



WEBINAR SERIES ON ADVANCED MOBILITY

Acknowledgement

The presenter wishes to acknowledge the IEEE Vehicular Technology Society for their sponsorship of the Webinar Series on Advanced Air Mobility.

Air Corridors: Highways in the Airspace for Advanced Air Mobility Services

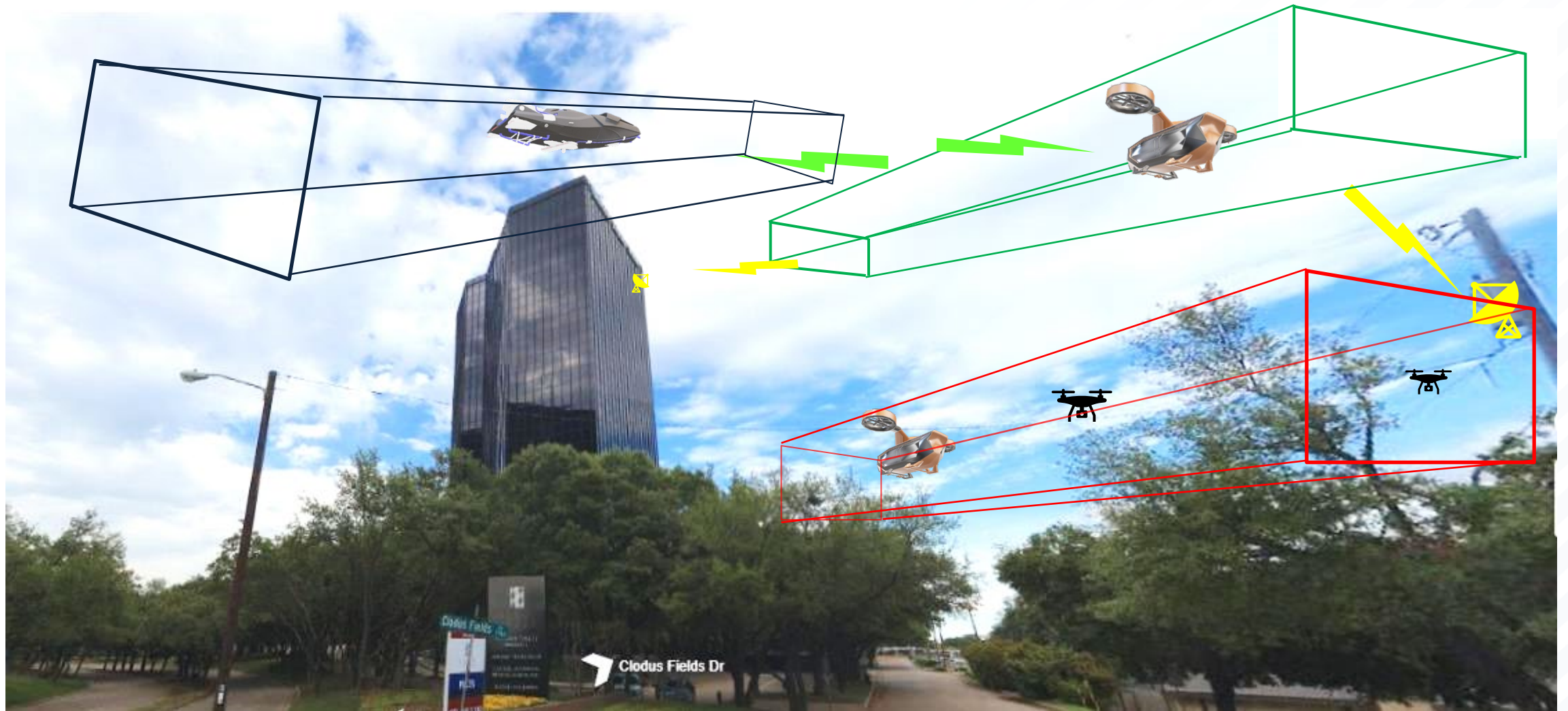
March 6th, 2023

Kamesh Namuduri

Professor, Department of Electrical Engineering

University of North Texas

Advanced Air Mobility Services



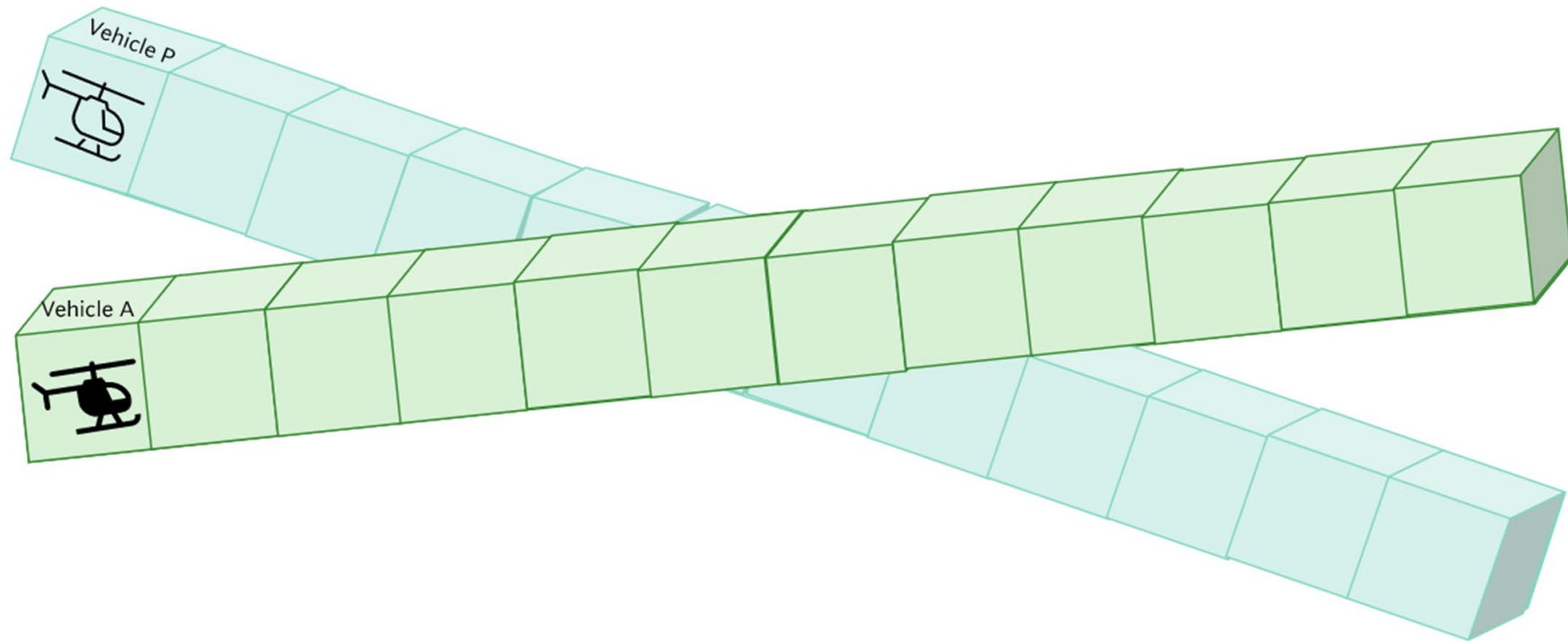
Key Challenges to Implementing AAM Services

- Autonomy
- Traffic Management at Scale
- Communication Support
- Air-to-Air Conflict Management
- Security and Privacy
- Community Acceptance
- Regulations and Best Practices

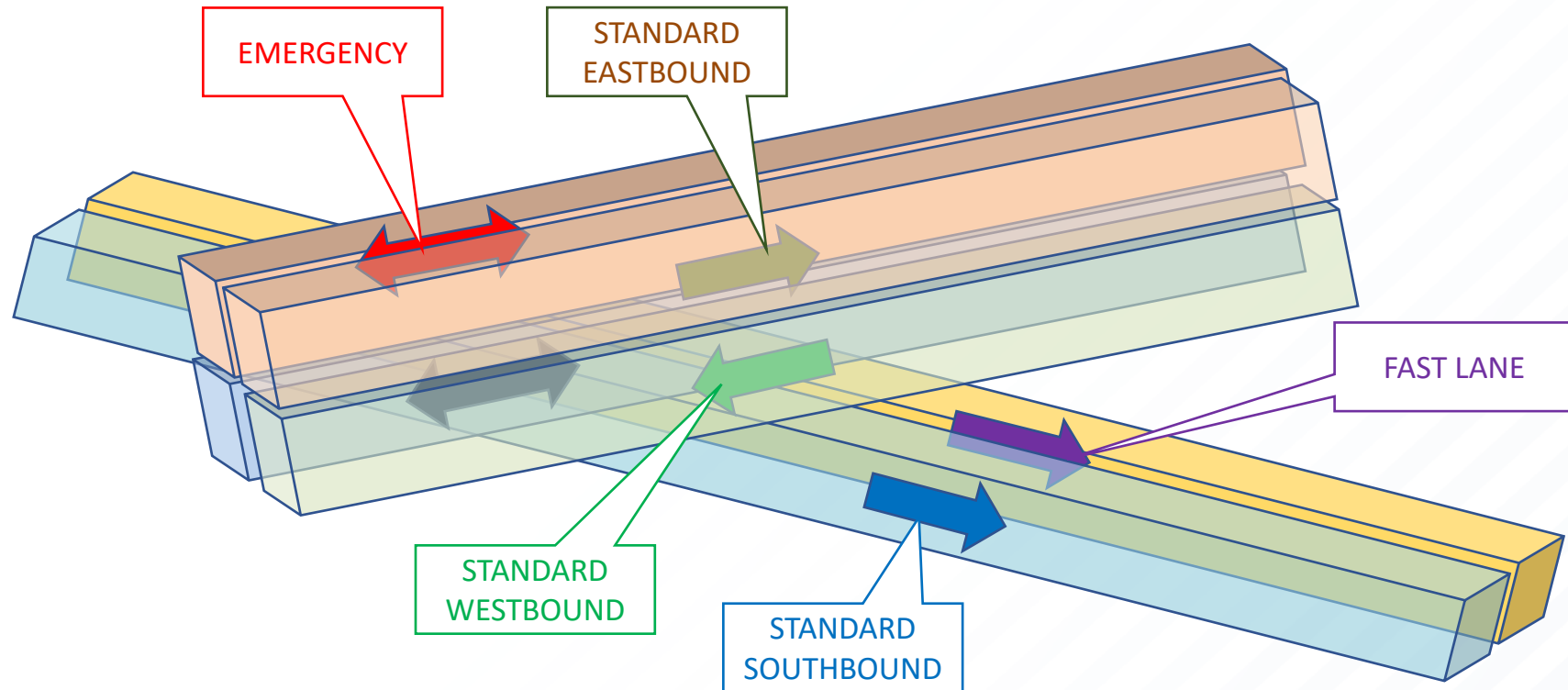
Key Concepts in Airspace Management

- Air Corridors: Structured airspaces reserved (to some extent) for AAM services
- Geofences: virtual three dimensional “boundaries” each UAS flies within
- UAS-to-UAS Communications: An alternative solution for traffic coordination

