Large-Scale Simulation of a Distributed Sensing Network Supporting Regional Urban Air Mobility Operations

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Autonomous Systems – Distributed Sensing
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Outline

1. Introduction
2. Single Flight Simulation
3. Multi-Vehicle Simulation Scenarios
4. Next Steps
5. Conclusion

Objective

- **Simulation Approach for Transforming Transportation in Densely Populated Regions (e.g., San Francisco Bay Area)**
  - **RVLT Model**: Simulates complex interactions of multiple vehicles in urban environments.
  - Focus on **large-scale UAM scenarios** for operational efficiency and safety.
- **Distributed Sensing**
  - Ground sensor nodes strategically deployed for **enhanced situational awareness**.
  - Improves **real-time data collection**, **operational effectiveness**, and **safety**.
- **Key Factors Analyzed**
  - **Air Traffic Density**
  - **Infrastructure Requirements**
  - Integration of **empirical data** and **geographical realism**.
- **Actionable Insights**
  - Inform **policymakers**, **urban planners**, and **industry stakeholders**.
  - **Feasibility, efficiency, and safety** considerations for successful UAM deployment.

Key Barriers for UML 4+ and m:N Operations

- **Airspace Surveillance & Conformance Monitoring**
  - Low-altitude airspace corridors and vertiport monitoring
  - Independent airspace control and fleet management
- **Precision Navigation**
  - Precision Approach and Landing (PAL)
  - GPS-Free Position Navigation & Timing (PNT)
- **Autonomous Airspace Operations**
  - Autonomous m:N fleet management
  - Self-autonomy services (e.g., detect-and-avoid, self-sequencing)
- **Distributed Monitoring for Weather & Urban Hazards**
  - Networks detecting local weather hazards and mitigation planning
- **Distributed Systems Health Management**
  - Vehicle and air traffic health monitoring, cybersecurity services
- **Onboard Aircraft Wireless Sensor Networks**
  - Airflow, structural, and propulsion monitoring

Leveraging Distributed Sensing Technologies for UAM

- **Distributed Sensing** can overcome key barriers by enabling interconnected systems of smart vehicles and airspaces using wireless networks.
- **Simulation Role**:
  - Simulate multi-vehicle and single-vehicle UAM scenarios in complex environments (e.g., San Francisco Bay Area).
  - Assess impact of air traffic density, weather, and infrastructure on UAM operations.
- **RVLT Model**:
  - Captures vehicle dynamics and environmental factors to optimize UAM operations.
- **Impact on Urban Transportation:**
- Efficient, sustainable, and rapid aerial transport.
- Inform policymakers, urban planners, and stakeholders on UAM feasibility.

Large-Scale UAM Simulation: San Francisco

- **Initial Simulation (Previous Work)**
  - Focused on **2 vertiports**, **single flight**, and **7-8 sensors** along the route.
  - **Pilot view camera** captured imagery for vertiport scenes and landing lights.
- **Current Simulation (Expanded Scope)**
  - **50 vehicles** navigating to **22 vertiports**, with **60-70 sensor ground stations**.
  - Transition from **1:1 vehicle-to-vertiport** to **M:N configuration**.
  - Significant enhancement in **sensor array** and **vehicle fleet**.
- **Simulation Enhancements**
  - Focus on **approach & landing procedures** and **urban environment modeling**.
  - **Sensor Types**: Visual Cameras, IR Cameras, Lidars, Radars, Multispectral Cameras.
  - **Onboard Sensors**: Capture in-flight parameters and flight trajectories.
- **Simulation Benefits**:
  - Identifying sensor limitations and saving costs in real-time flight tests.

