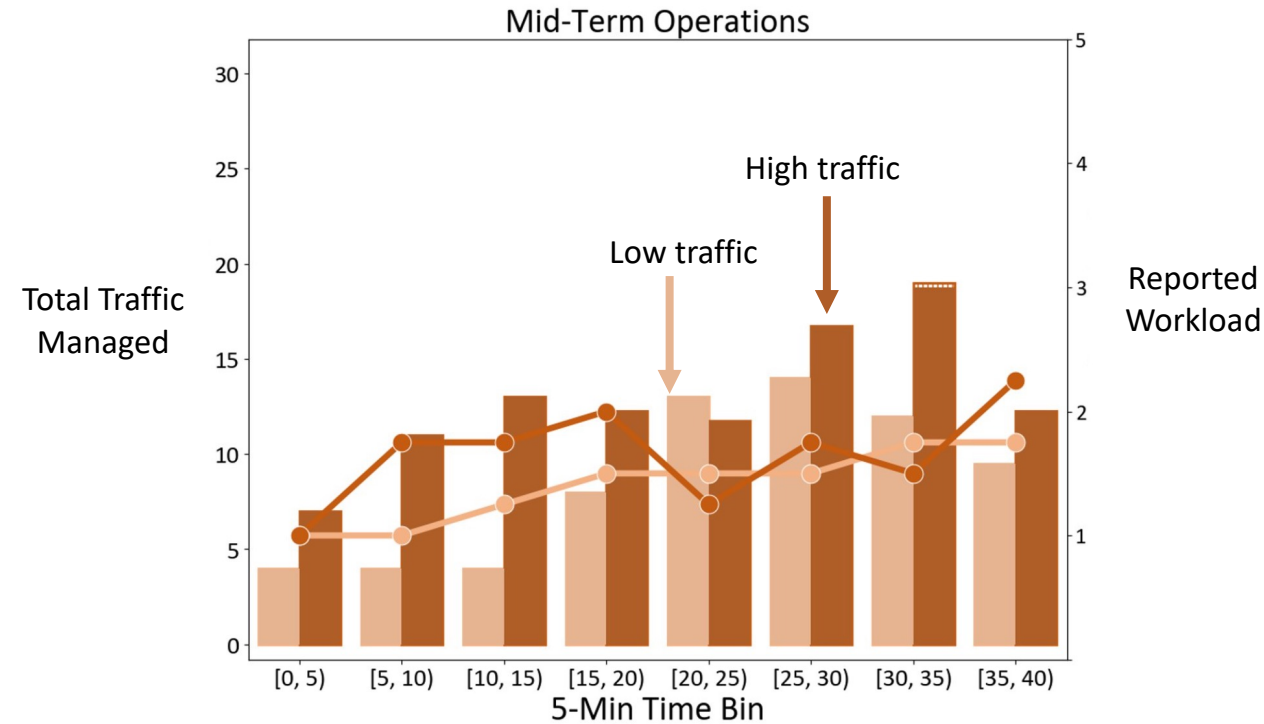
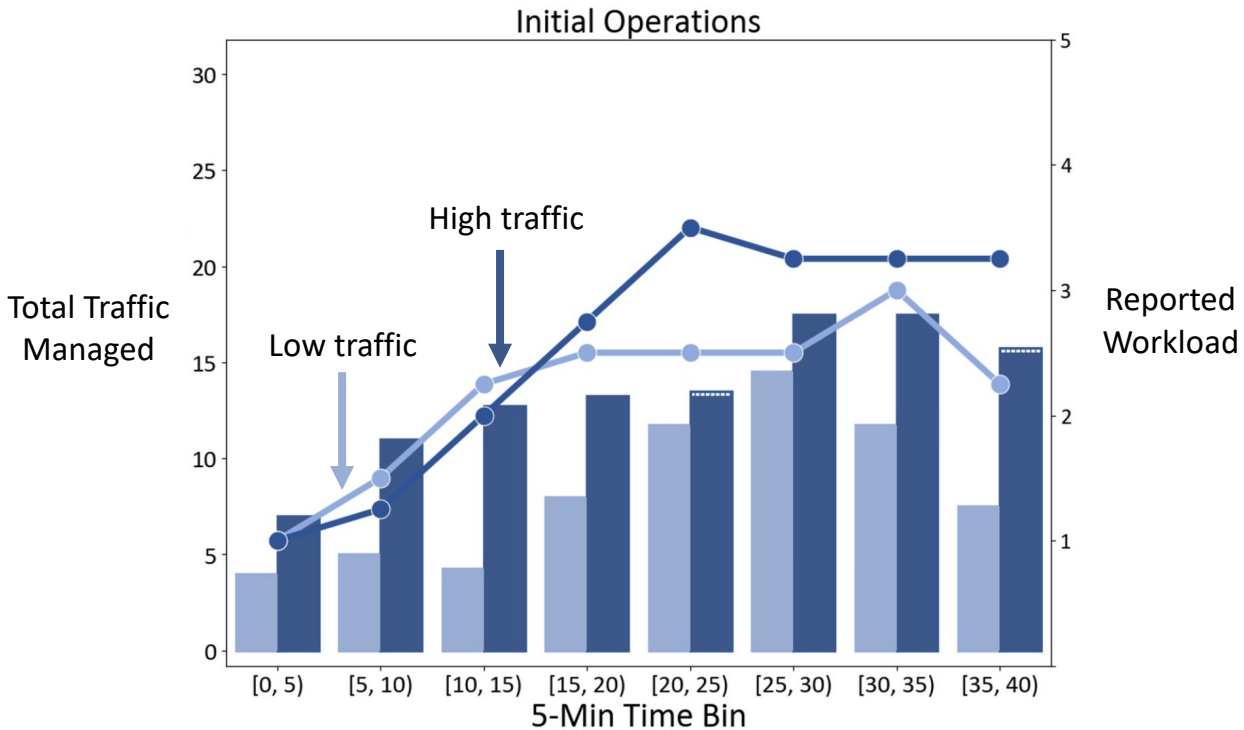
Mid-term Operations: Corridors



