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Air Traffic Management eXploration

Initial Assessment of Lost Command and Control Link Procedures

Jordan Sakakeeny, David Thipphavong, Todd Lauderdale, and Husni Idaris – NASA Ames Research Center

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Introduction

- Uncrewed Aircraft (UA) Systems (UAS) have grown increasingly popular in recent years
- No UAS are routinely and seamlessly integrated into the airspace, especially in and amongst conventional crewed traffic
- A key initial use case is using remotely piloted large, fixed-wing UAS (e.g., C208) from conventional airports to deliver cargo
- Replacement of regional air cargo flights with UAS would yield ~200,000 UAS flights per year in the United States



Background

- The command and control (C2) link system is how a remote pilot (RP) can operate the UA
- The C2 link conveys aircraft information (uplink, downlink, and **voice**)
- When the C2 link is severed, a lost command and control link state (LC2L) is declared



LC2L: Now What?

- In the event of a LC2L, the UA will execute a LC2L procedure
- These procedures are a set of defined actions that are pre-programmed into the UA
- Existing standard LC2L procedures:
 - International Civil Aviation Organization (ICAO) Remotely Piloted Aircraft Systems Panel (RPASP)
 - RTCA, Inc. Special Committee 228 (SC-228) “Guidance Material: Standardized Lost C2 Link Procedures for Uncrewed Aircraft Systems” or “DO-400”
- **Research Question: Are existing standard procedures sufficient to support safe, scalable integration of LC2L UAS into the airspace?**



Particularly Problematic Domain for LC2L

- Under LC2L, RP can no longer operate the UA, nor can they use the UA to relay voice
- **Gap:** Aircraft are typically controlled via voice in the terminal area; a LC2L UA cannot follow this paradigm
- **Need:** Assessment of LC2L procedures in a realistic airspace environment
- **Contribution:** Developed a realistic environment for assessment
- Environment allows for testing “what if?” questions



Modeling the Airspace

- Used NASA's National Airspace System (NAS) Digital Twin (NDT)
- Modeled airspace
 - Standard Terminal Arrival Procedures (STAR)
 - Instrument Approach Procedures (IAP)
 - Played back recorded background traffic
- Modeled accurate arrival procedures in nominal and off-nominal scenarios



Nominal and Off-Nominal Arrival Procedure

- Nominal:
 - Identified real flights that flew between airports of interest
 - Modeled vectored control instruction that Air Traffic Control (ATC) gave in the terminal area
- Off-Nominal (DO-400):
 - The UA flies to its last clearance, then
 - The UA proceeds directly to the Initial Approach Fix of the published approach, then
 - The UA executes the published approach



Traffic Scenario in the D10 TRACON

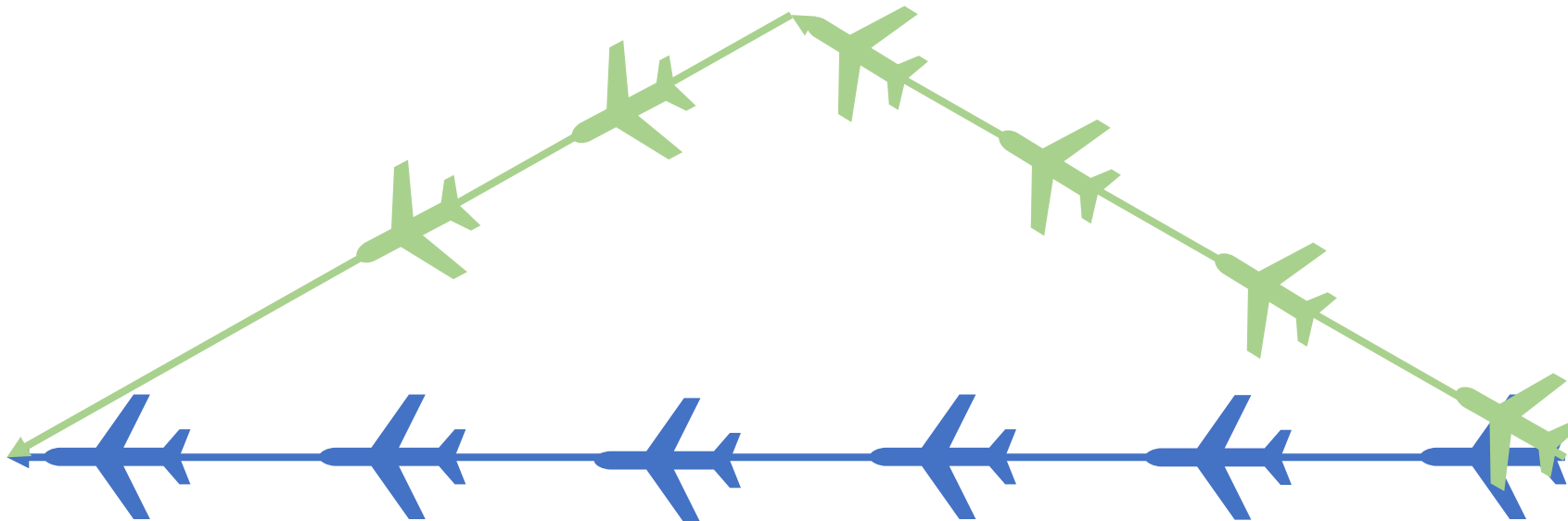
- Played back recorded traffic from January 18, 2022
- Approximately 4,700 recorded flights (IFR and VFR) from Fort Worth Center and surrounding area
- Simulation time from 1400-1800 UTC (0800-1200 local)
- Used Cessna 208B Grand Caravan (C208) as the simulated remotely piloted UAS
- In each simulation, eleven UAS, spaced in 10-minute increments, were flown along a route
- Nine different routes = 99 total simulated UAS in this study
- No conflict resolution (e.g., ATC or Detect and Avoid) was active