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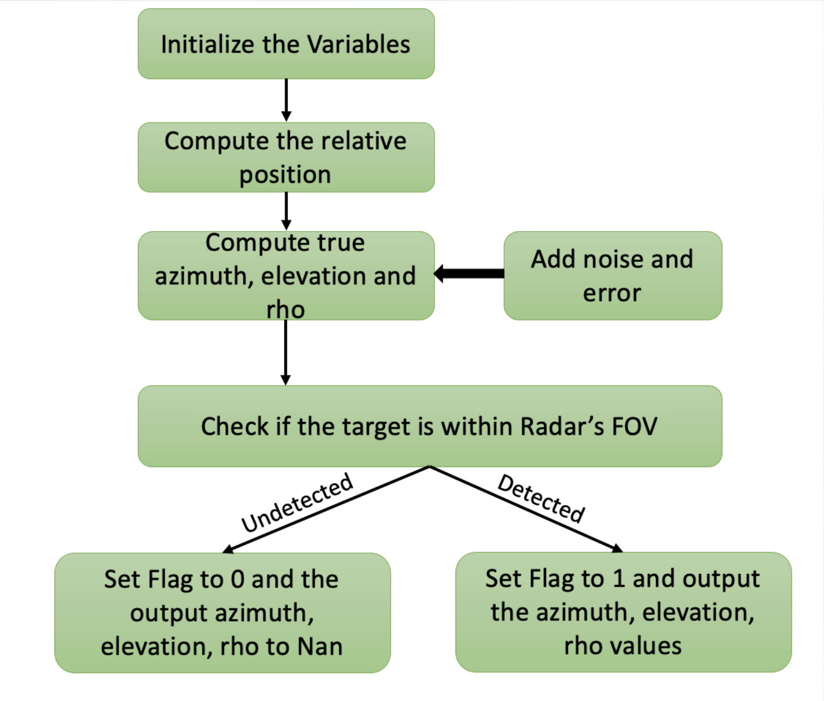
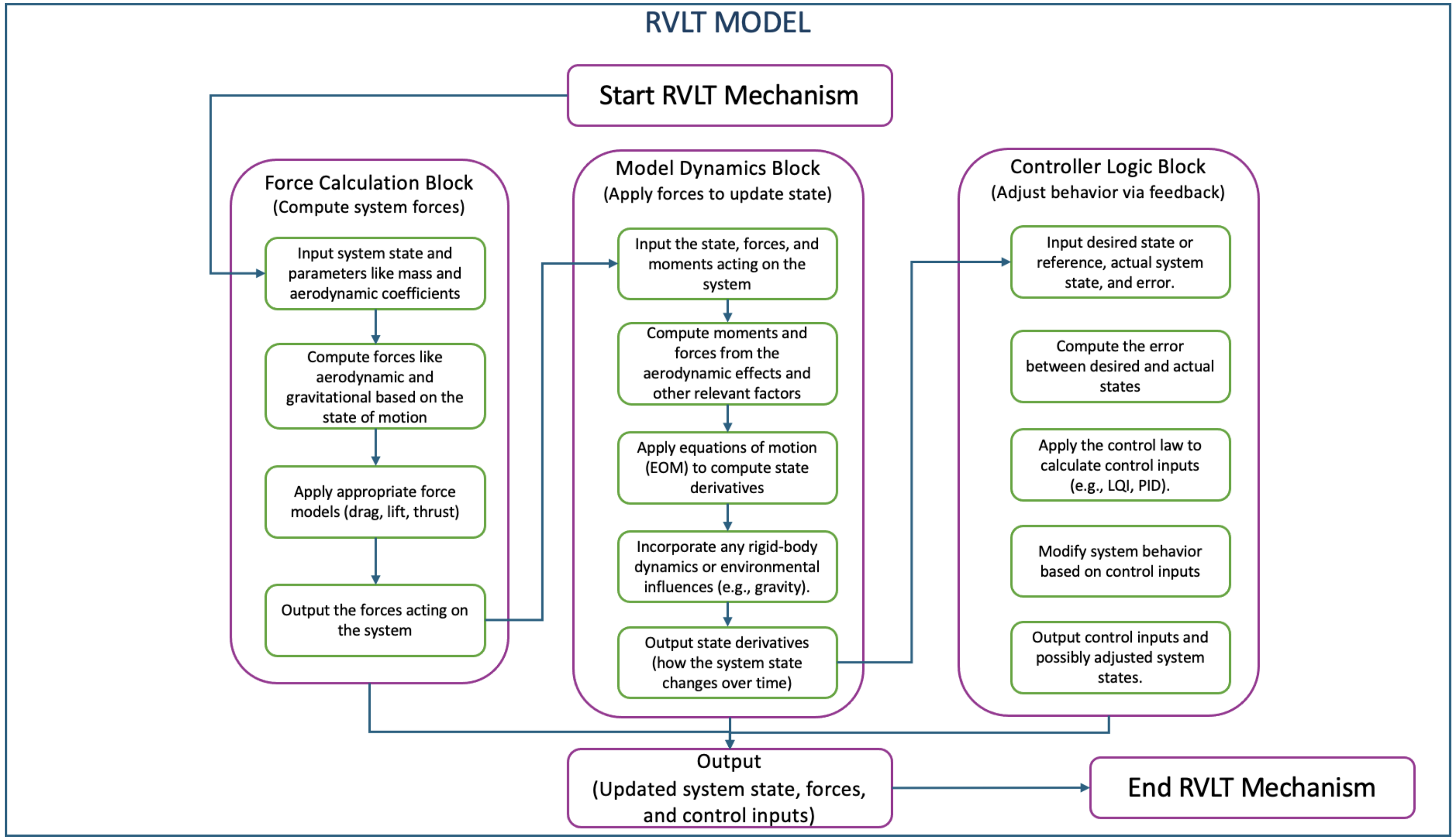