DAL RESULTS

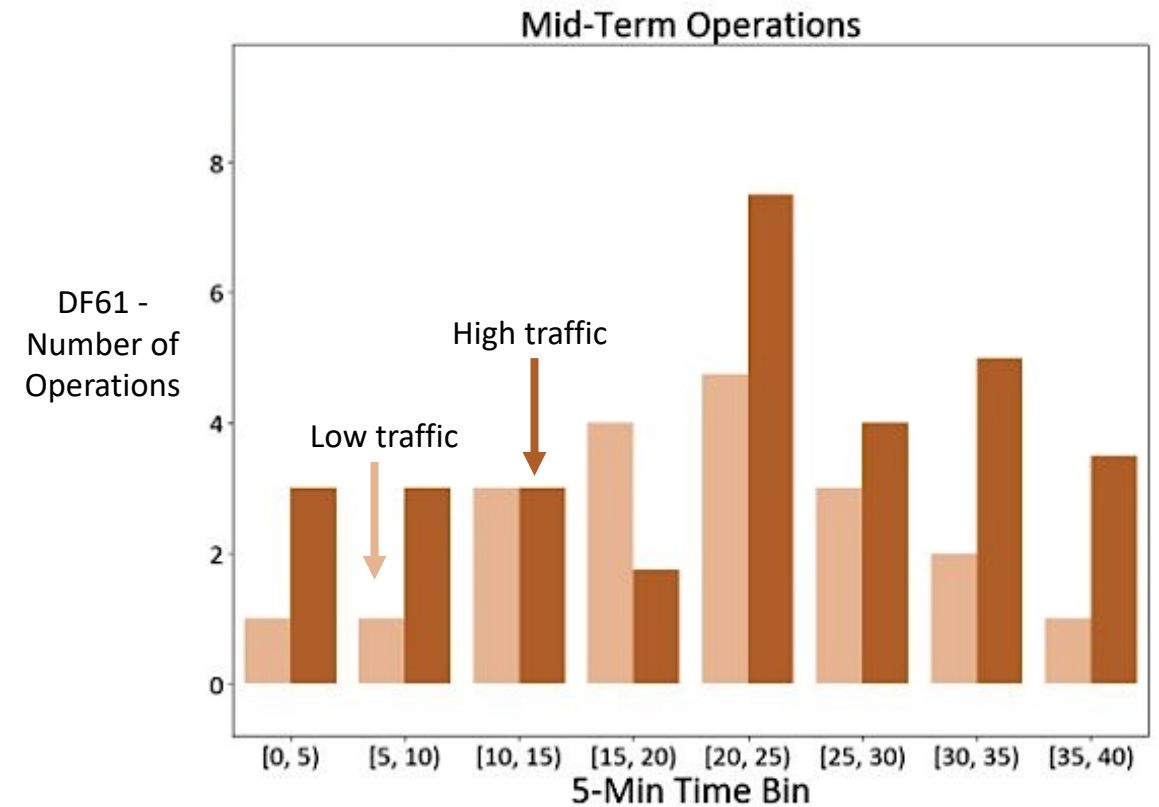
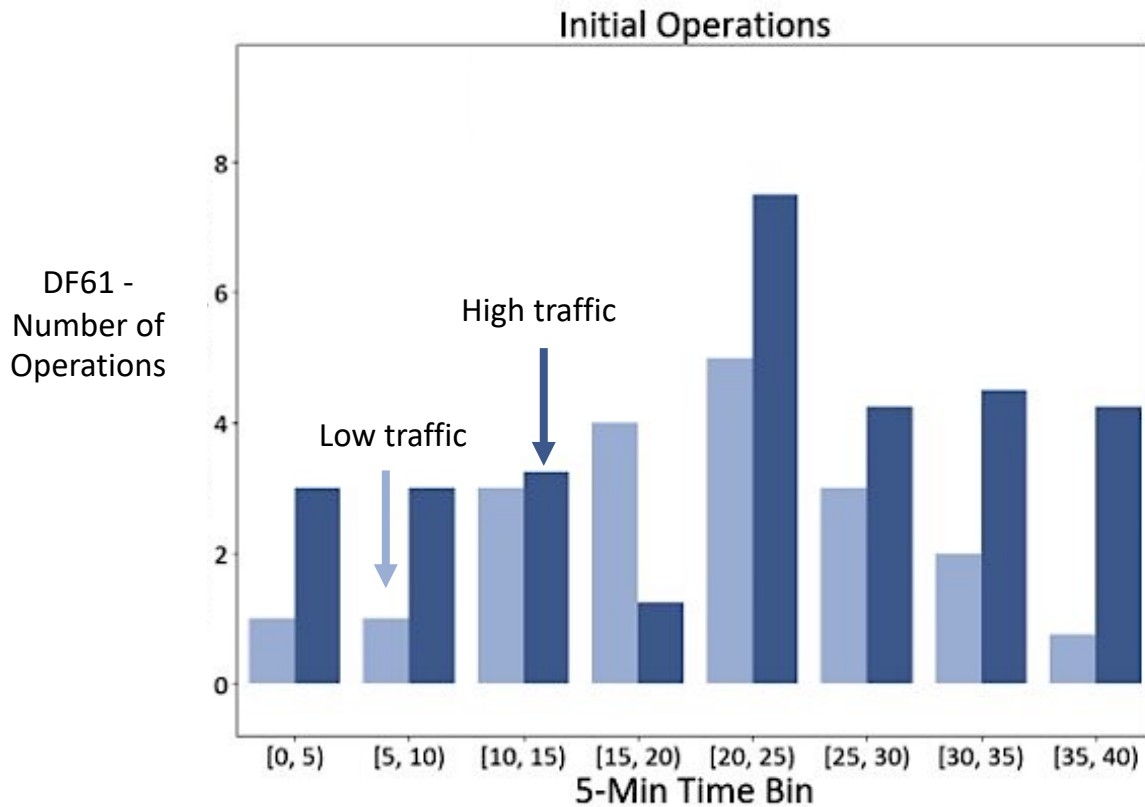


Results: DAL Helo Total UAM Traffic Managed Inside CBA and Reported Workload



$N = 2$

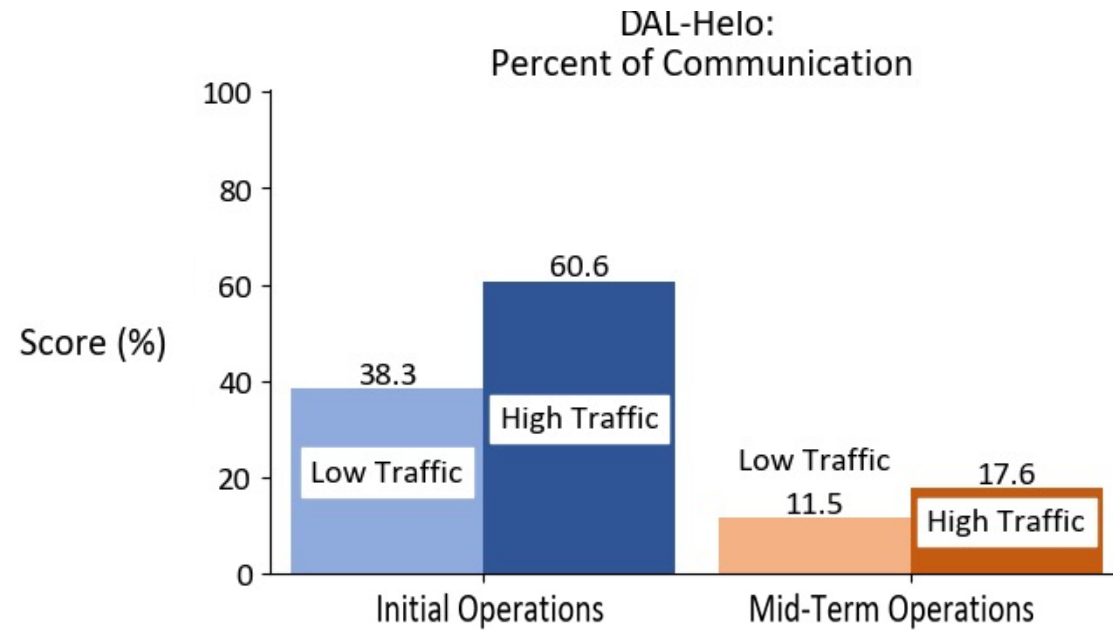
- Handled the same level of traffic under both Initial and Mid-term conditions
- Reported workload was lower under the low traffic condition vs. high traffic condition for Initial operations
- Reported workload was lower in the Mid-term vs. Initial operations, but generally was acceptable (under 3.5) for all conditions



The peak number of UAMs arriving at DAL parking garage is 5-8 in a five min period depending on traffic levels.



