A SIMULATION ARCHITECTURE FOR AIR TRAFFIC OVER URBAN ENVIRONMENTS SUPPORTING AUTONOMY RESEARCH IN ADVANCED AIR MOBILITY

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NASA Ames Research Center (ARC): Intelligent Systems
Autonomous Systems – Distributed Sensing
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Outline

1. Introduction
2. Simulation Infrastructure
3. Simulation Goals
4. Simulation Scenarios & Results
5. Conclusion

Objective

- NASA investigates concepts, aircraft, and operations related to Advanced Air Mobility (AAM)
- Most challenging scenario for AAM – enabling safe routine access in densely populated urban centers
- Requires a moderately high-fidelity simulation capability for development and evaluation of autonomy technologies in the urban environment while utilizing AAM concept vehicle dynamics
- Essential to simulate air and ground-based sensors, such as radar and LiDAR
- Enables the evaluation of NASA research concepts in autonomy for urban AAM operations on the path toward flight test evaluation

AAM Challenges

- Traditional surveillance and landing systems - not practical for AAM operations
- AAM concepts require higher accuracy and performance compared to the current National Airspace System
- Cannot use GPS for self-reporting surveillance and navigation technologies in GNSS degraded environments as GPS can be highly unreliable in urban areas with high raised building and skyscrapers

Distributed Sensing Goals

- DS concepts enable continuous and real-time monitoring of the physical and environmental conditions from overlapping sensors through the entire length of the flight
- Develop a framework for incorporating geographically distributed (non-co-located) sensors and remote observations
- Address sensor drop-outs from degradation
- Provide persistent estimates across observations that meet minimum quality requirements and continuous evaluation of quality from each observation source (cross-validation and confidence)

Problem Statement

- Not practical to flight test all the AAM operations without proof of concept
- Simulating the state-of-the-art sensors in a distributed framework
  - Provides a proof of concept
  - Saves time and money
- This simulation architecture -
  - Helps test various normal to adverse flight situations
  - Fuses all the sensor modules for the RVLT aircraft model in an urban scenario
  - Follows the proposed guidelines of the Federal Aviation Administration