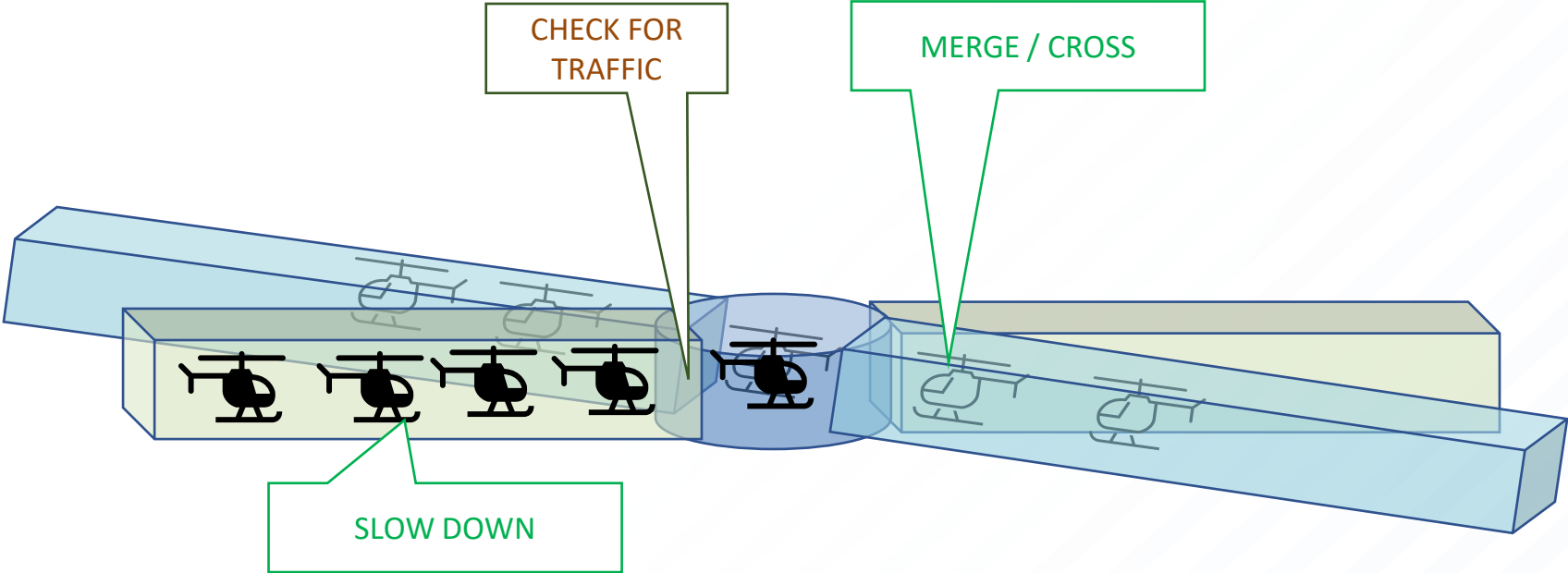
Air Tracks and Air Corridors



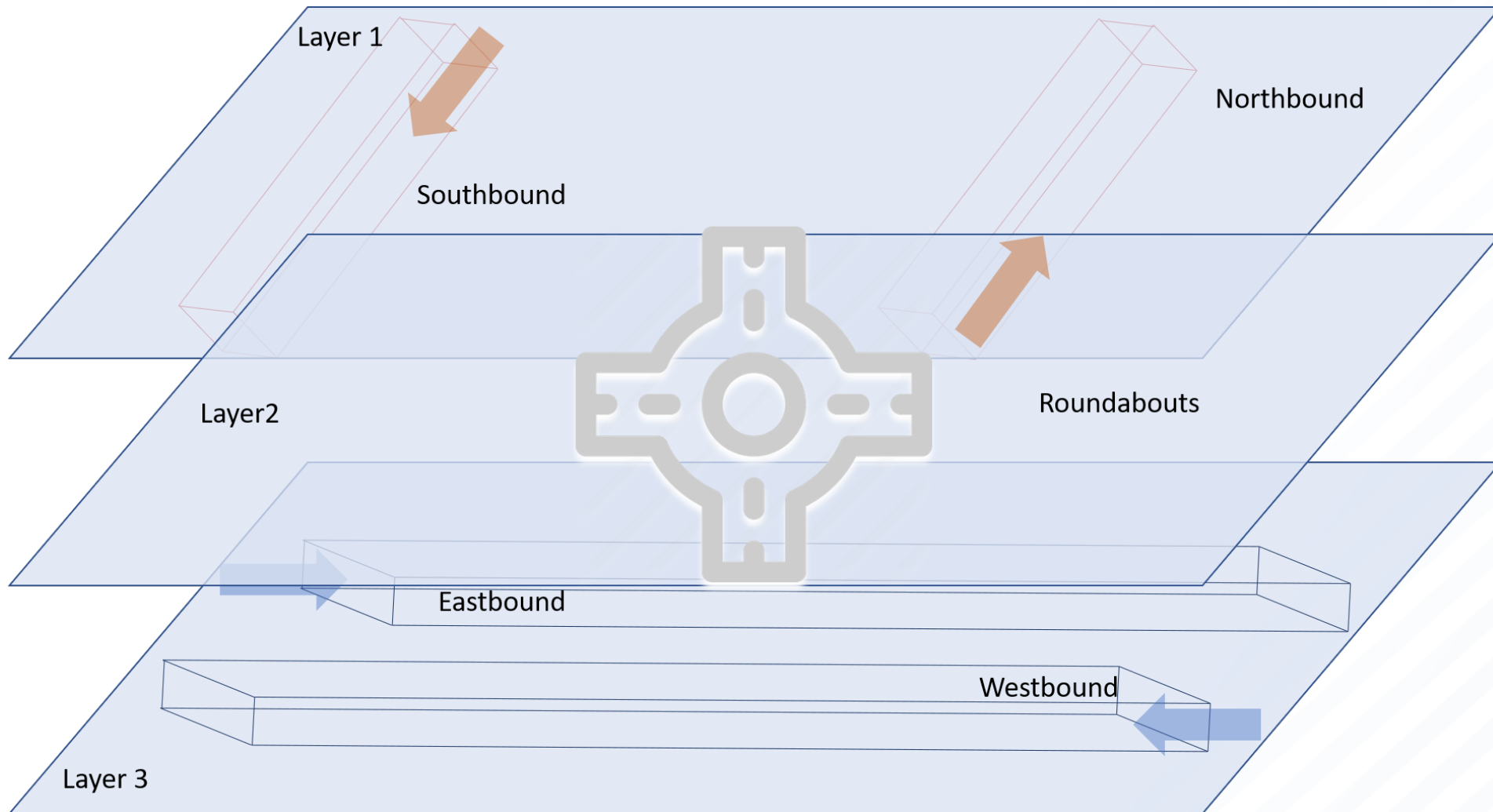
Air Corridors / Skylanes



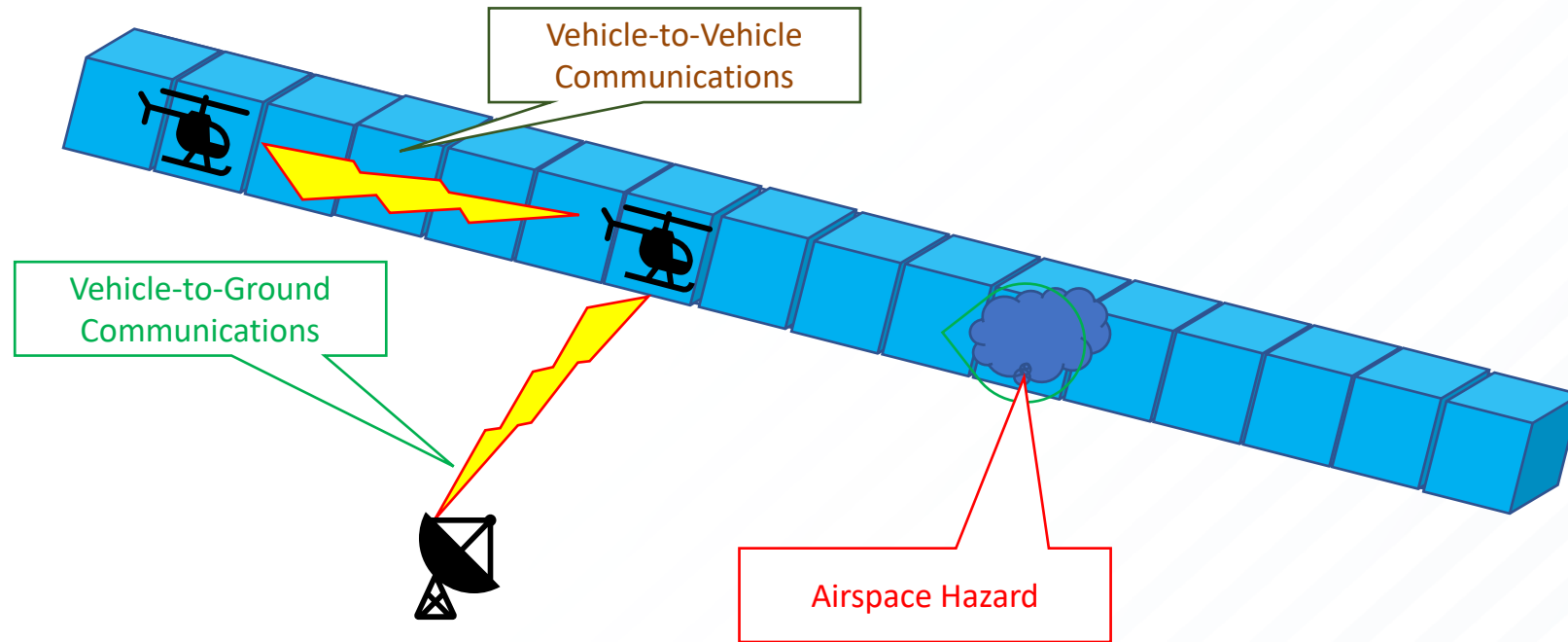
Circular Intersection (Roundabout)