Results: DAL Helo Percentage of Verbal Communications



$N = 2$

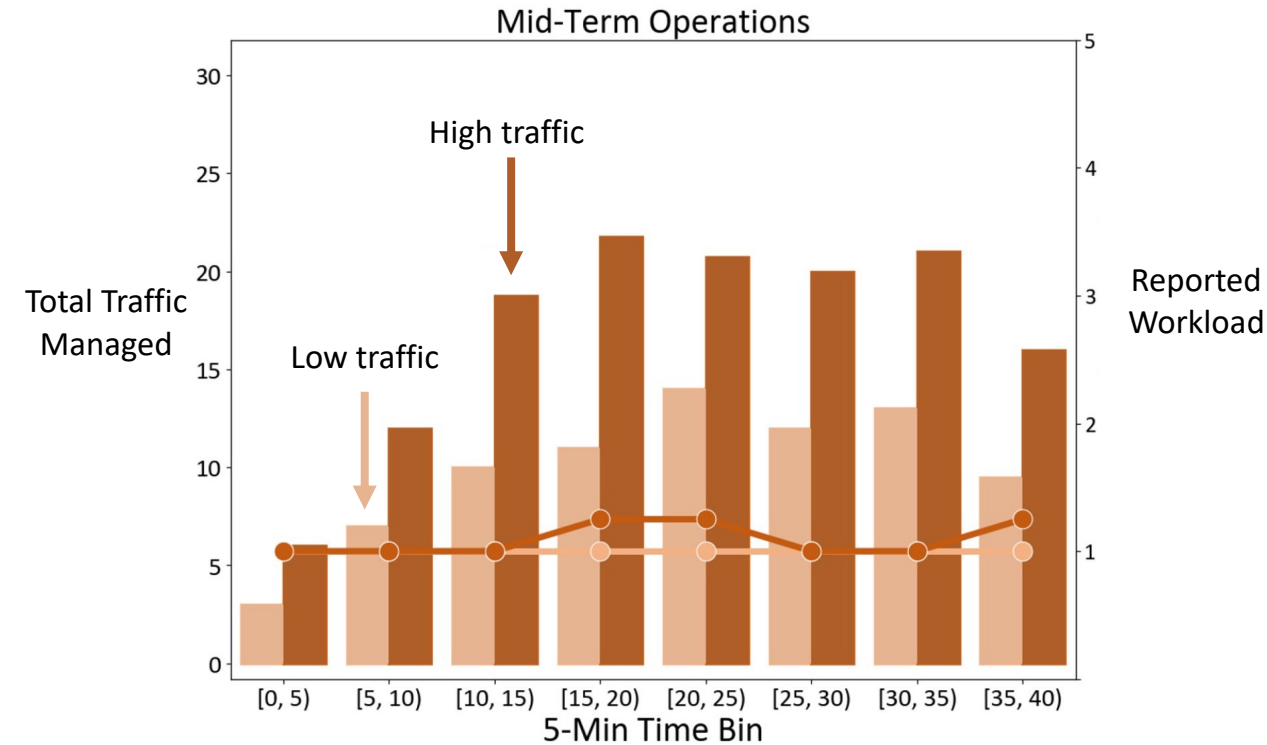
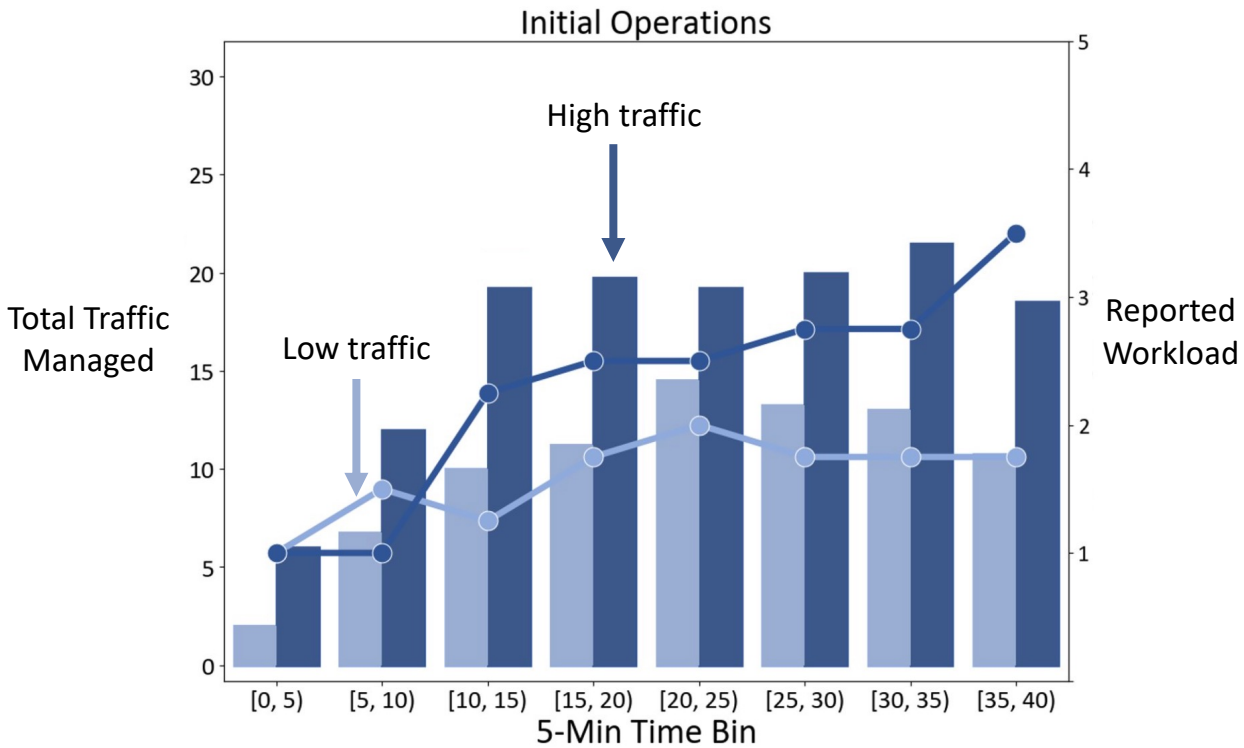
DAL Helo percentage of verbal communications dropped substantially during Mid-term operations.