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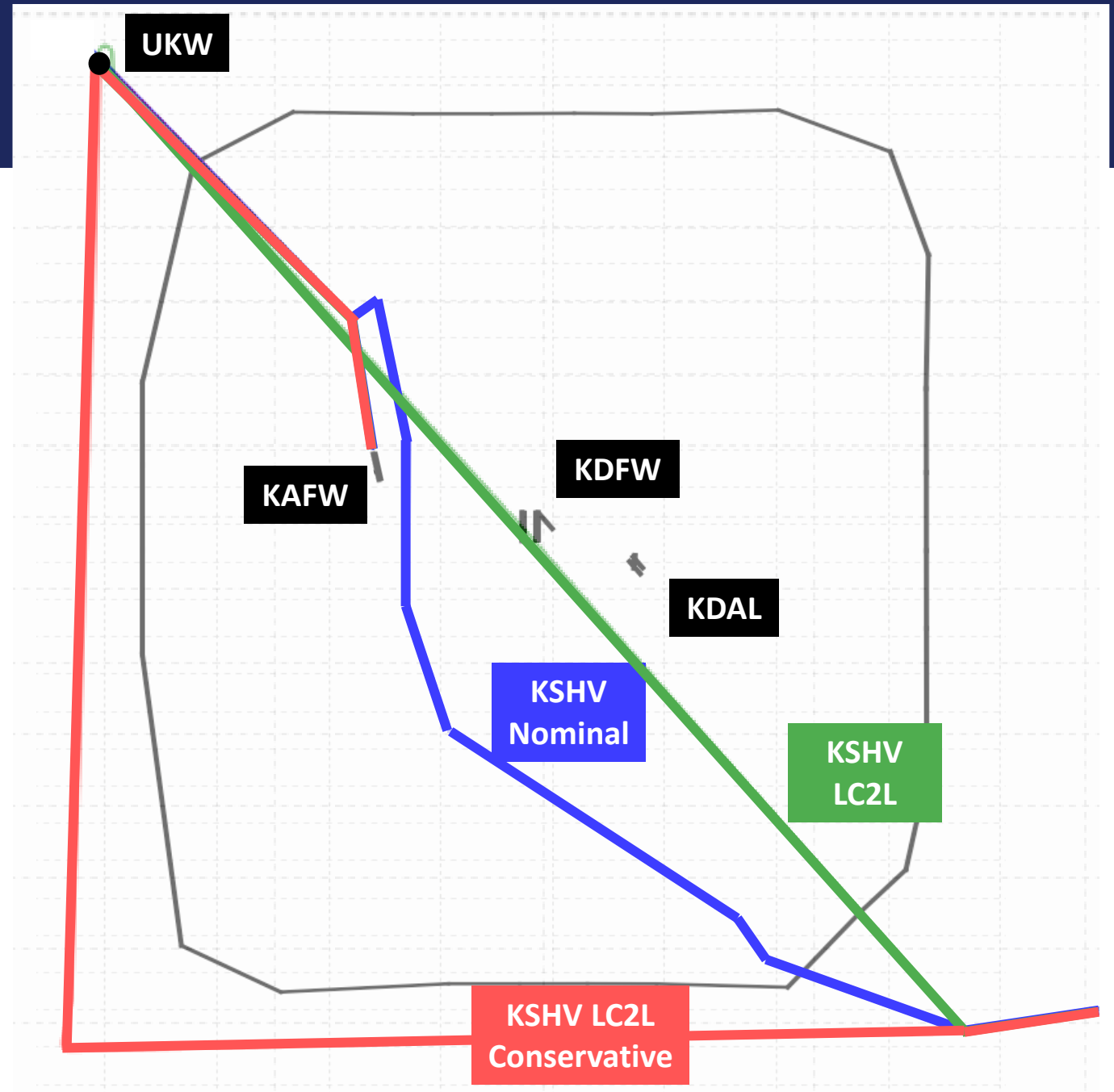
Loss of Separation