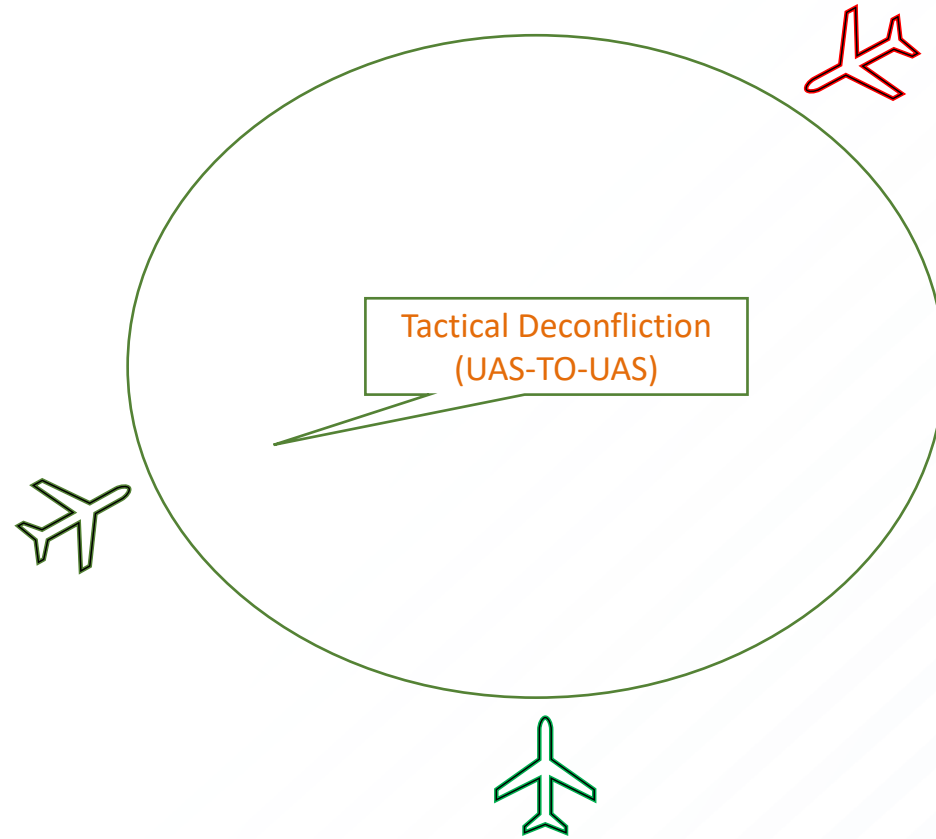
Multi-Layer Air Corridor



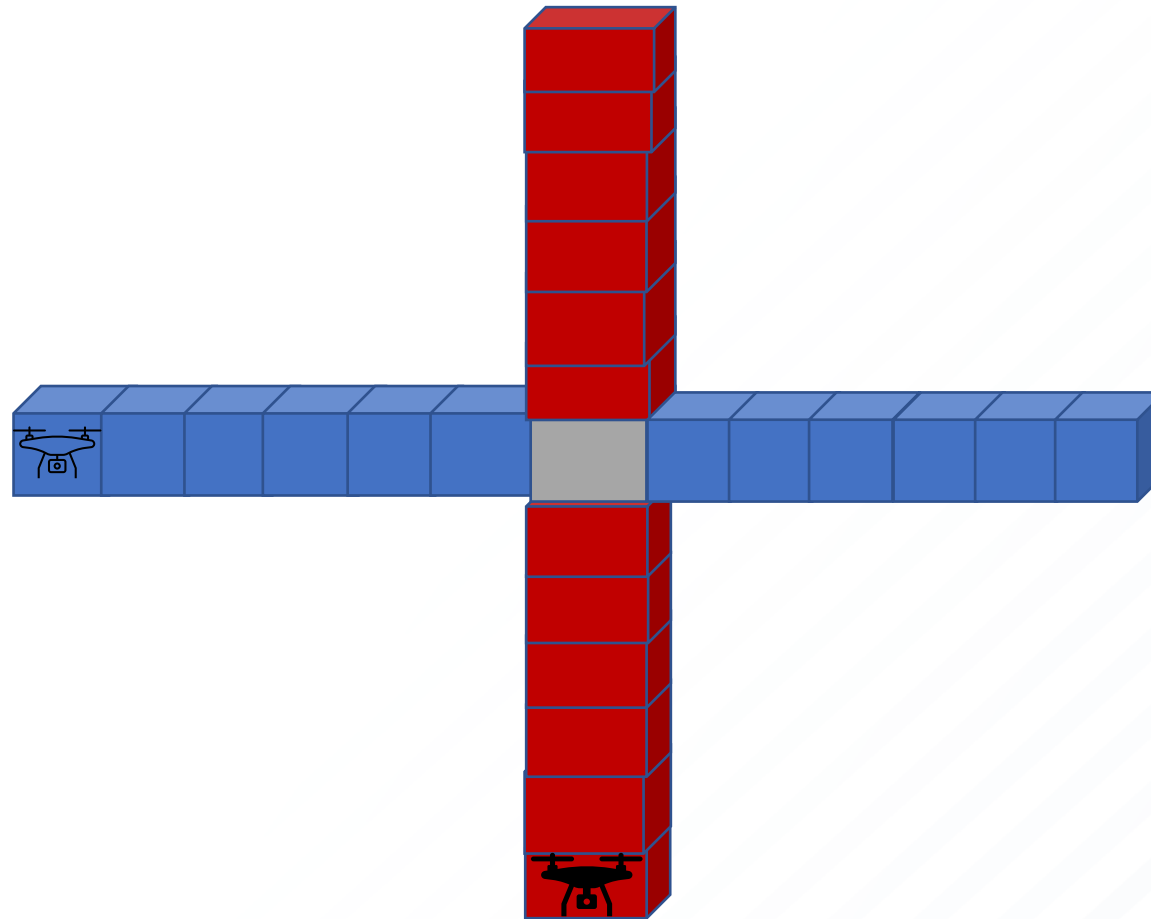
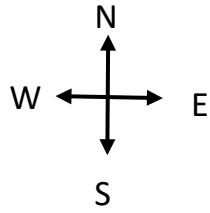
Challenge: Detect And Avoid






Challenge: Collision Avoidance

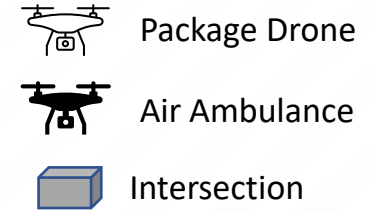
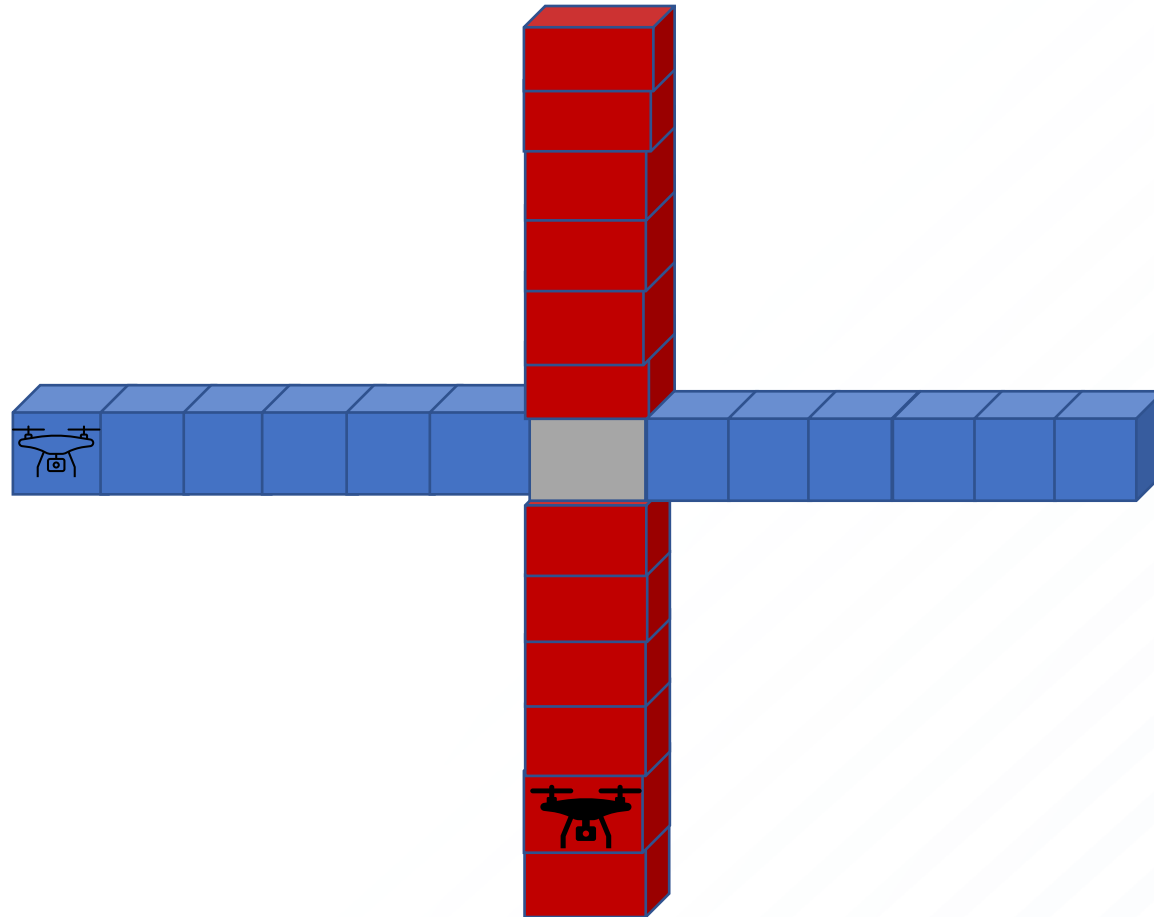
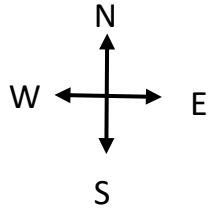


Challenge: Right of Way

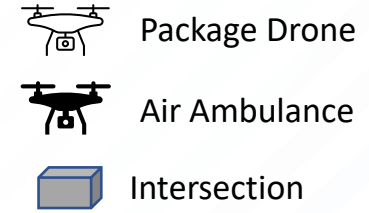
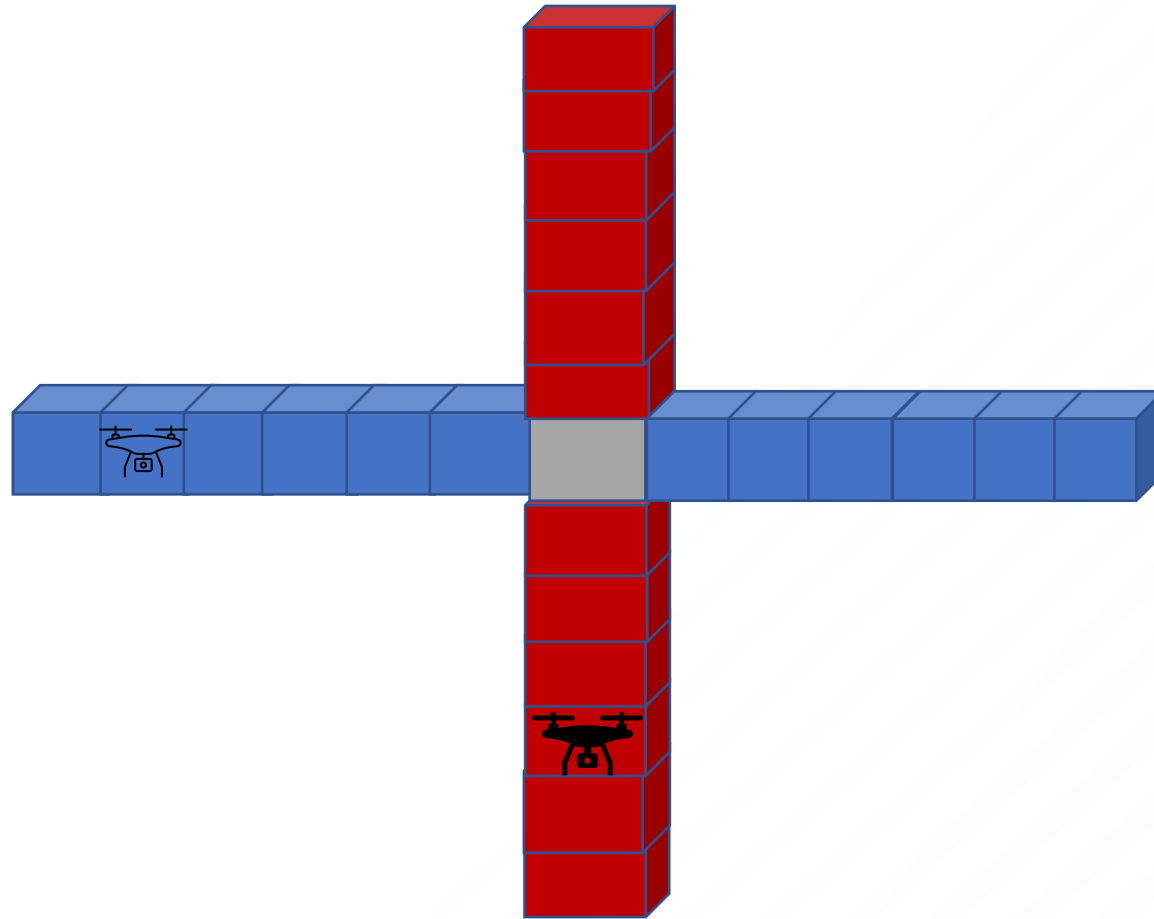
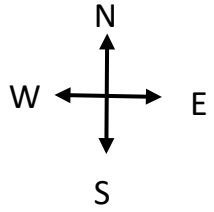