DFW RESULTS

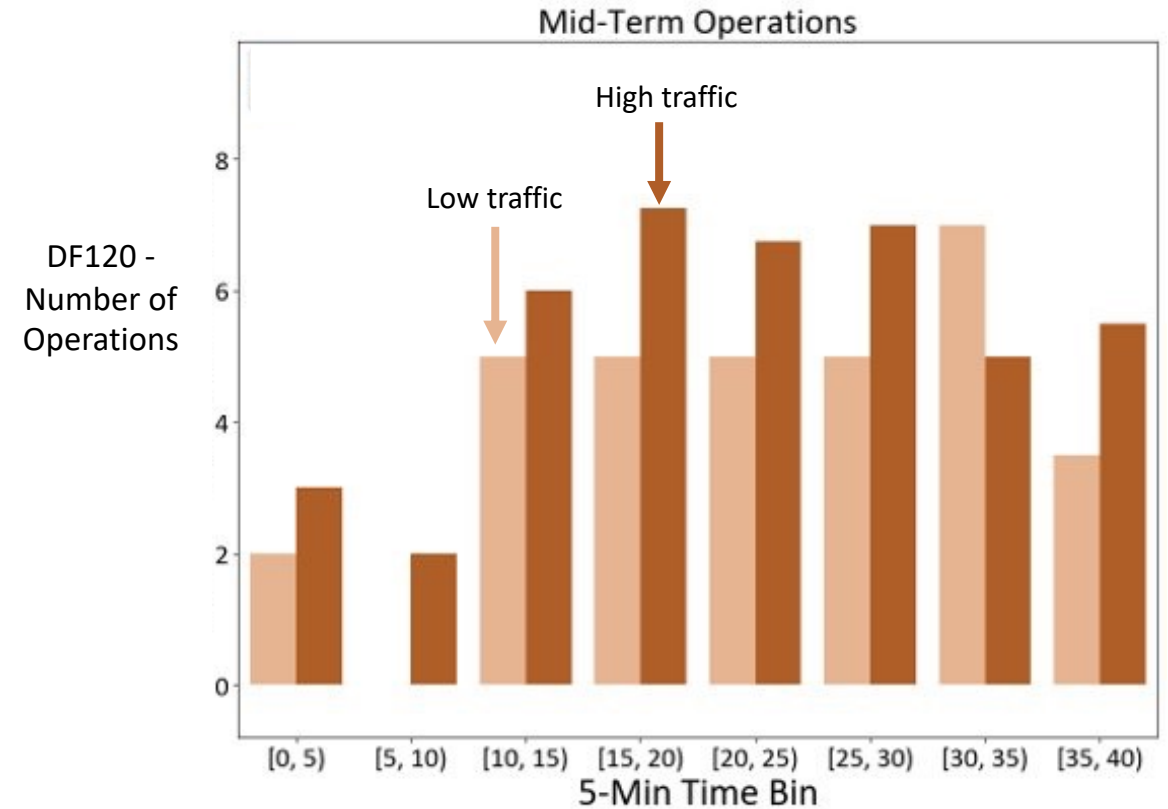
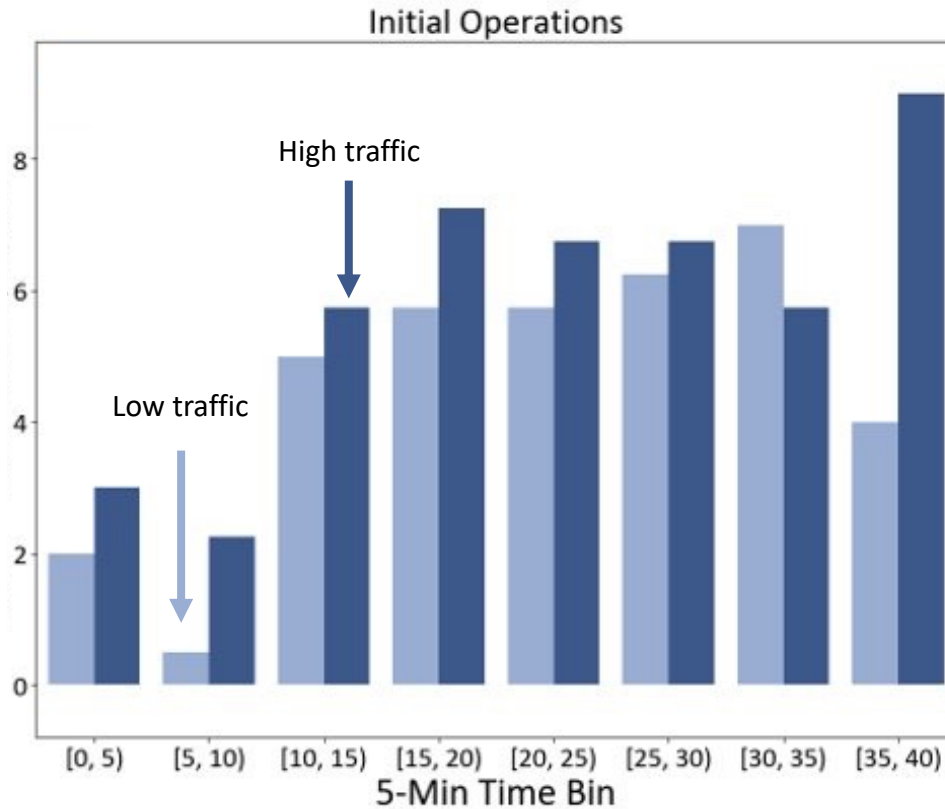


Results: DFW Helo Total UAM Traffic Managed Inside CBA and Reported Workload



$N = 2$

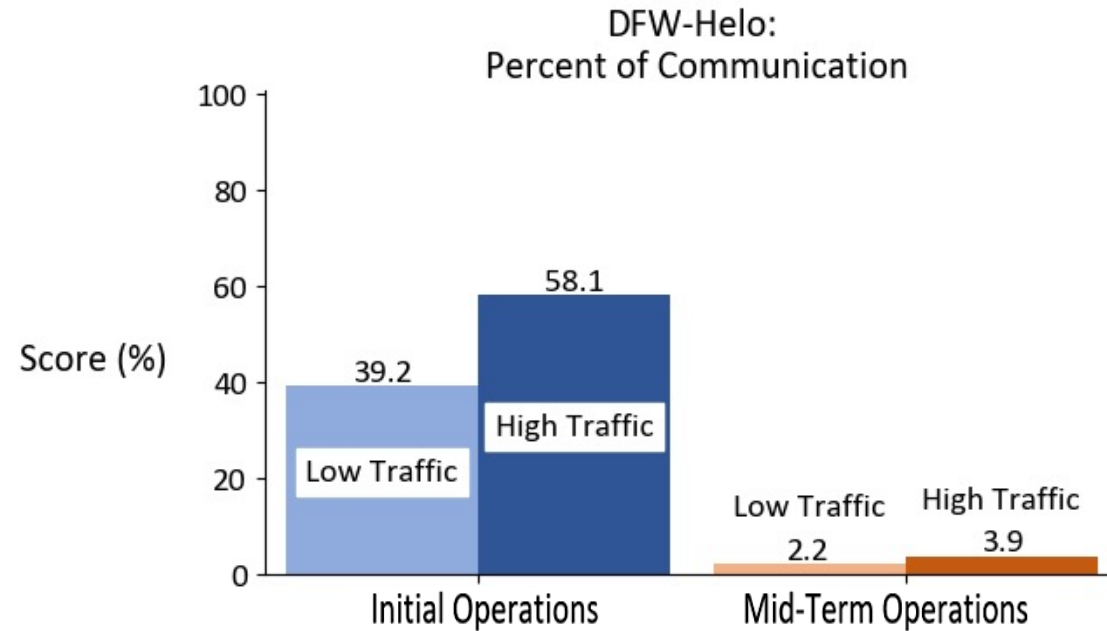
- Handled approximately the same level of traffic under both Initial and Mid-term operations
- Workload reported by DFW Helo is lower in the Mid-term vs. Initial operations but acceptable in all conditions (below 3)



The peak number of operations in 5 min period ranges from 7-9 in the Initial operations condition.



Results: DFW Helo Percentage of Verbal Communications



$N = 2$

DFW Helo percentage of verbal communications dropped substantially during Mid-term operations.