- Loss of separation (LOS) between a simulated UA and a recorded background aircraft) were recorded, where a LOS is defined as:
 - A simulated UA being within 1000 ft vertically and
 - 3 nmi horizontally of any recorded background aircraft (IFR or VFR)
- A LOS indicates a situation where ATC, the other pilot, and/or the UA itself would need to act to resolve the LOS
- The number of unique aircraft with which a simulated UA loses separation provides a first-order estimation of the impact on additional workload an LC2L procedure might have
- $\mathcal{L} = \text{Number of unique LOS (3 nmi)}$



Example Routes

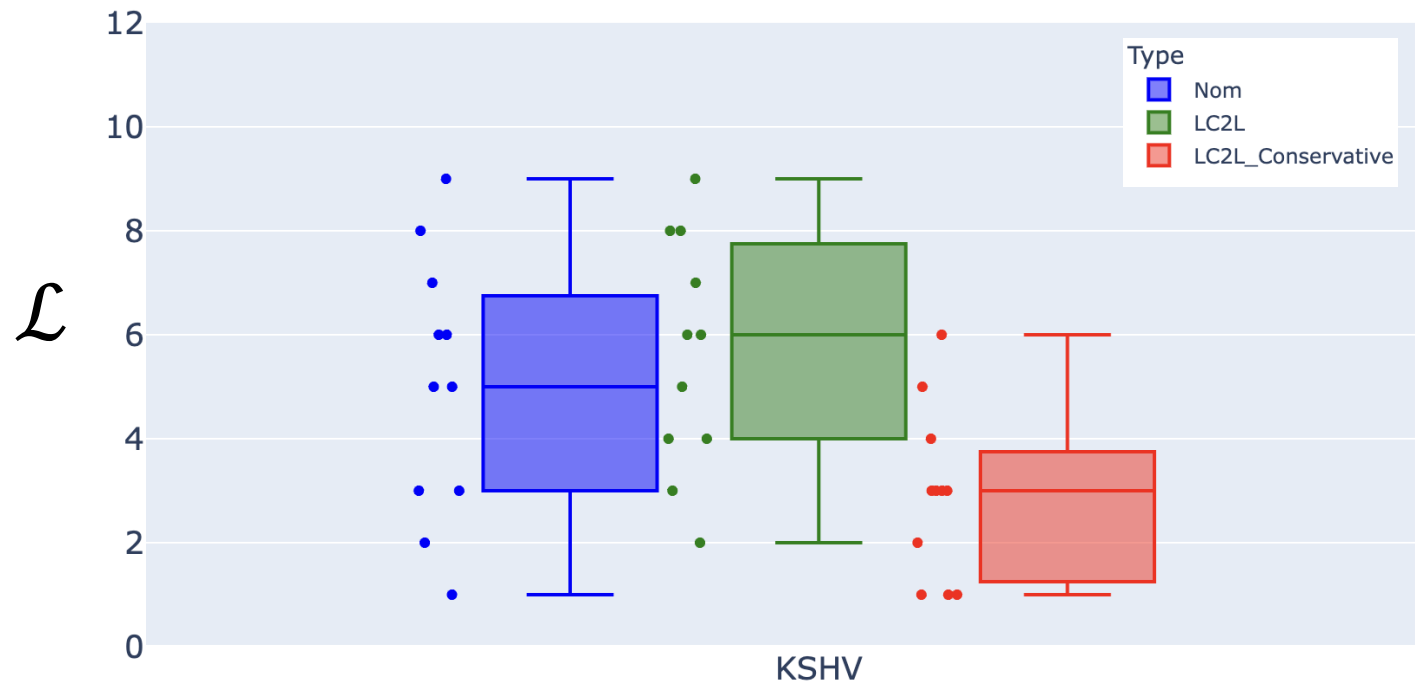
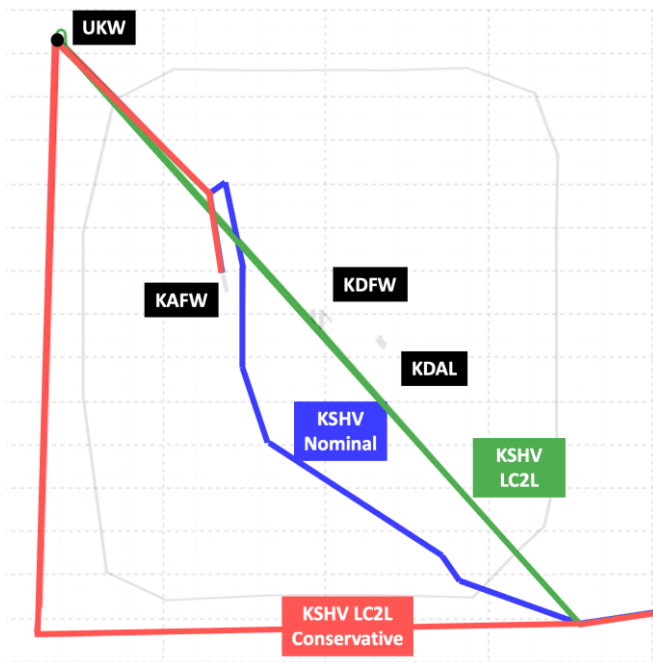
- Nominal route
 - Modeled after real flight using STAR and vectored controlled instructions
- LC2L route
 - Follows DO-400 procedure
 - Does not use STAR
- LC2L conservative route
 - “What if?”
 - Notional attempt to mitigate LOS