-  Package Delivery Drone
-  Air Ambulance
-  Intersection

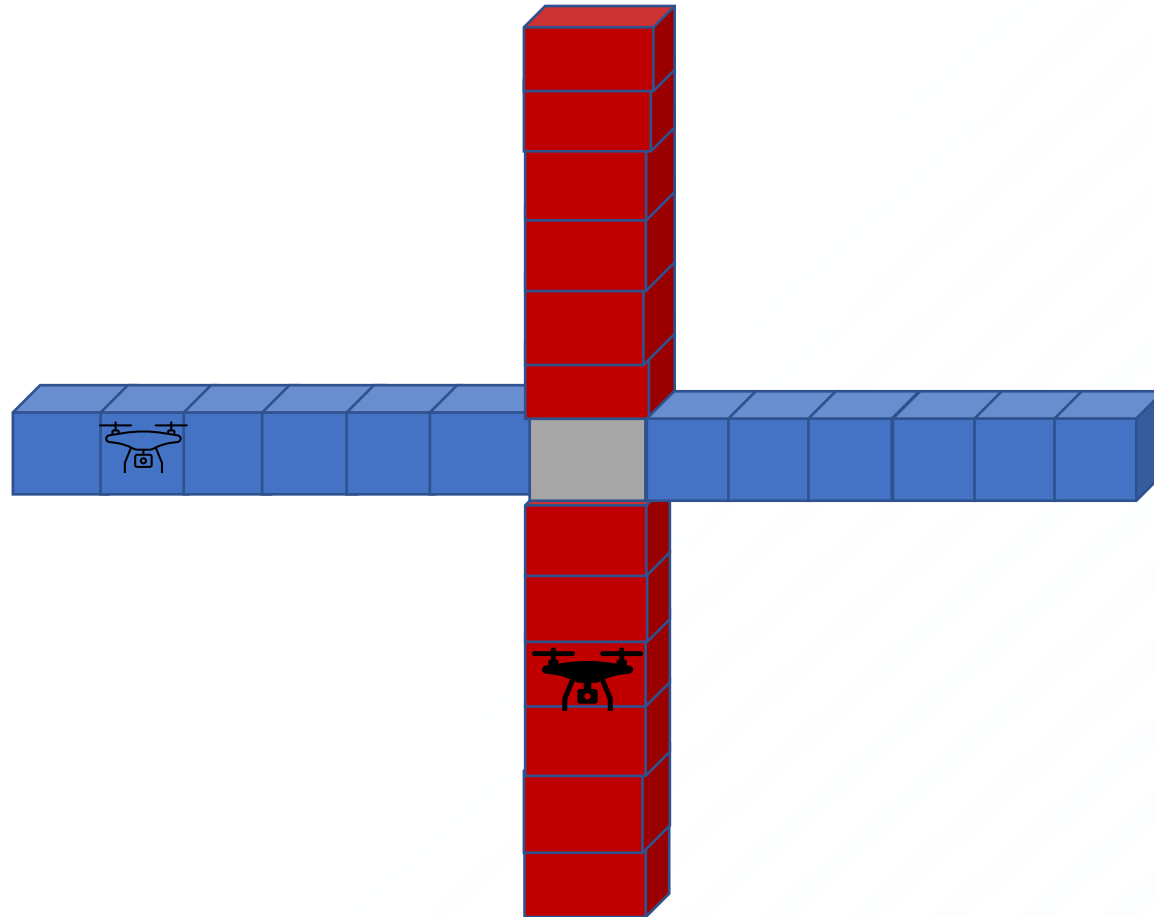
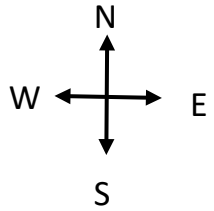
Modeling an Intersection






Modeling an Intersection

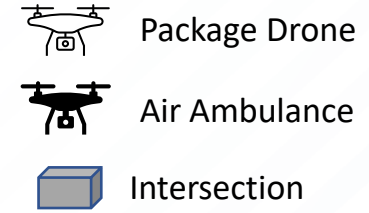
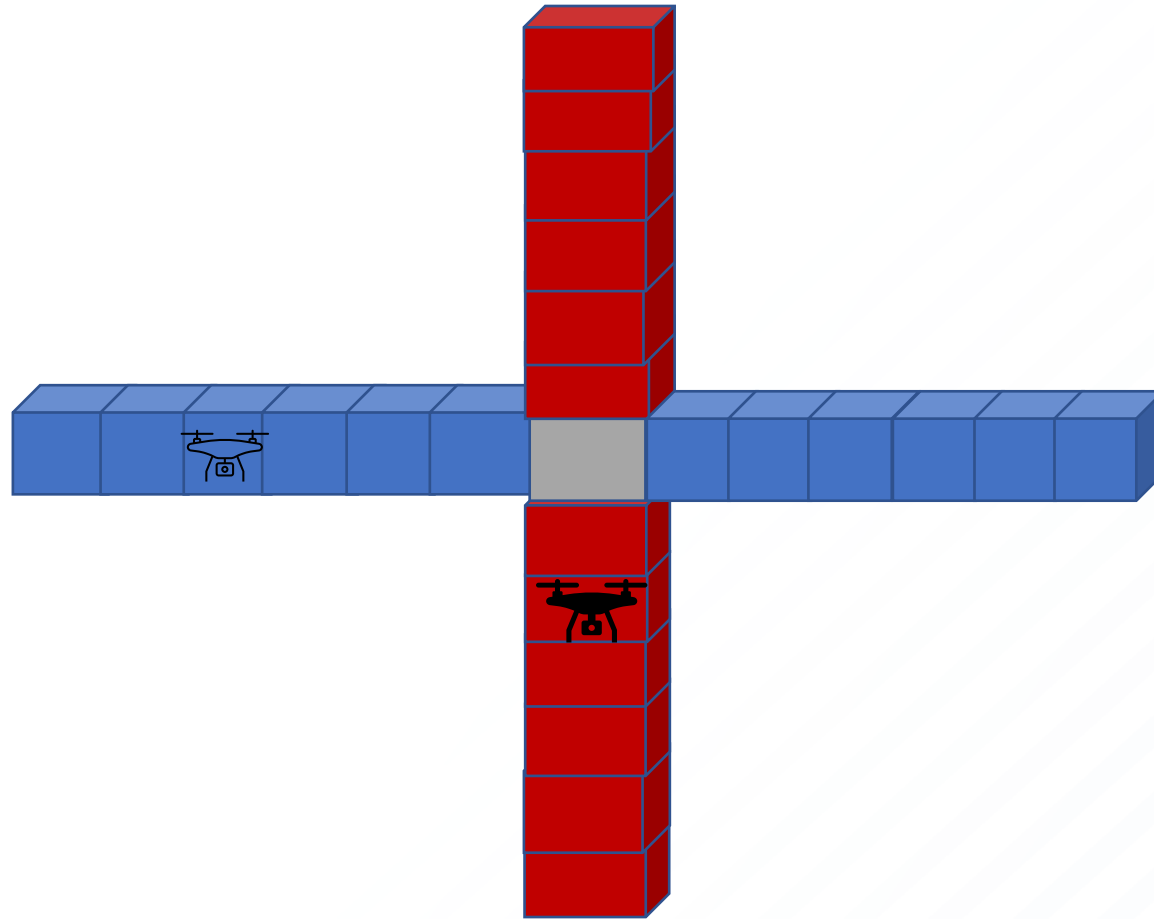
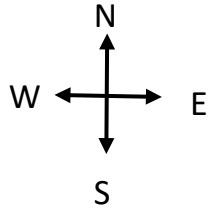


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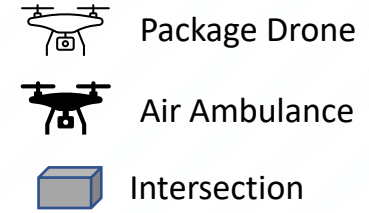
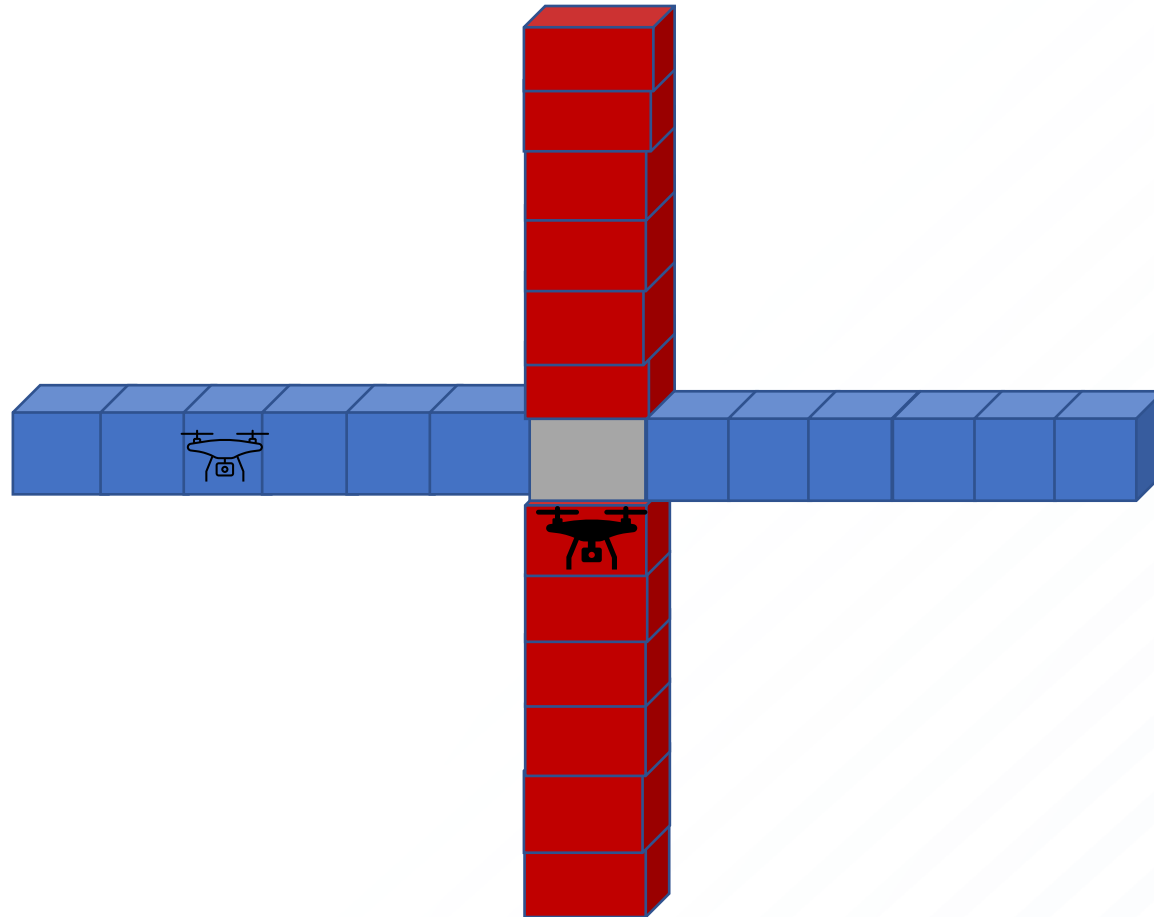
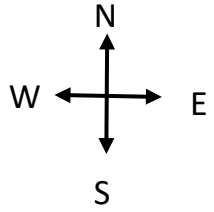