Results: Average Number of UAM Operations by Vertiport



		DAL Parking Garage	DFW Central Terminal
	UAM Traffic level	Avg No. of operations over 40 min	
Initial Operations	Low	16	29
	High	26	37
Mid-Term Operations	Low	16	30
	High	27	37

- DAL Parking Garage UAM throughput ranged from 24 to 40 operations per hour (extrapolated)
- DFW Central Terminal UAM throughput ranged from 43 to 55 operations per hour (extrapolated)



SUMMARY



- Procedures, routes, and letter of agreements made operations in the Initial term feasible
- New airspace structures and technologies allowed controllers to have spare capacity shown by lowered workload
- UAM operations that required crossing runways at DAL required more interaction with ATM environment
 - Peak rate over 5 min: 5-8 operations
 - Hourly rate: 24-40 operations /hr
 - Communication reduction: 60% to 20% (initial vs. Mid term)
- UAM operations that flew parallel legacy traffic at DFW and stayed in the UAM Corridors
 - Peak rate over 5 min: 7-9 operations
 - Hourly rate: 43-55 operations /hr
 - Communication reduction: 60% to 3% (initial vs. Mid term)



- Explore procedures, information requirements for *off-nominal* UAM operations
- Explore third party service functionality and messaging among third party services to ATC, Fleet Operator, and pilot



Acknowledging the Village



Airspace Procedures Team

Savvy Verma
Rania Ghatas
Richard Mogford
Dan Wood
Megan Shyr
Gabriella Torres
Amir Farrahi
Jillian Keeler

Software Development Team

Alan Lee
Carla Ingram
David Shapiro
Wayne Bridges
Jacob Pfeiffer
Rod David
Matt Blanken
Marty Pethel
Jack (Chok) Lai
Hugh (Huu) Huynh
Phil (Phu) Huynh
Jeff Hernandez
Leonard Bagasol
Stephan Mueller
John Murphy
Adam Sorci
Jay Nguyen

Joby Team

Eric Mueller
Tom Prevot
Christabelle Bosson

Special Thanks

Kushal Moolchandani
Yoon Jung



QUESTIONS?