Loss of Separation by Route Type

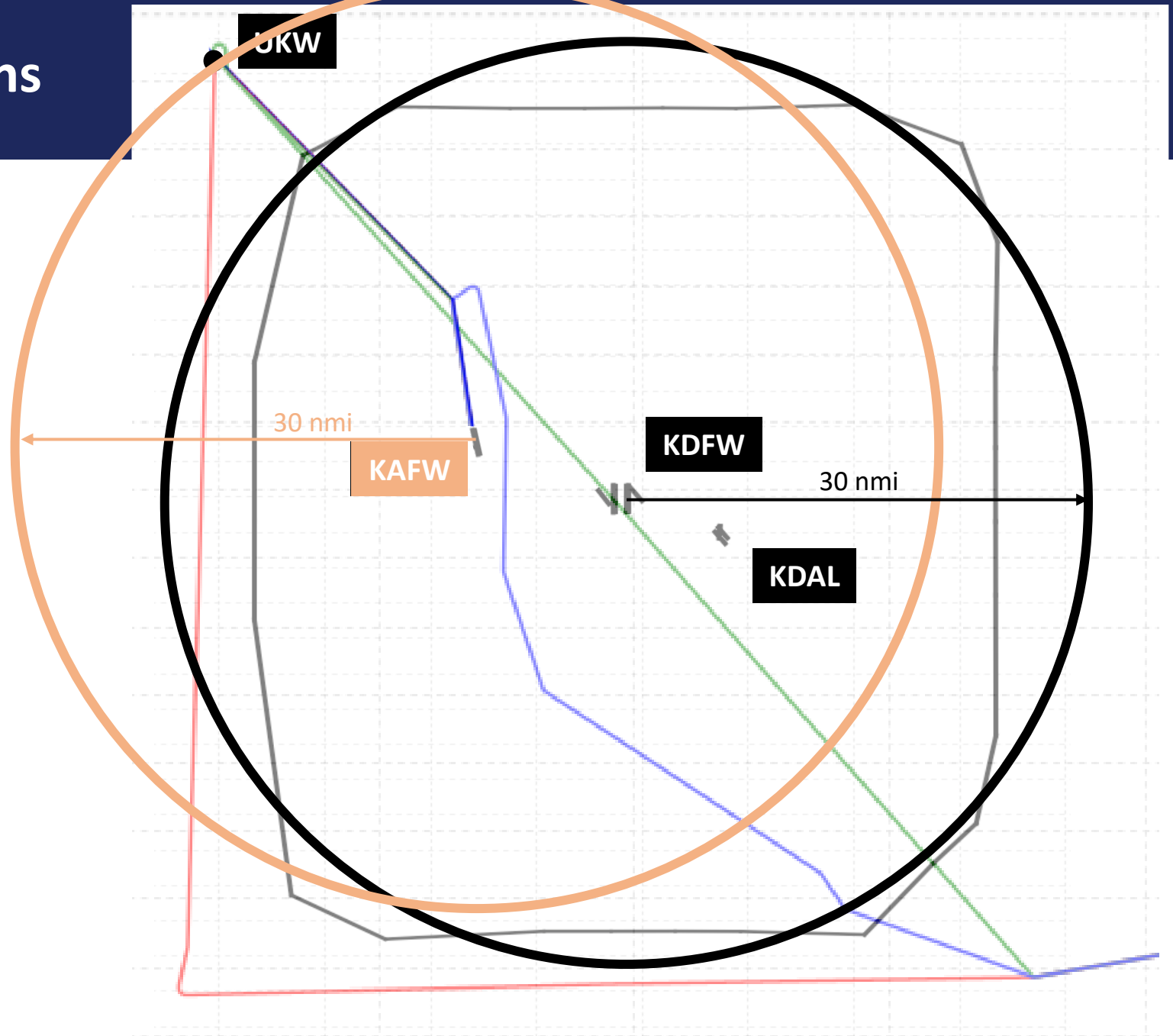
- $\mathcal{L}$ = Number of unique LOS (3 nmi)
- Results indicate that $\mathcal{L}$ increases with time spent inside the busier TRACON area
- $\mathcal{L}$ was lower for “conservative” LC2L route that went around the TRACON