-  Package Drone
-  Air Ambulance
-  Intersection

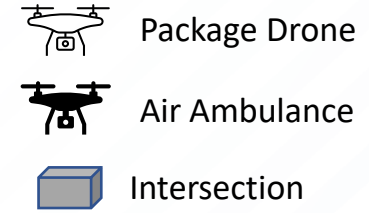
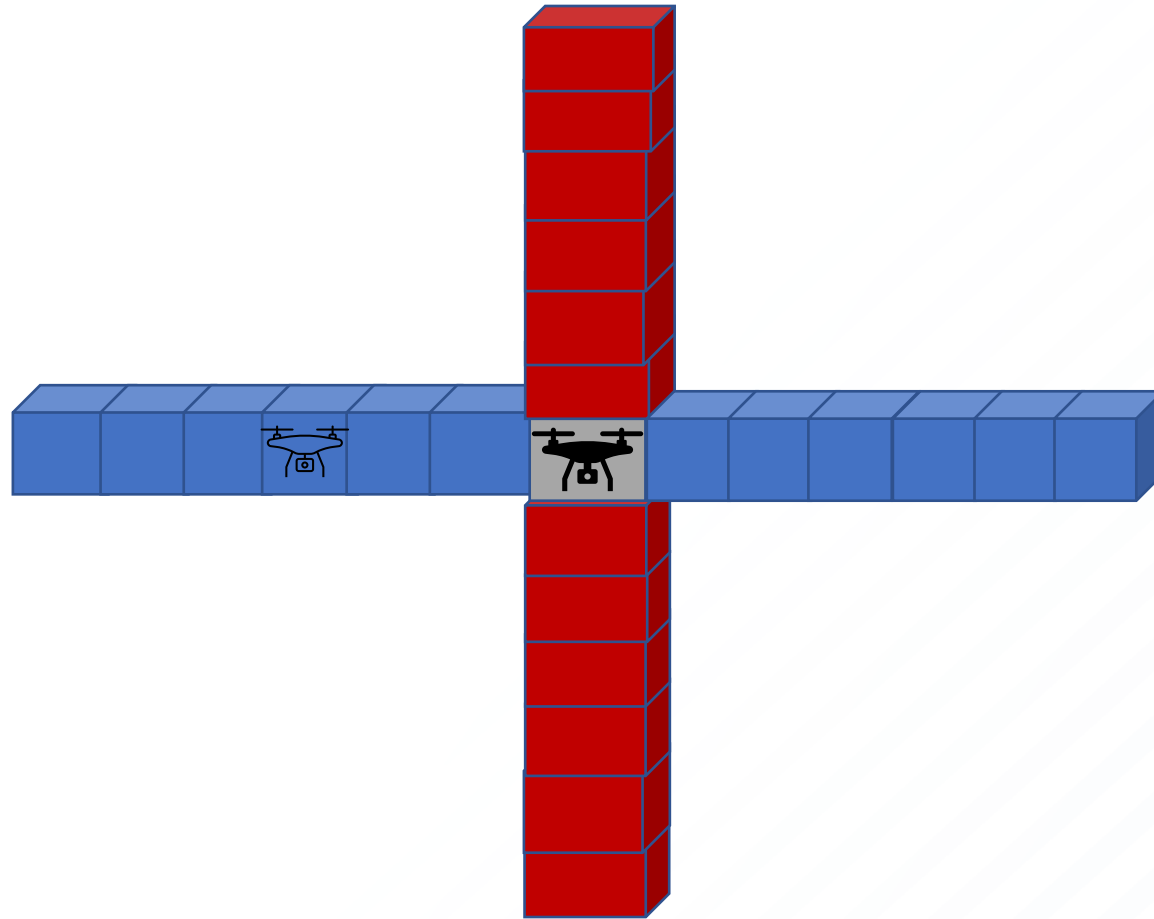
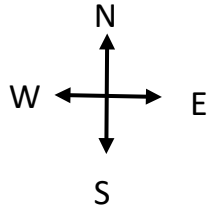
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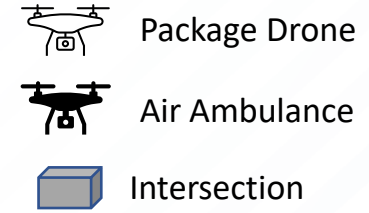
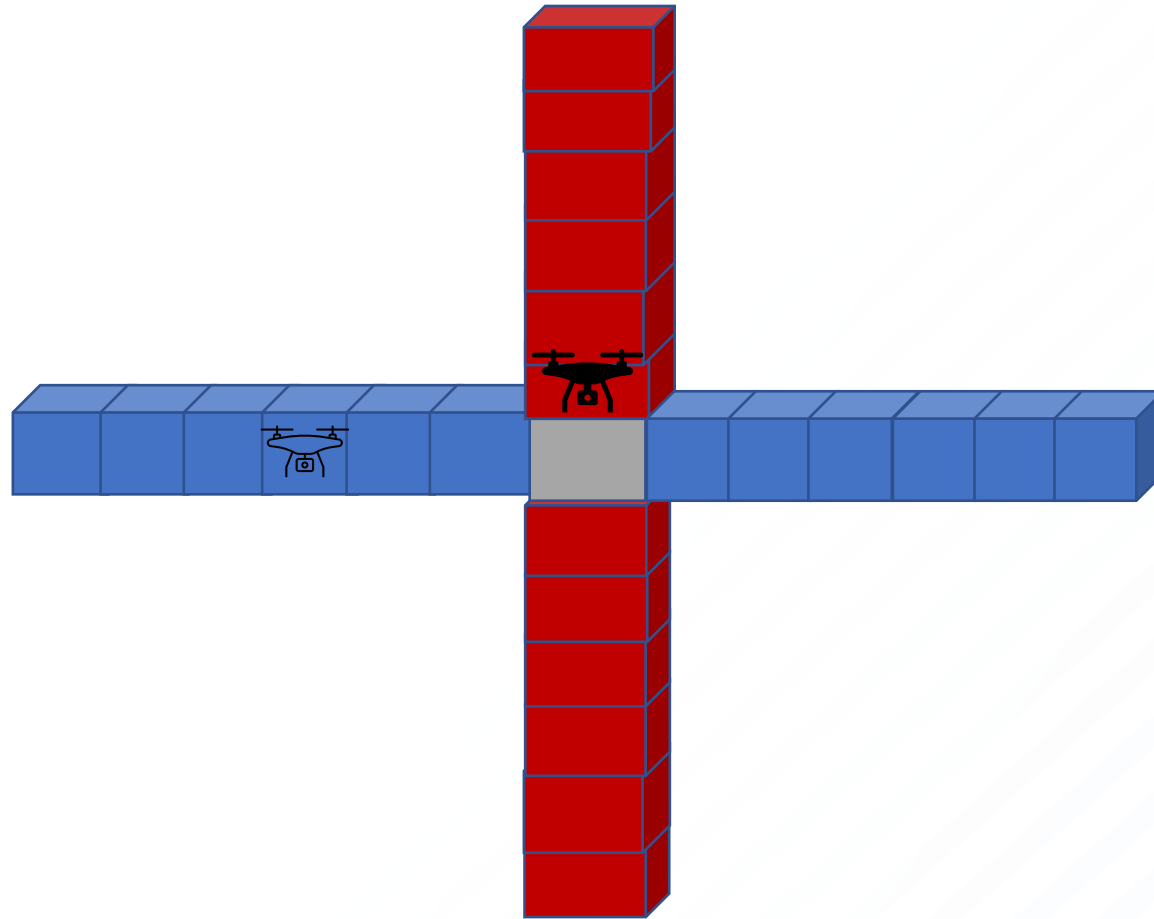
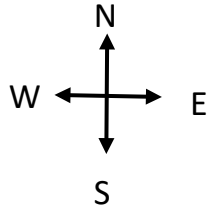
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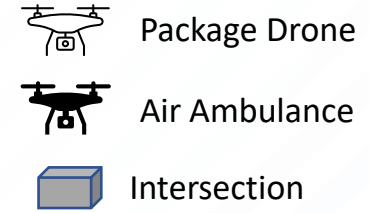
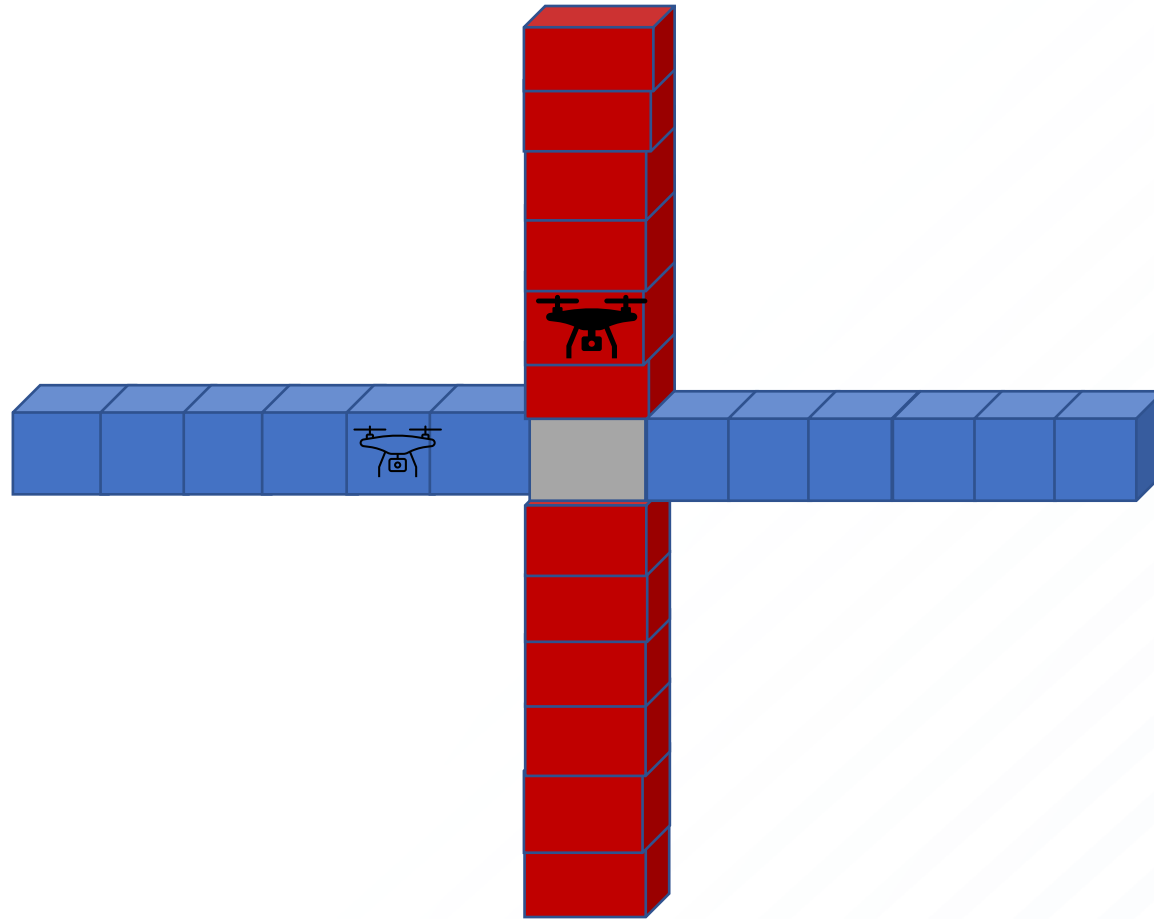
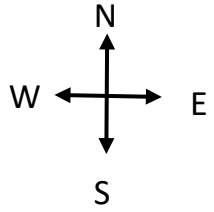
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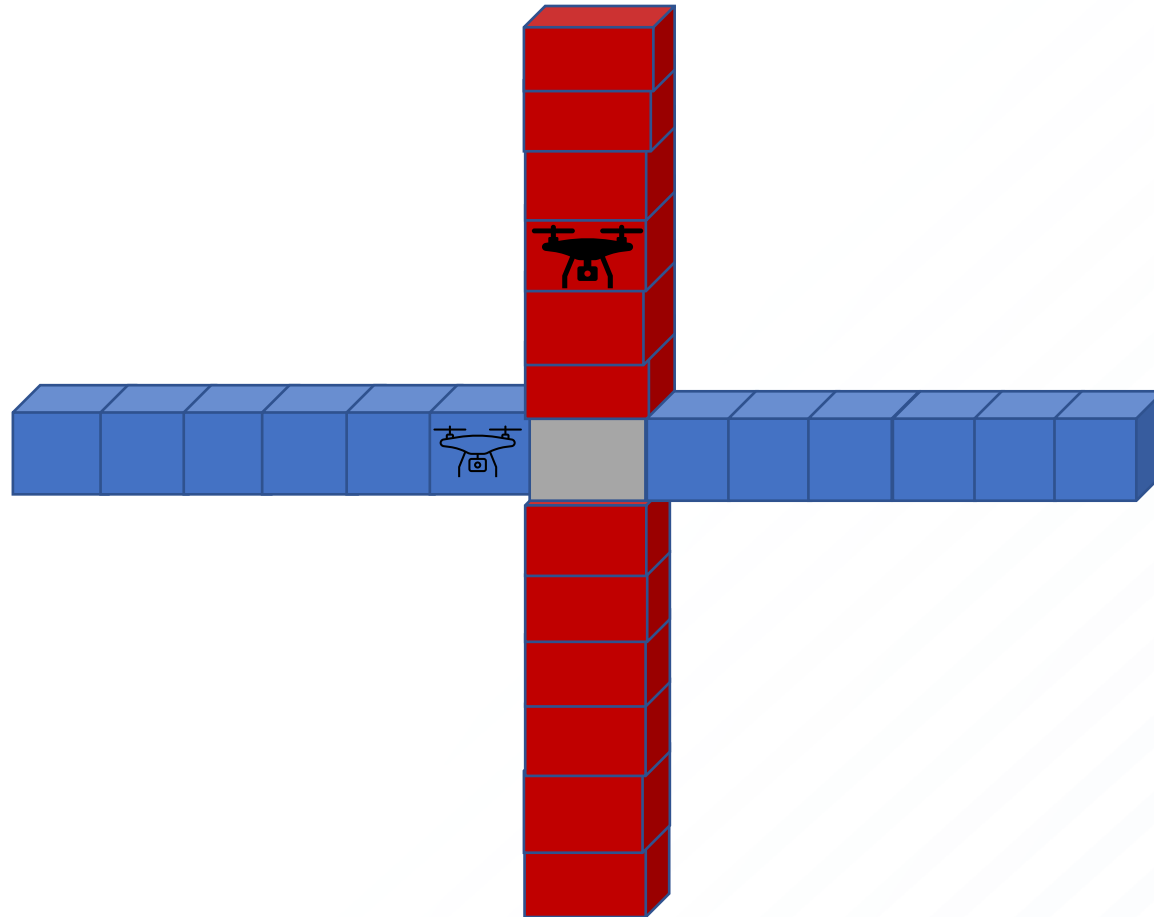
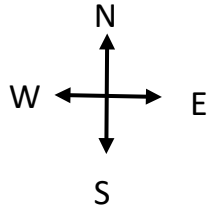
Modeling an Intersection