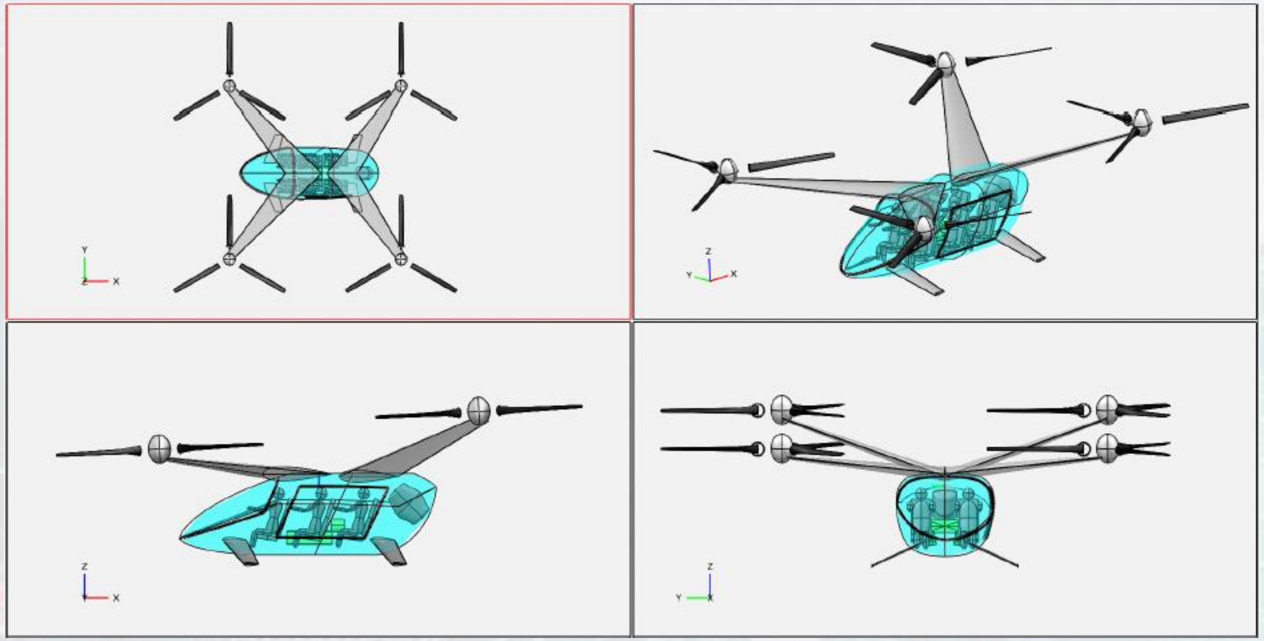
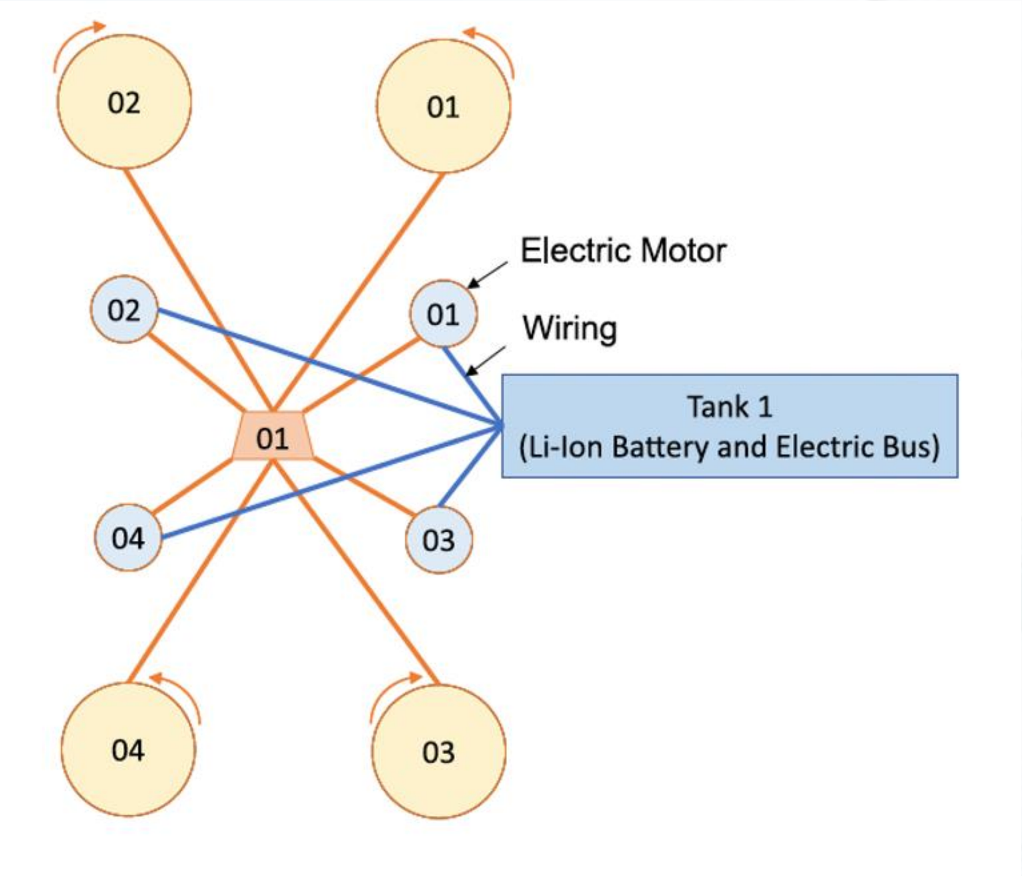
Single Flight Simulation