Defining Flight Domains

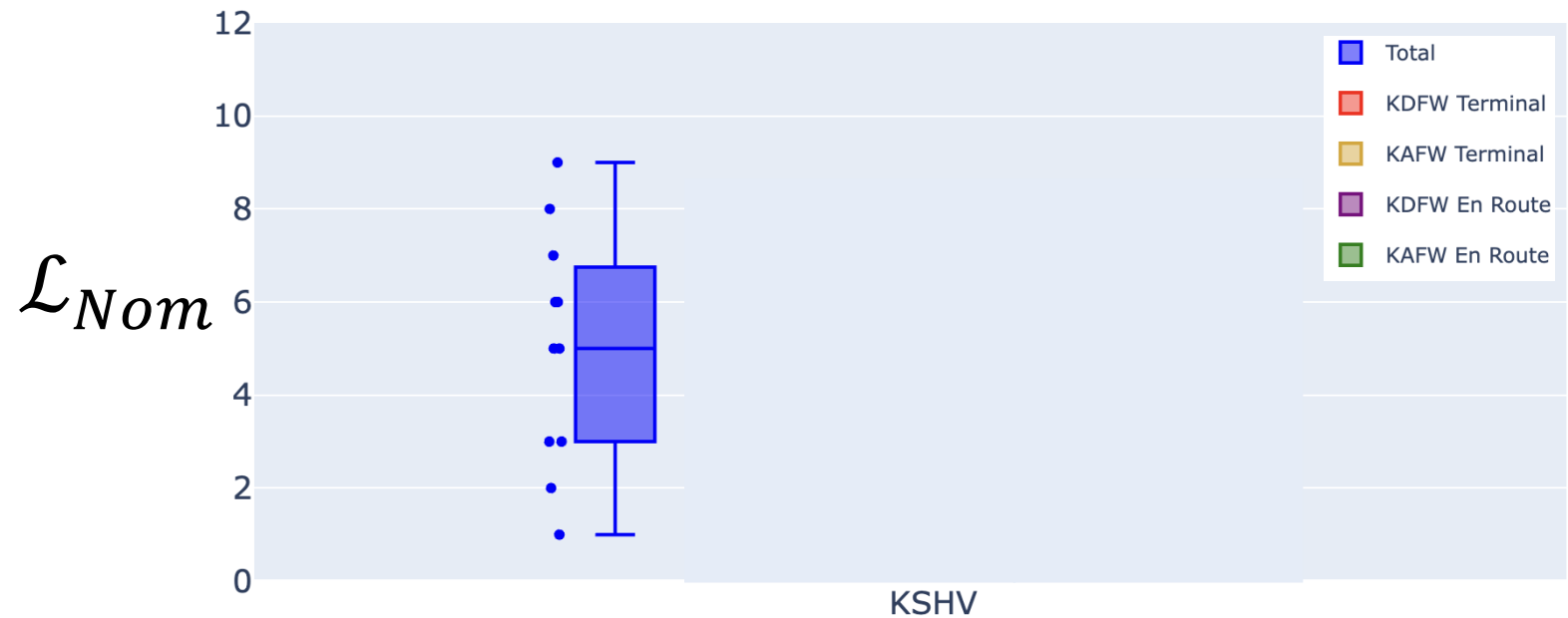
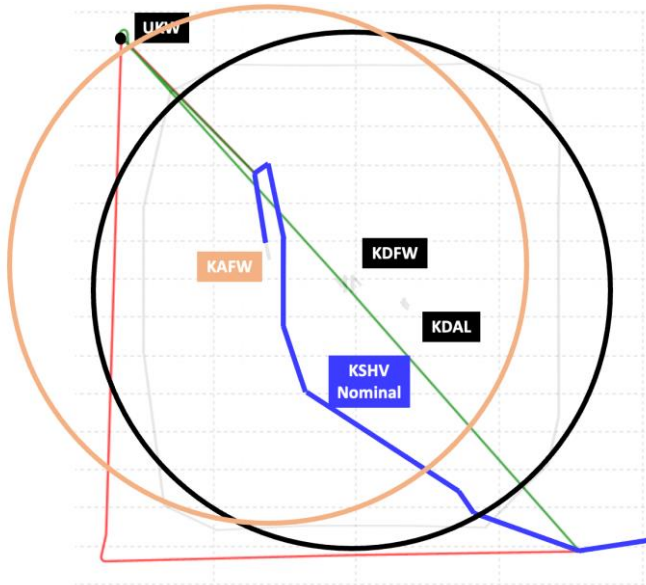
- Terminal area
 - <30 nmi from arrival airport
- En route area
 - >30 nmi from arrival airport
- DFW Terminal
- AFW Terminal