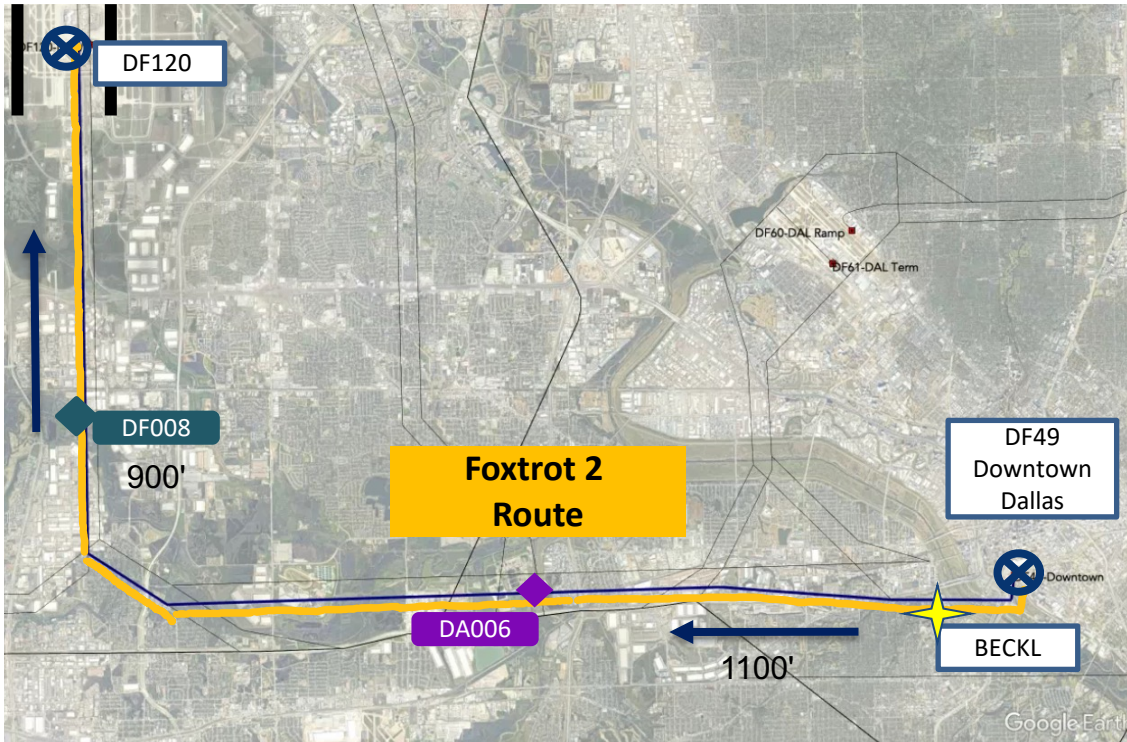
JILLIAN.N.KEELER@NASA.GOV

ERIC.R.MUELLER@JOBYAVIATION.COM

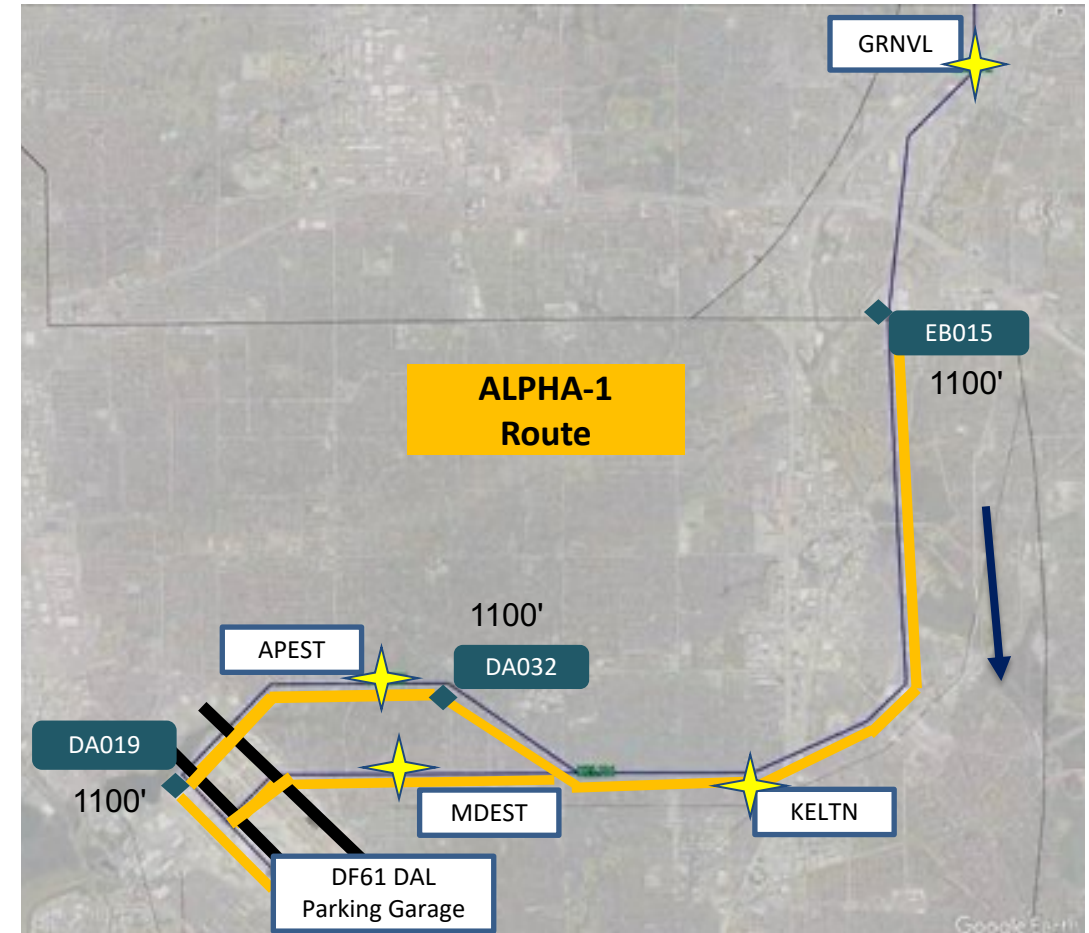


BACKUP

DFW Vertiport

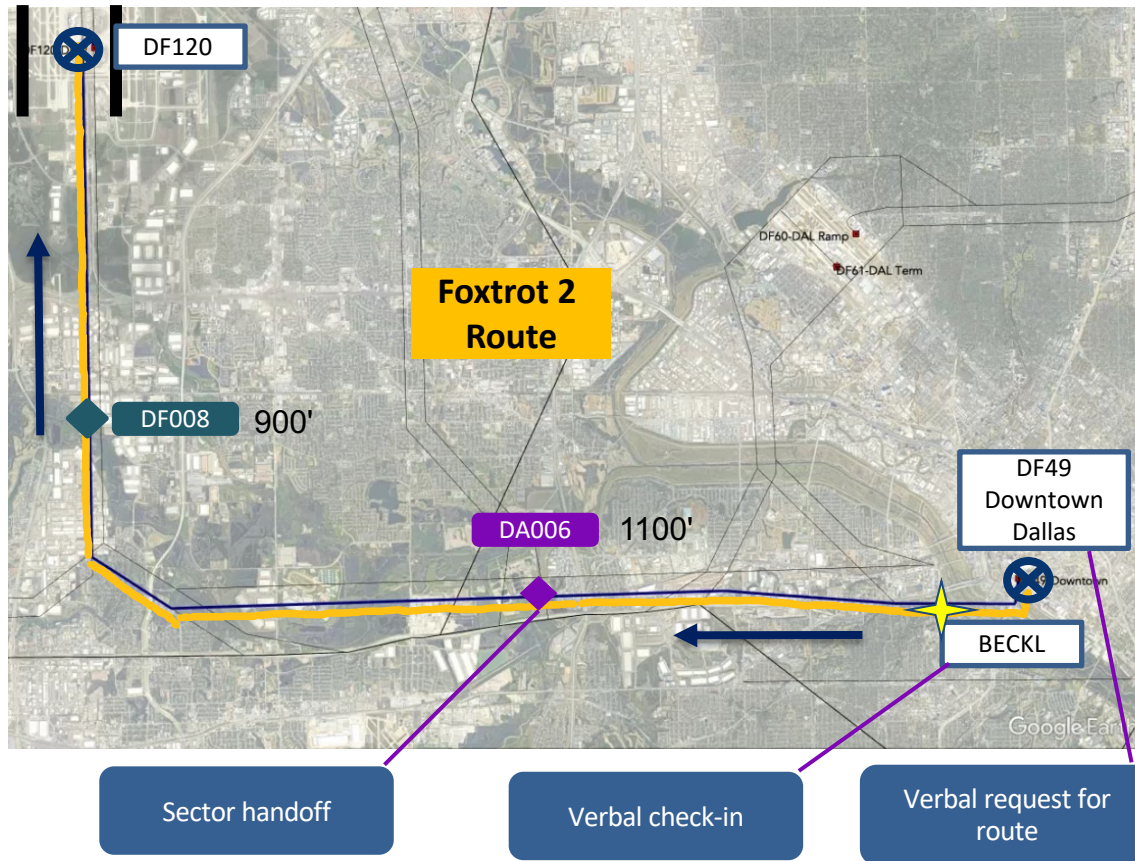


DAL Vertiport

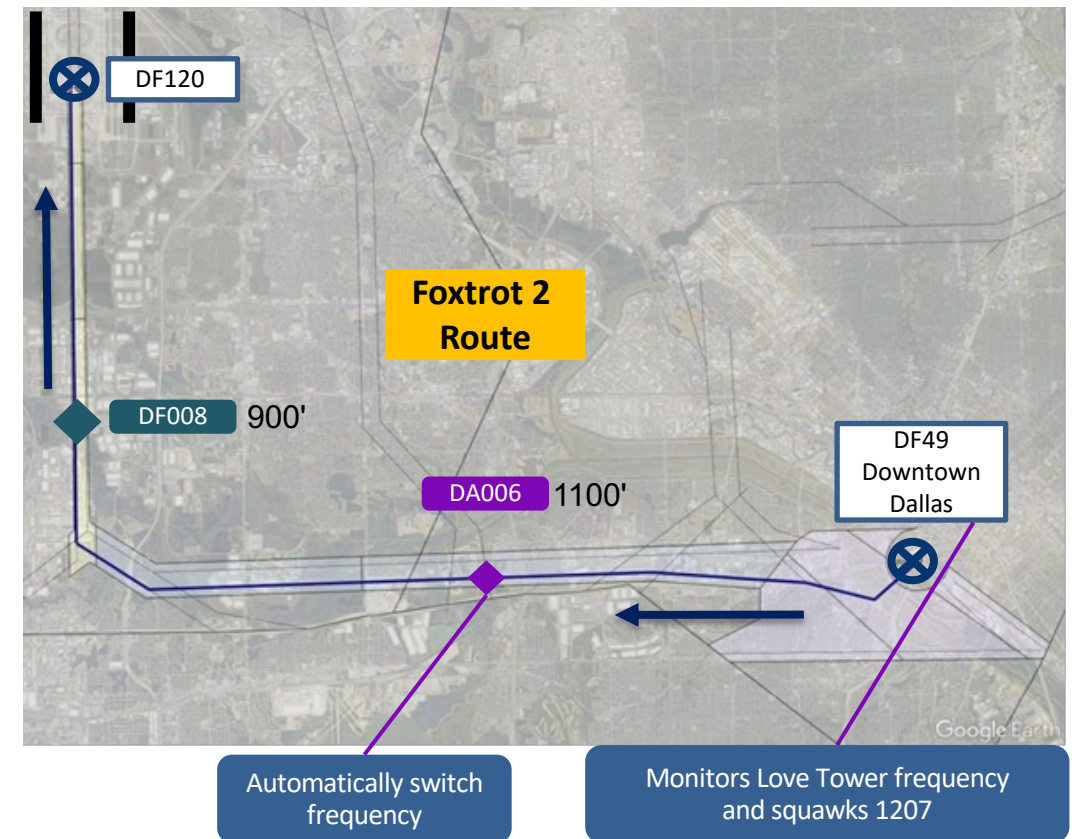


*Altitude in MSL