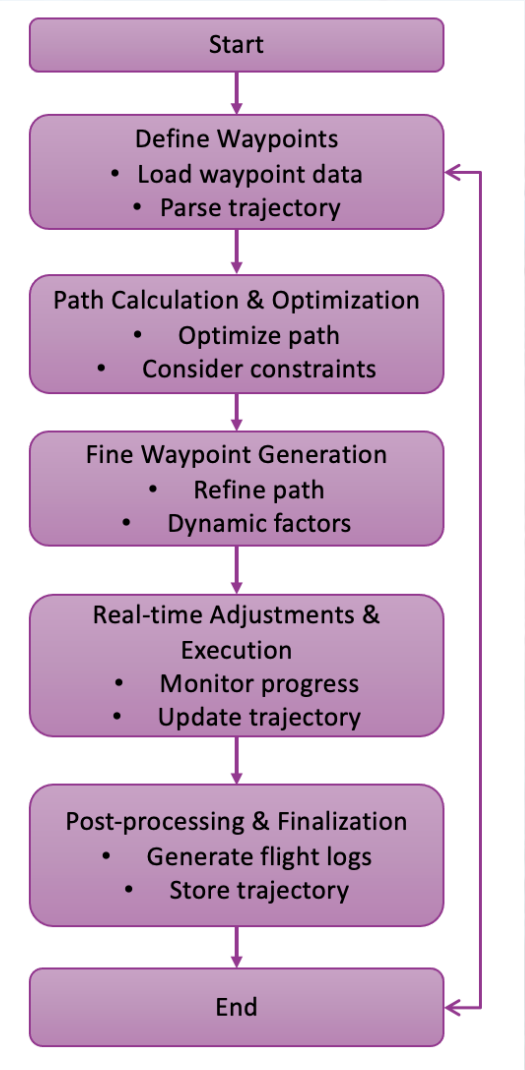
RVLT Model





02
01
Electric Motor
02
01
Wiring
Tank 1
(Li-Ion Battery and Electric Bus)
01
04
03
04
03