Loss of Separation by Flight Domain – Nominal Route

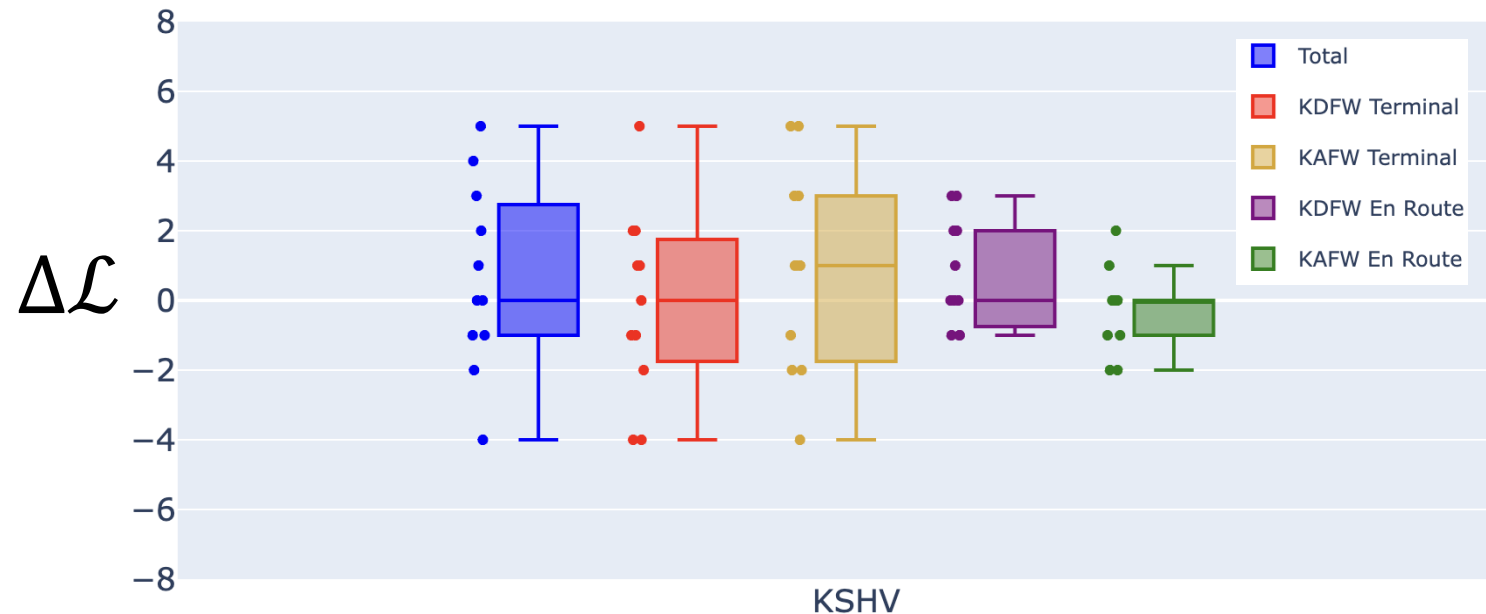
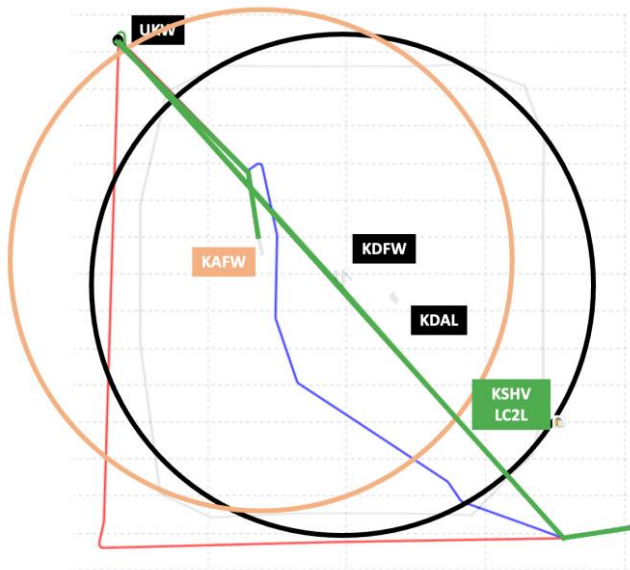
- Number of unique LOS across the entire flight for nominal route
- Baseline values
- Most LOS occur in the terminal area
- LOS en route do occur