Modeling an Intersection

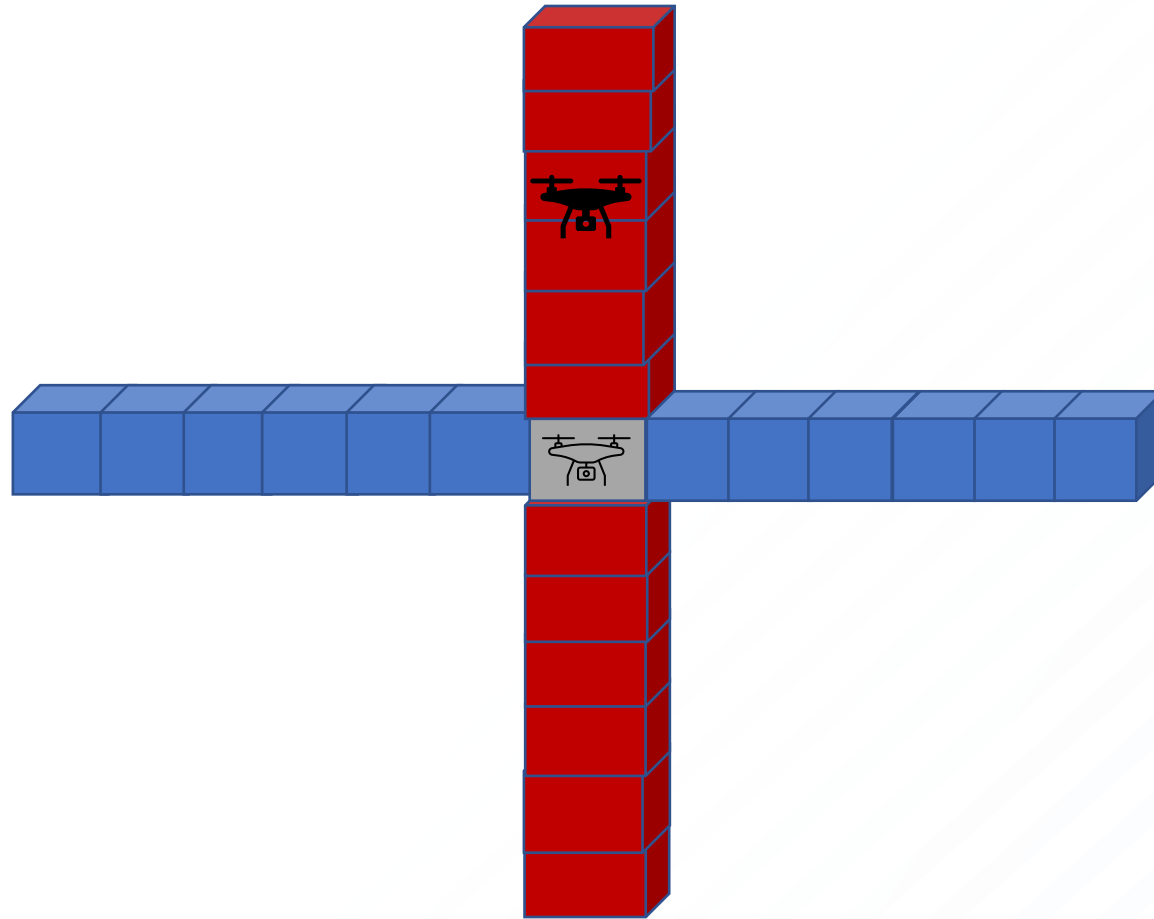
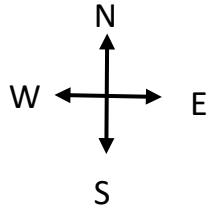





Modeling an Intersection



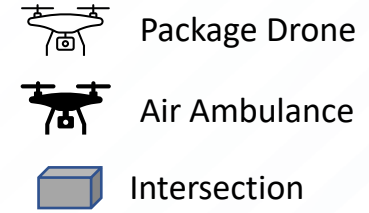
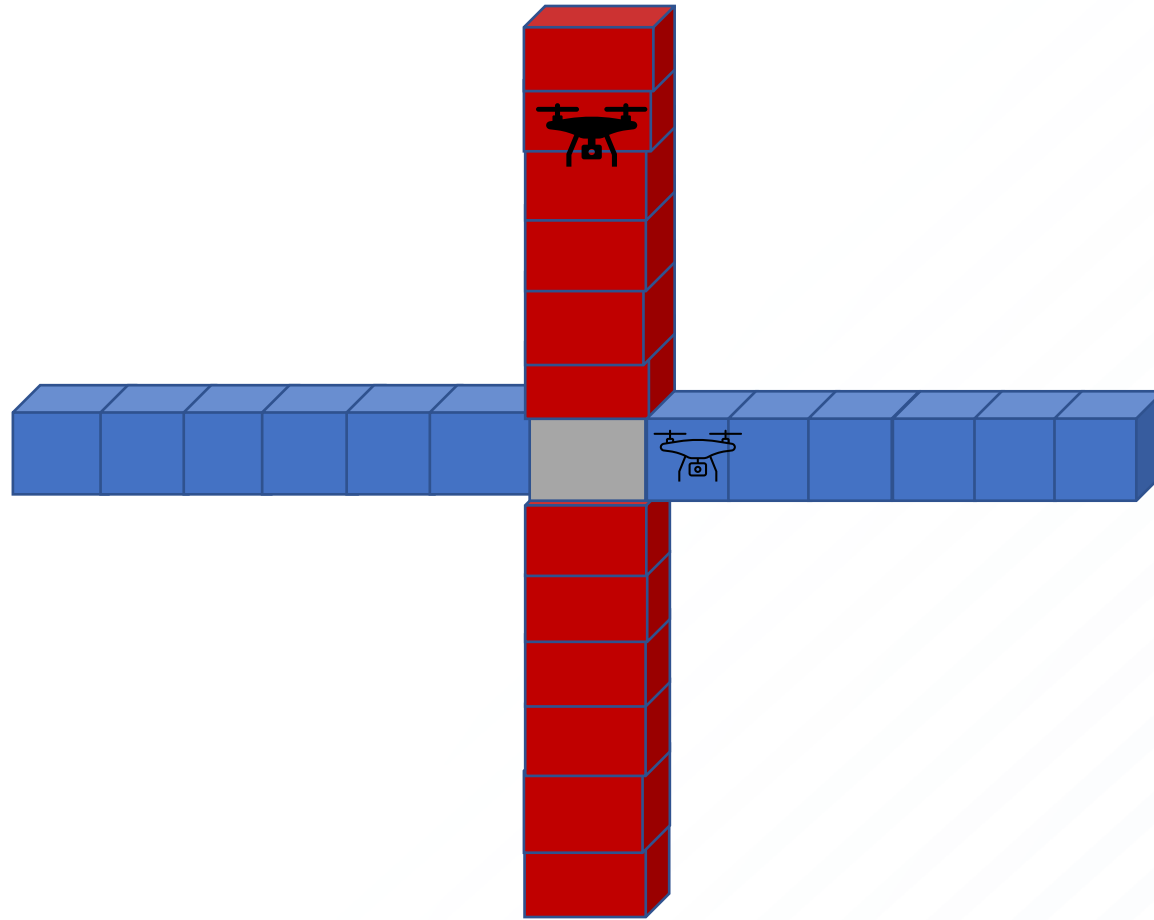
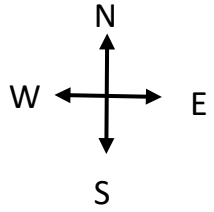
-  Package Drone
-  Air Ambulance
-  Intersection