Flight Trajectory Planning and Generation



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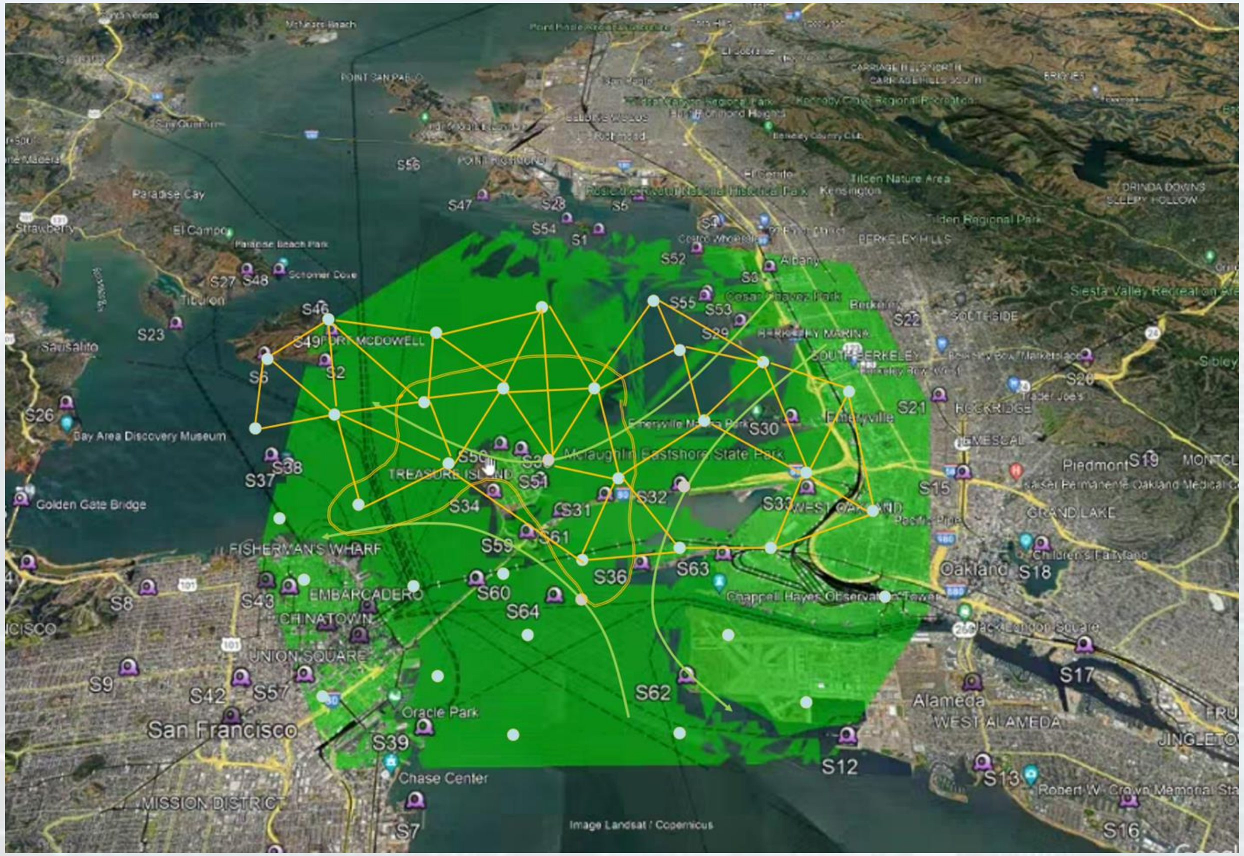