Initial Term Procedures

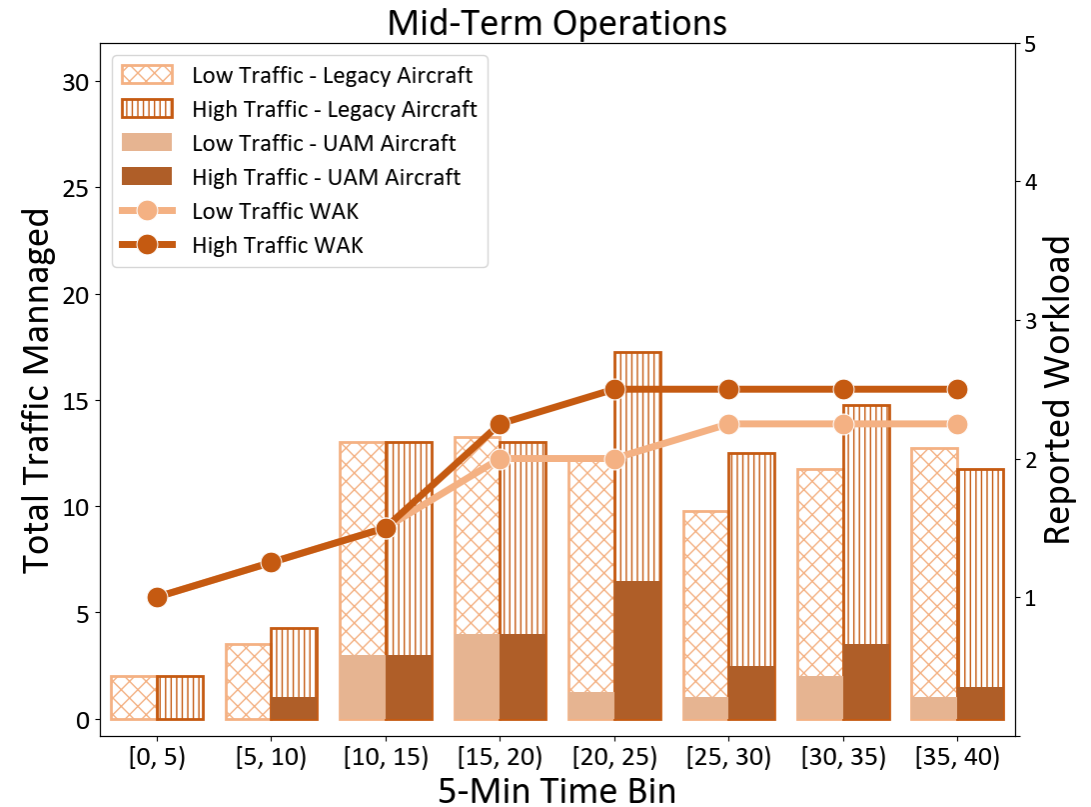
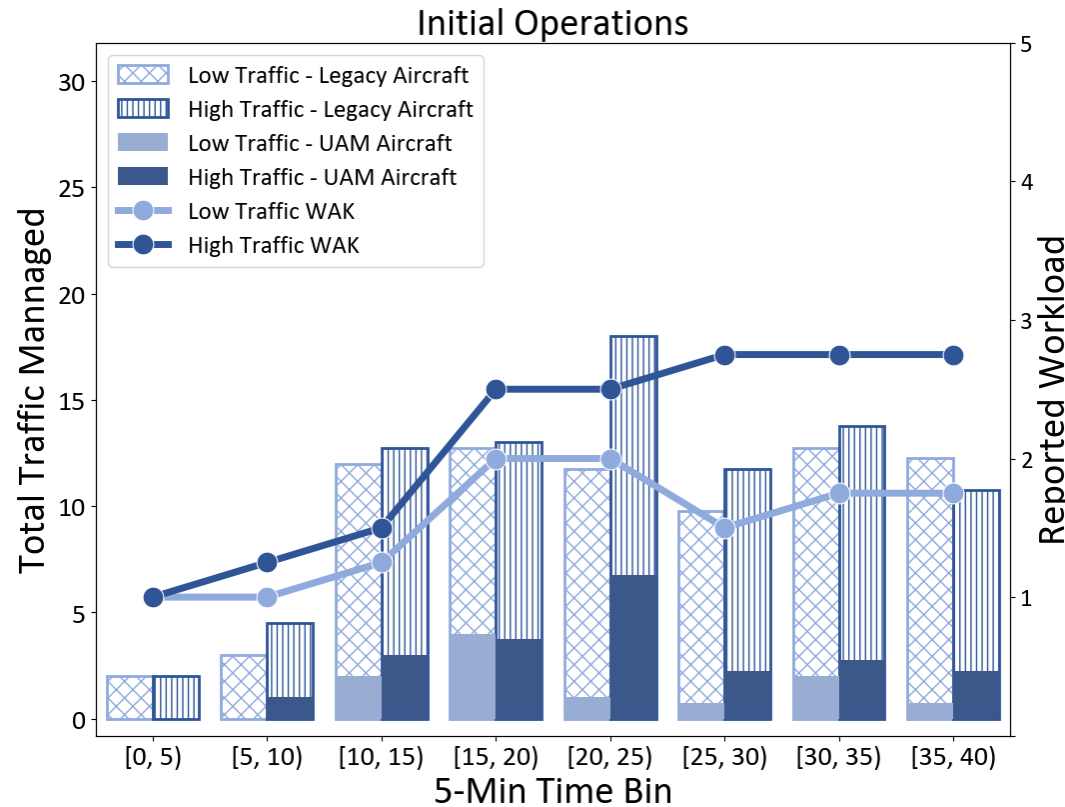


Mid-term Procedures





Results: DAL Local Total Traffic Managed Inside CBA and Reported Workload

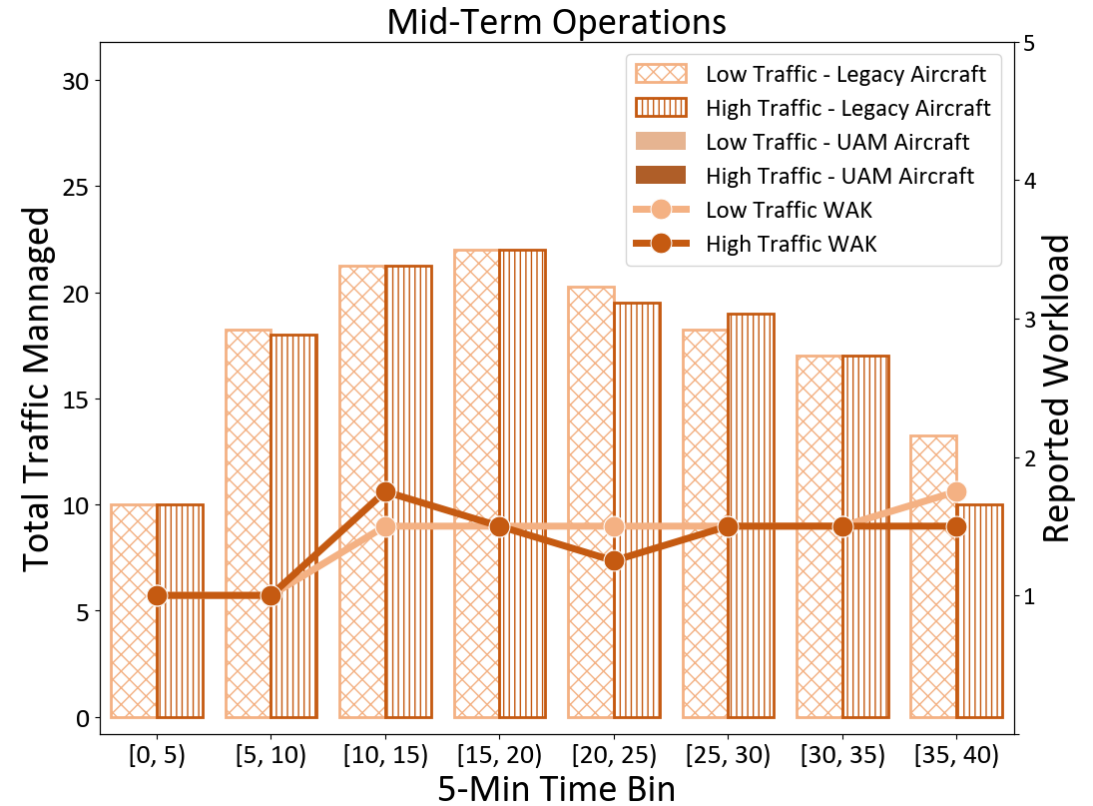
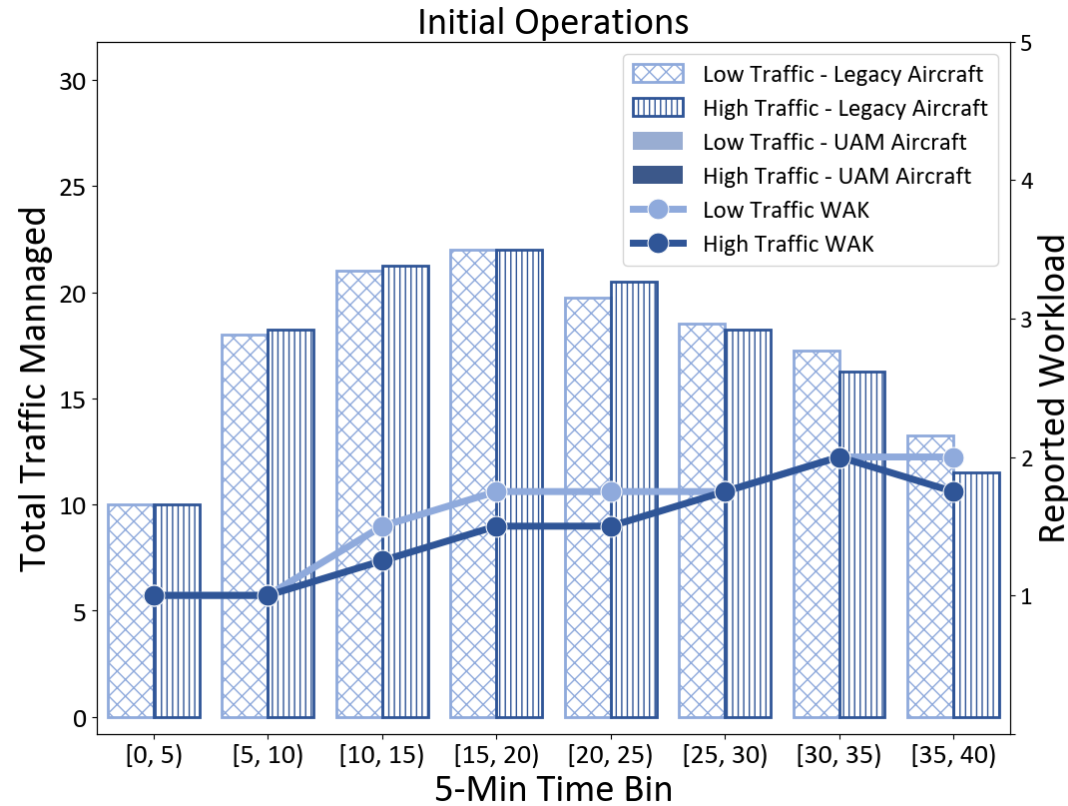