Modeling an Intersection

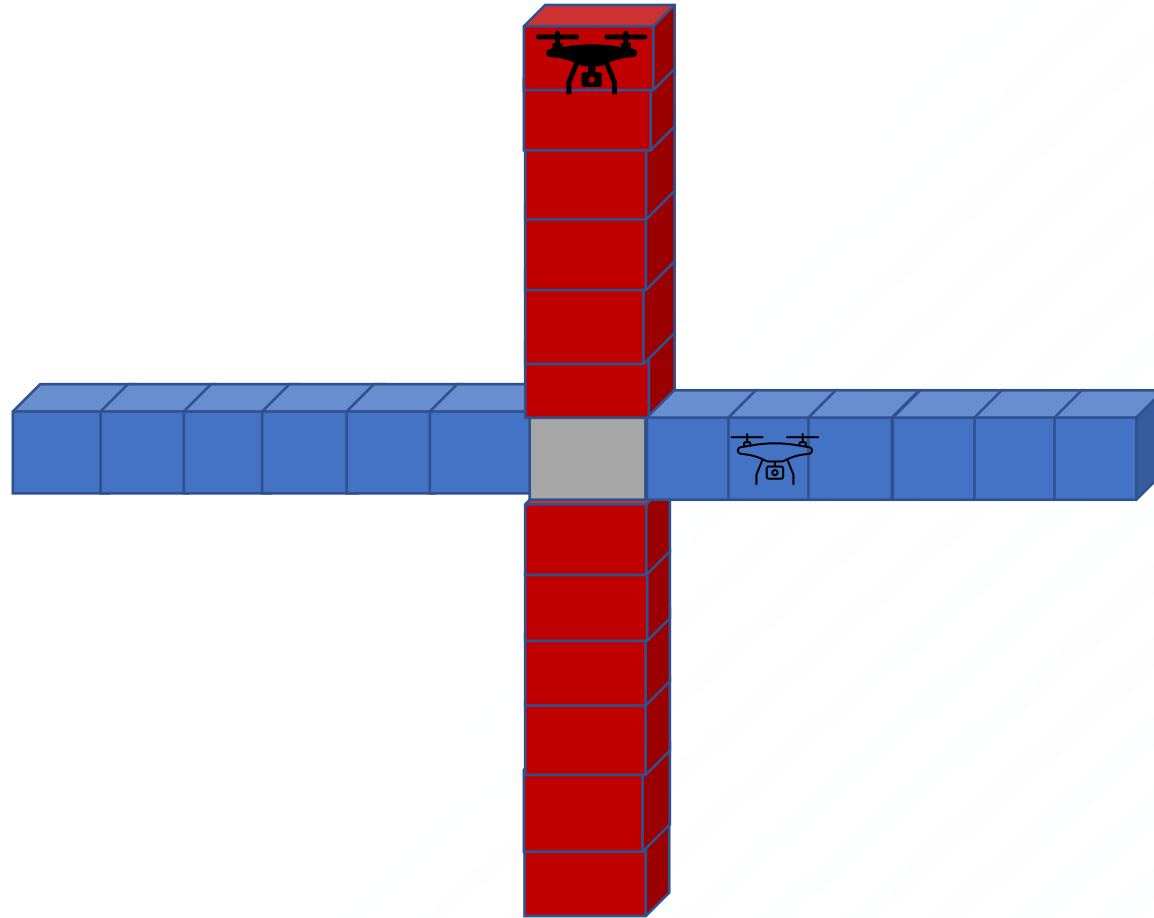
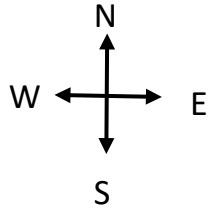





-  Package Drone
-  Air Ambulance
-  Intersection

Modeling an Intersection



Modeling an Intersection



-  Package Drone
-  Air Ambulance
-  Intersection

Literature on Air Corridors: The Tube Model (2004-2009)

- A Yousefi, G.L. Donohue, and L. Sherry. High-volume tube-shape sectors(HTS): A network of high capacity ribbons connecting congested city pairs. In Proceedings of the 23rd Digital Avionics Systems Conference, Salt Lake City, CT, 2004.
- B. Sridhar, S. Grabbe, K. Sheth, and K.D. Bilimoria. Initial study of tube networks for flexible airspace utilization. In AIAA Guidance, Navigation, and Control Conference and Exhibit, Keystone, Colorado, 21-24 August 2006.
- G. Gupta, B. Sridhar, and A. Mukherjee. Freeways in the sky: Exploring tube airspace design through mixed integer programming. In INFORMS Annual Meeting, Washington, D.C., October 2008.
- M. Xue and P. Kopardekar. High-capacity tube network design using the hough transform. In AIAA Guidance, Navigation and Control Conference and Exhibit, Honolulu, Hawaii, August 18-21 2008.
- Xue, Min. "Design Analysis of Corridors-in-the-sky." In *AIAA guidance, navigation, and control conference*, p. 5859. 2009.

“The space is discretized into grids. Each grid has 10 nautical miles in width and 2 minutes in height. A grid can be looked on as a safety zone, which means only one flight is allowed in it.”

Recent and Relevant Literature (2021-2022)

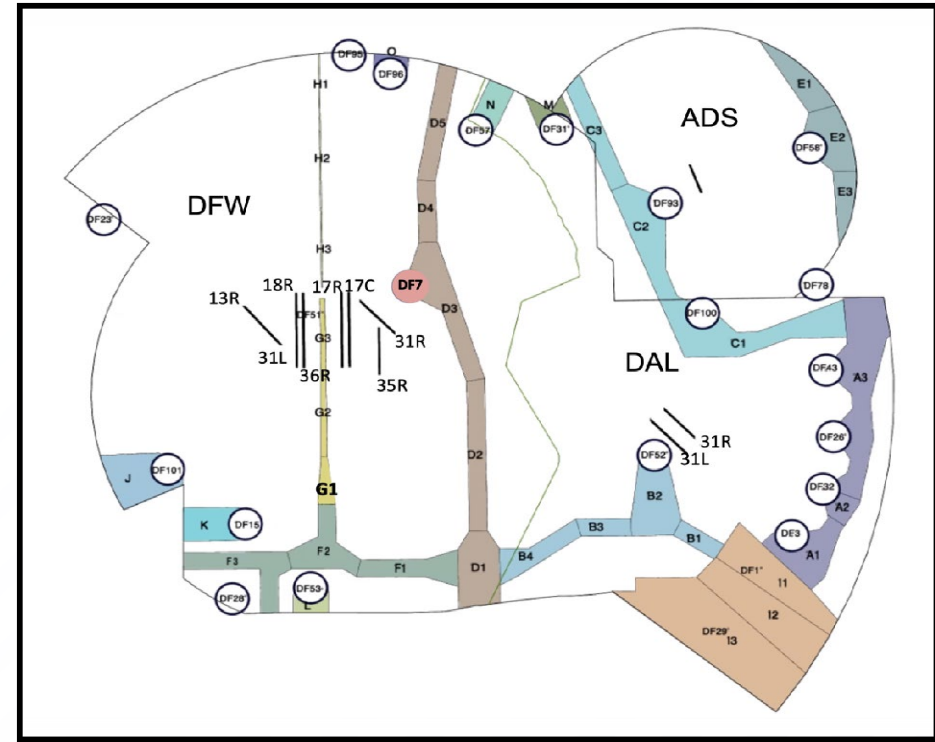
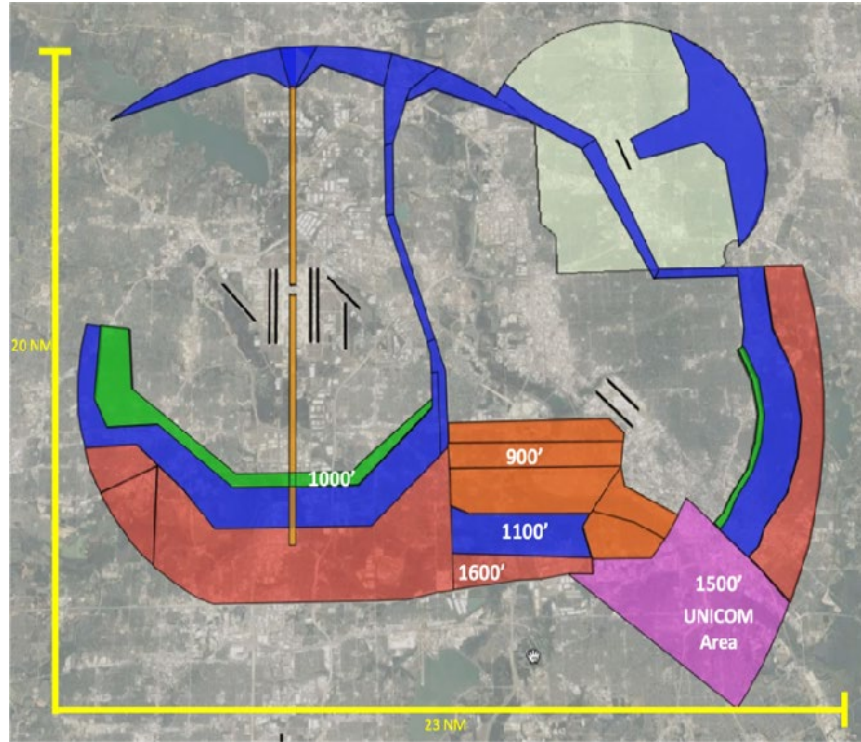
- M. Stevens and E. Atkins, "Geofence Definition and Deconfliction for UAS Traffic Management," in IEEE Transactions on Intelligent Transportation Systems, vol. 22, no. 9, pp. 5880-5889, Sept. 2021.
- M. S. Islam, S. Mukherjee, K. Namuduri, M. Compere, M. I. Akbas, P. Molnár, and R. Subramanian. 2021. "Air Corridors: Concept, Design, Simulation, and Rules of Engagement" Sensors 21, no. 22,
- X. Jiang, X. Peng, V. Bulusu, C. Poliziani, G. Chatterji and R. Sengupta, "A Metrics-based Method for Evaluating Corridors for Urban Air Mobility Operations," 2022 IEEE International Smart Cities Conference (ISC2), Pafos, Cyprus, 2022, pp. 1-7.
- S. Verma, V. Dulchinos, R. D. Wood, A. Farrahi, R. Mogford, M. Shyr, and R. Ghatas, "Design and Analysis of Corridors for UAM Operations," 2022 IEEE/AIAA 41st Digital Avionics Systems Conference (DASC), Portsmouth, VA, USA, 2022, pp. 1-10.