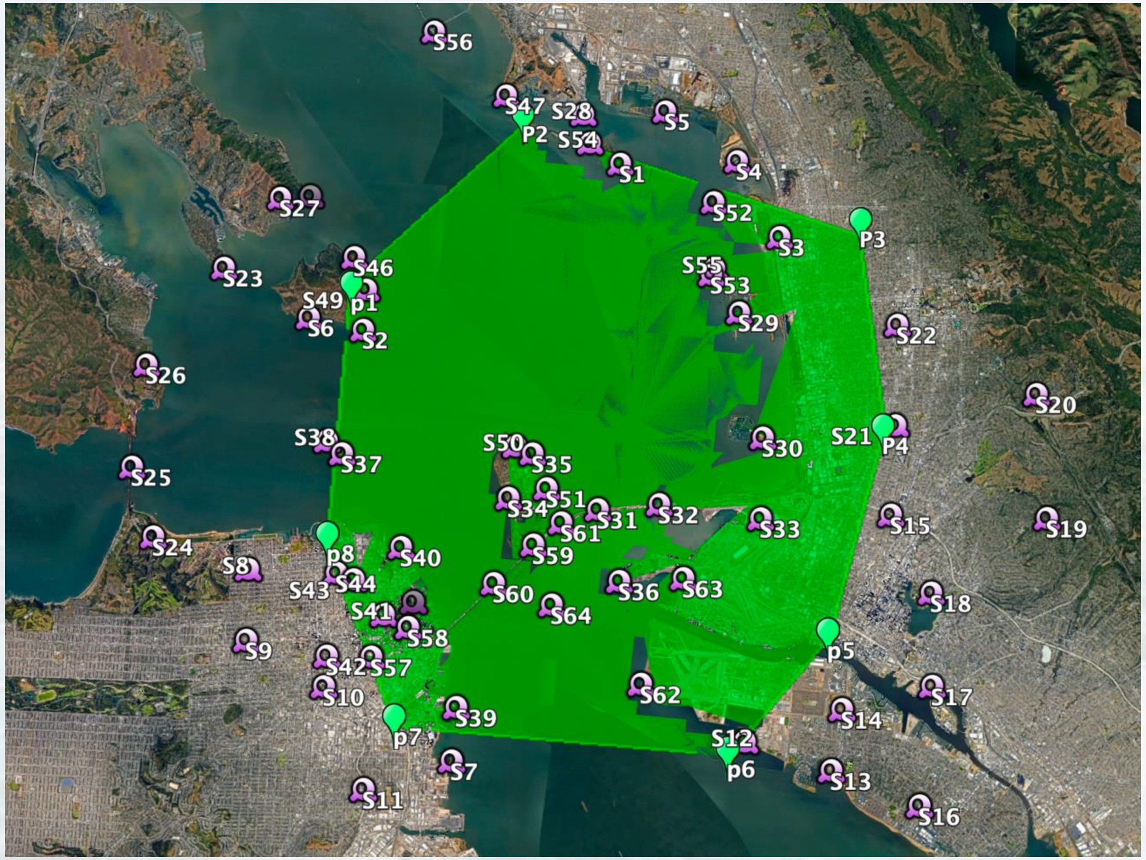
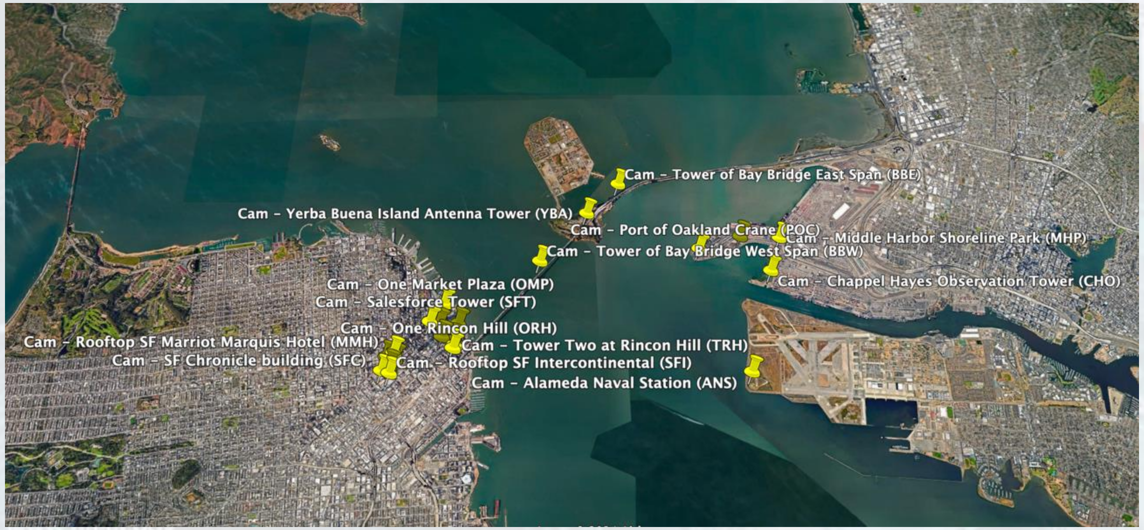
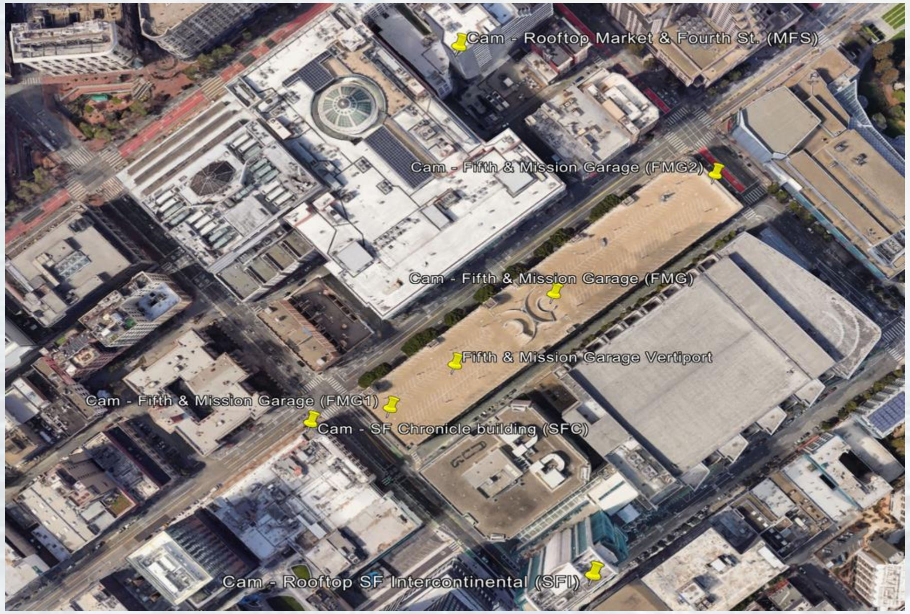
Dense Sensor Population