$N = 2$

- DAL Local position handled both legacy traffic and UAM arrivals
- Trends show that ATC managed same level of traffic under both Initial and Mid-term conditions
- Overall workload was similar between the Initial and Mid-term operations for this position
- Trends show that workload reported by DAL Local was acceptable (under 3) for all conditions



Results: DFW Local Total Traffic Managed Inside CBA and Reported Workload



$N = 2$

- DFW Local managed legacy traffic only
- No difference in level of traffic managed or workload reported between the two conditions



Traffic Scenarios



	Arrivals	Departures	Total
DFW Vertiports	25	21	46
DAL Vertiports	16	16	32
Dallas Downtown	19	15	34

Low UAM Traffic Scenario

	Arrivals	Departures	Total
DFW Vertiports	41	29	70
DAL Vertiports	28	26	54
Dallas Downtown	21	27	48

High UAM Traffic Scenario

	Arrivals	Departures	Total
DFW (17R, 17L, & 17C)	29	48	77
DFW (18R & 18L)	22	23	45
DAL (13R & 13L)	28	15	43

Background Legacy Traffic



Planned vs. Actual Operations



Low UAM Traffic Scenario

	Initial Operations							Mid-Term Operations					
	Arrivals		Departures		Total			Arrivals		Departures		Total	
	Planned	Actual	Planned	Actual	Planned	Actual		Planned	Actual	Planned	Actual	Planned	Actual
DFW Vertiports	25	13	21	17	46	30	DFW Vertiports	25	13	21	18	46	31
DAL Vertiports	16	11	16	13	32	24	DAL Vertiports	16	11	16	13	32	24
Dallas Downtown	19	10	15	13	34	23	Dallas Downtown	19	10	15	13	34	23

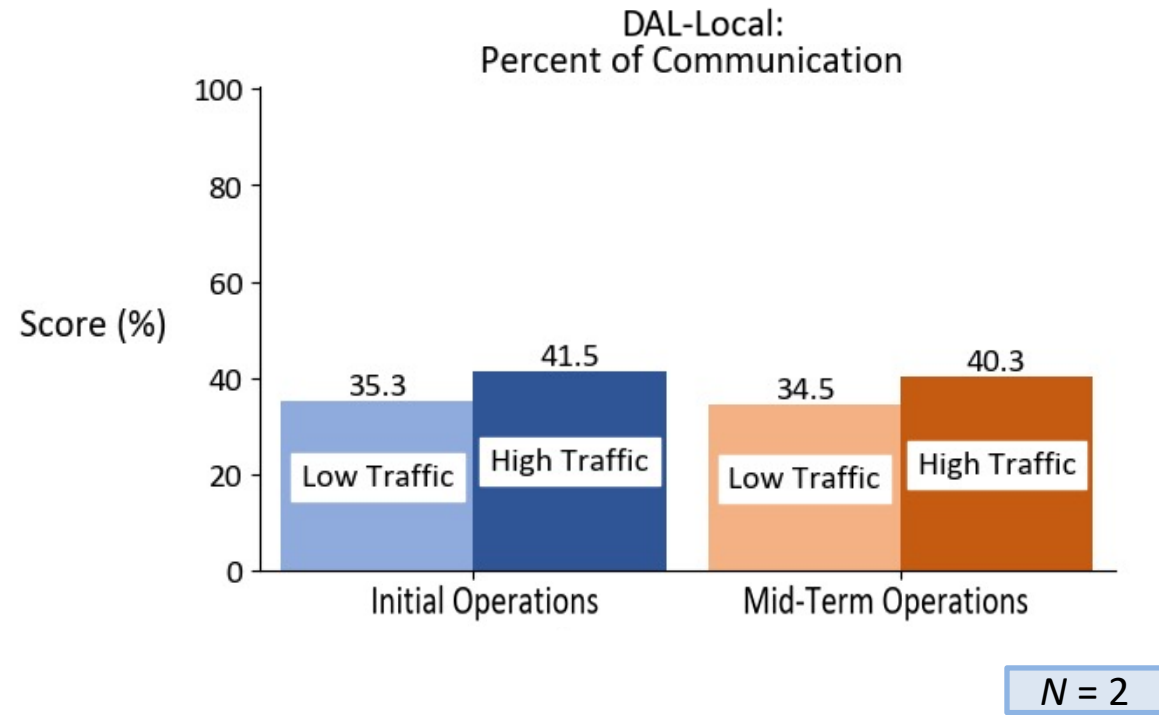
High UAM Traffic Scenario

	Initial Operations							Mid-Term Operations					
	Arrivals		Departures		Total			Arrivals		Departures		Total	
	Planned	Actual	Planned	Actual	Planned	Actual		Planned	Actual	Planned	Actual	Planned	Actual
DFW Vertiports	41	21	29	25	70	46	DFW Vertiports	41	21	29	25	70	46
DAL Vertiports	28	17	26	22	54	39	DAL Vertiports	28	18	26	23	54	41
Dallas Downtown	21	11	27	22	48	33	Dallas Downtown	21	12	27	22	48	34

*45 min scenarios



Results: DAL Local Percentage of Verbal Communications





Results: DFW Helo & DFW Local Percentage of Verbal Communications