Geofence

Definition: In the context of UAS, the term geofencing is used to describe virtual three dimensional “boundaries” each UAS flies within or avoids as a no-fly zone (NFZ)

M. Stevens and E. Atkins, "Geofence Definition and Deconfliction for UAS Traffic Management," in IEEE Transactions on Intelligent Transportation Systems, vol. 22, no. 9, pp. 5880-5889, Sept. 2021.

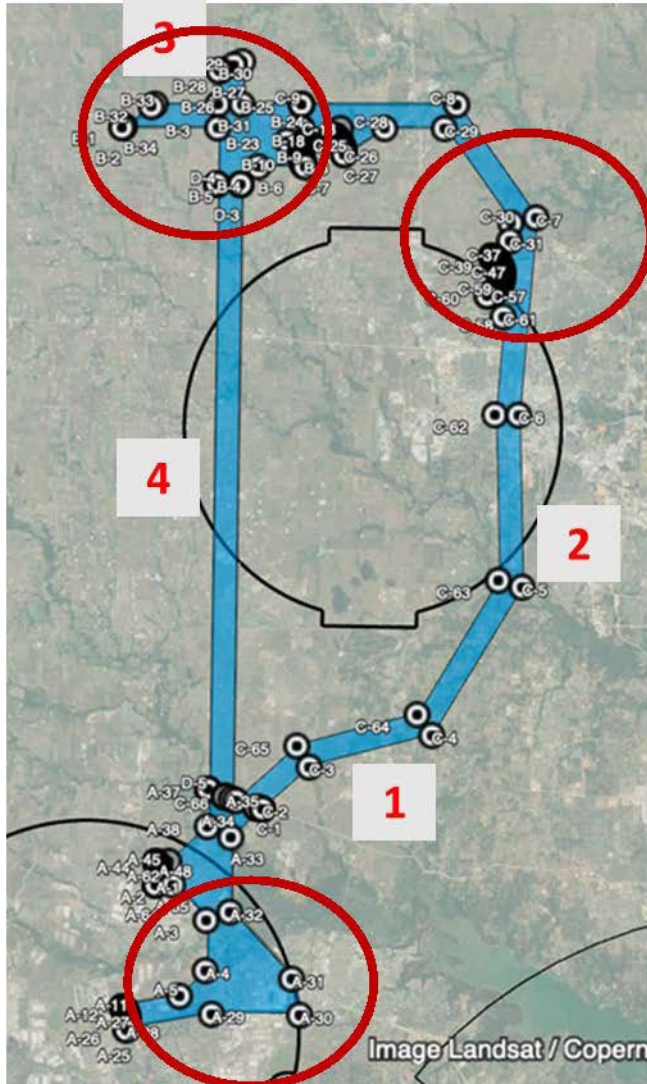
Real Air Corridors in Dallas-Fort Worth, Texas, USA (Courtesy: NASA)



S. Verma, V. Dulchinos, R. D. Wood, A. Farrahi, R. Mogford, M. Shyr, and R. Ghatas, "Design and Analysis of Corridors for UAM Operations," 2022 IEEE/AIAA 41st Digital Avionics Systems Conference (DASC), Portsmouth, VA, USA, 2022, pp. 1-10.

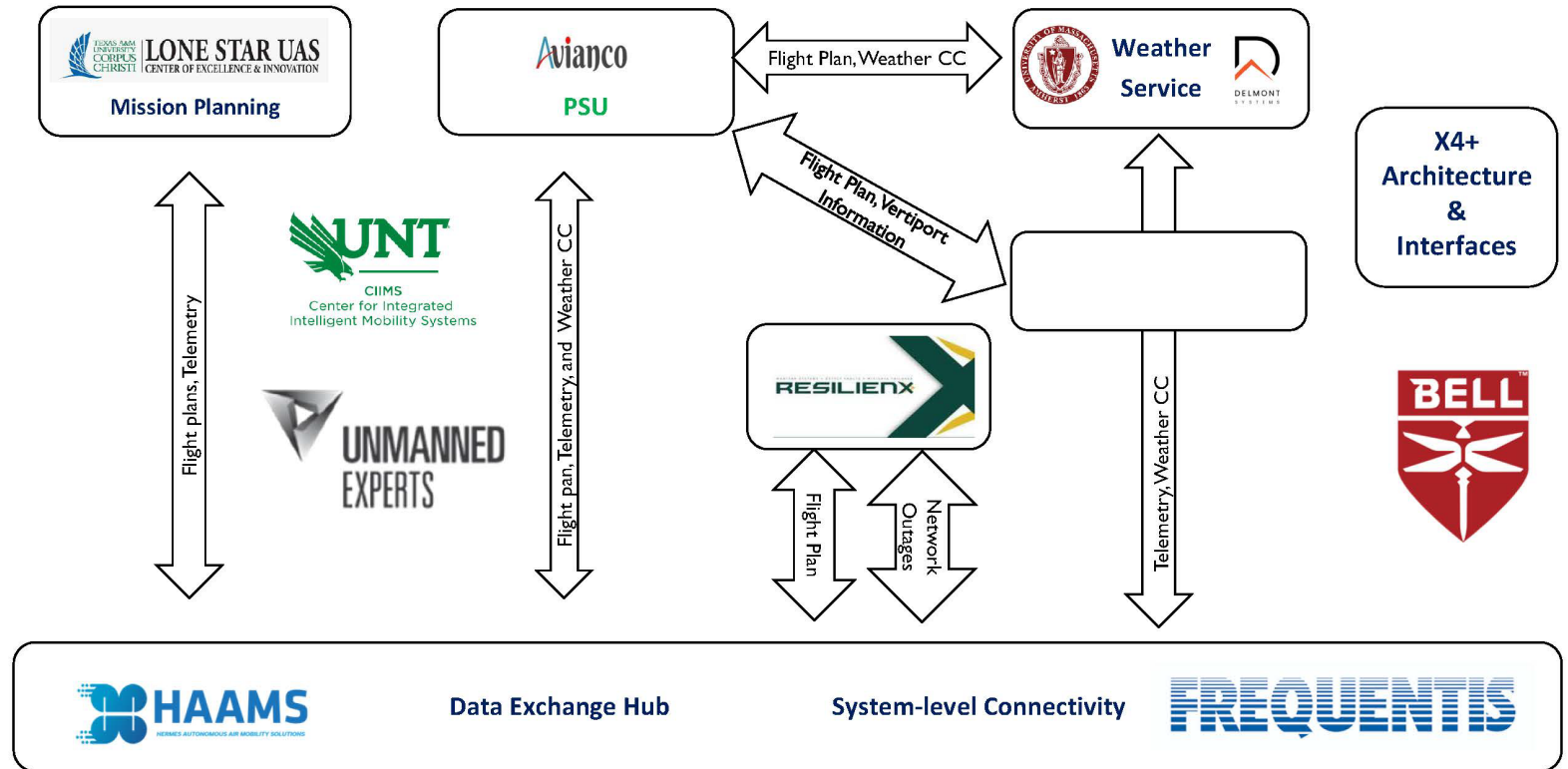
First Flight Test in DFW Air Corridor (October 11th, 2022)

Rose Lane



UNT Discovery Park

Mobility Innovation Zone



Designing Air Corridors in Dallas-Fort Worth, Texas, USA (Courtesy: NASA)

- Air corridor design required identifying airspace that was 2,500 ft laterally or 1,000 ft vertically separated from traditional traffic.
- The corridors were located only in Class B and Class D airspace and housed tracks or pre-defined routes that connected 34 potential vertiports in the region.
- All the corridor volumes were assumed to have a floor of 400 AGL and a ceiling of 600 with UAM flights planned to fly at 500 ft AGL or approximately 1,100 ft MSL.

S. Verma, V. Dulchinos, R. D. Wood, A. Farrahi, R. Mogford, M. Shyr, and R. Ghatas, "Design and Analysis of Corridors for UAM Operations," 2022 IEEE/AIAA 41st Digital Avionics Systems Conference (DASC), Portsmouth, VA, USA, 2022, pp. 1-10.

Communication Support for AAM Services

- Communication support is required for traffic management, tracking, coordination, positioning (interference mitigation), BVLOS and BRLOS communications (relaying), routing, and others.
- Satellite, Cellular, and Direct V2V are three candidate technologies each with its own advantages and disadvantages offering various bandwidth, latency, coverage, reliability, and QoS tradeoffs.
 - Satellite: Unlimited coverage, large latency, and large Doppler effect
 - Cellular: Medium coverage, medium latency, and less availability
 - Direct: Limited coverage, low latency, and less reliability

UAS-to-UAS Communications

In September 2022, The Radio Technical Commission for Aeronautics (RTCA) identified five use cases for UAS to UAS communications.

1. Collision Avoidance
2. Merging/spacing and sequencing of Traffic
3. Airborne Separation
4. Airborne Rerouting
5. Sensing and Sharing of Airspace Hazard Information

IEEE P1920.2 WG is developing a standard for UAS-to-UAS Communications which is expected to be released by the end of 2023.

Air Corridor Emulation on AERPAAW

Air Corridors Emulation | IEEE DataPort (ieee-dataport.org)
<https://ieee-dataport.org/documents/air-corridors-emulation>

John Kesler, Mihail L. Sichitiu, Kamesh Namuduri, February 12, 2023,
"Air Corridors Emulation"

Thank You!

Thank you for attending today's Webinar on Advanced Air Mobility. The recording will be available on the IEEE Knowledge Portal sponsored by VTS, as well as the VTS Resource Center, hosted by IEEE. If you are interested in becoming a member of IEEE VTS, please visit the VTS website at [www dot VT society dot org](http://www.vtsociety.org). You are also invited to connect with VTS on social media and learn more about VTS events and activities through Facebook, Twitter, and LinkedIn.

Please join us for next month's Webinar on Advanced Air Mobility featuring Professor Rui Zhang on the topic of “UAV Communications for 5G/6G” on April 3rd, 2023.

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3 APRIL

UAV COMMUNICATIONS FOR
5G/6G

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