Loss of Separation by Flight Domain – LC2L Route

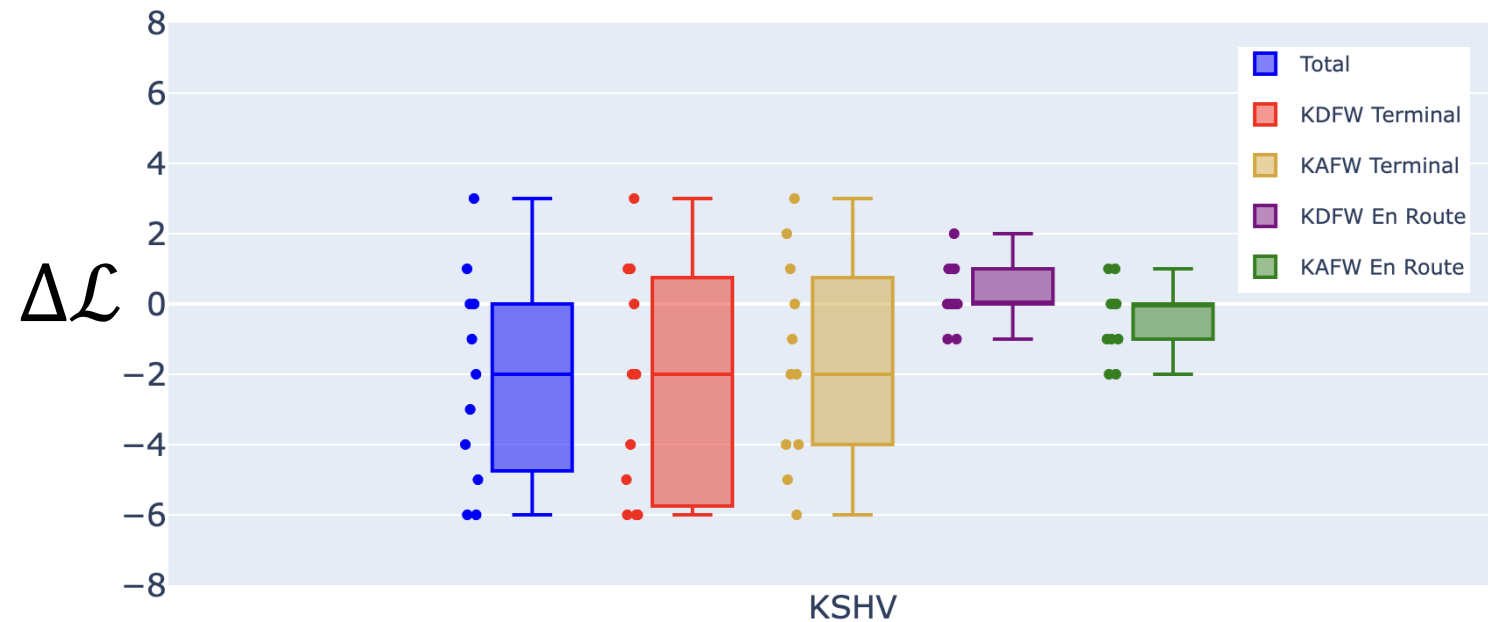
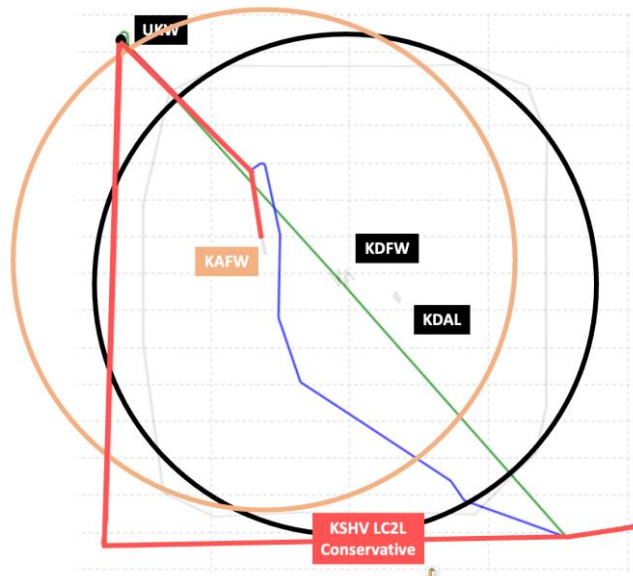
- Nominal Route Flight i had same departure time as LC2L Route Flight i
- $\Delta\mathcal{L}_i = \mathcal{L}_{LC2L,i} - \mathcal{L}_{Nom,i}$
- $median(\mathcal{L}_{LC2L}) \approx median(\mathcal{L}_{Nom})$
- In LC2L scenario, UAS cannot be maneuvered by ATC





Loss of Separation by Flight Domain – LC2L Conservative Route

- $\Delta\mathcal{L}_i = \mathcal{L}_{LC2L_Con,i} - \mathcal{L}_{Nom,i}$
- $median(\mathcal{L}_{LC2L_Con}) < median(\mathcal{L}_{Nom})$
- Results indicate $\mathcal{L}$ might be reduced by flying in “less busy” airspace





Conclusions

- Fulfilled a need
 - Developed a simulation framework for assessing LC2L procedures in a realistic airspace environment
 - Capability now exists to perform tradeoff analysis of different procedures
- Studied 99 simulated UA flights across nine routes and recorded the number of unique LOS for each flight
- Identified gaps in existing LC2L procedures



Future Work

- Work with standards organizations to refine procedures
- Add conflict resolution
 - Model ATC
 - Model operator automation for conflict resolution
- Build on the example of the LC2L “conservative” route
 - Design more routes that would mitigate losses
 - Design relative to metrics, such as probability of encountering VFR/IFR
- Assess the tradeoffs for LC2L procedures



Thank you!

Dr. Jordan Sakakeeny
jordan.a.sakakeeny@nasa.gov



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