Dense Sensor Population





M:N Operation

Sensor Network for Multiple Approach and Departure Paths

Holding Pattern

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Next Steps

- **Flight Tests**
  - Collaboration with **NASA Smart Mobility** and **NASA Armstrong** on **full-scale AAM aircraft flights**.
  - **Validate algorithms** and **datasets** developed through simulations in real-world scenarios.
- **Simulation Integration**
  - Discussions underway to integrate **simulation outputs** with other NASA teams.
  - Aim to enhance **M:N operations** and support the broader **UAM ecosystem**.
- **Goal**
  - Develop a **seamless, robust framework** leveraging **distributed sensing** and **advanced algorithms** to optimize **air mobility operations** across multiple platforms.

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Conclusion

- **Current Development**:
  - Integrates various factors to optimize **UAM operations**.
  - Incorporates **m:n concepts**, **holding patterns**, and **multiple approach paths** in vertiport navigation.
- **Challenges Encountered**:
  - **Simulating numerous camera videos** and **limitations of visualization software** (e.g., XPlane).
  - Need for **adaptive measures** in simulation setups.
- **Solution & Adaptation**:
  - Focus on **sensor emulation** to overcome visualization challenges.
  - Transition to **versatile platforms** like **Matlab** or **Reflection** for improved sensor output emulation.
- **Future Simulation**:
  - Leveraging **innovative approaches** to evolve the simulation framework.
  - Add nearly **100 flights** in the region of interest.
  - **Enhances simulation fidelity** for **informed decision-making** in UAM integration.

References

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Thank you for listening! Questions?