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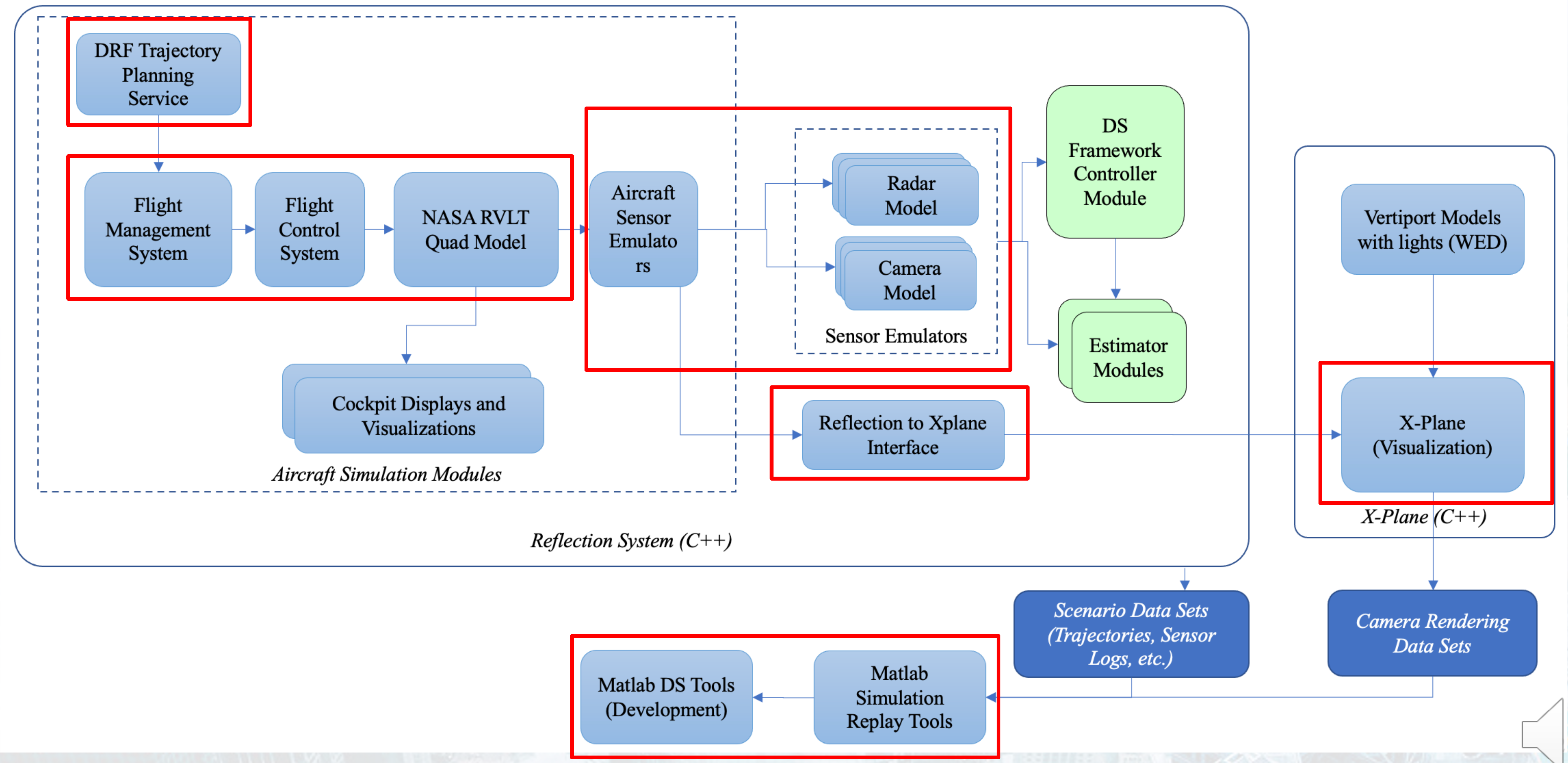
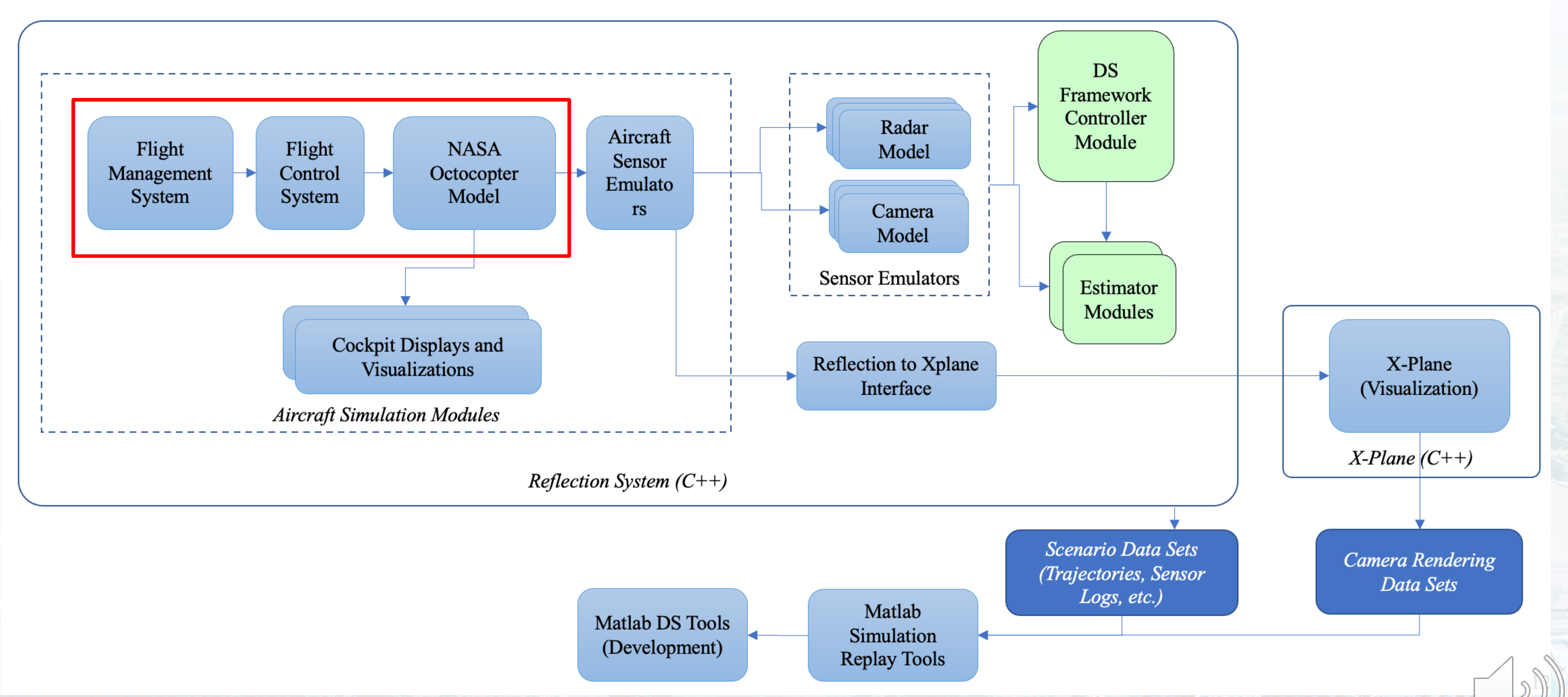
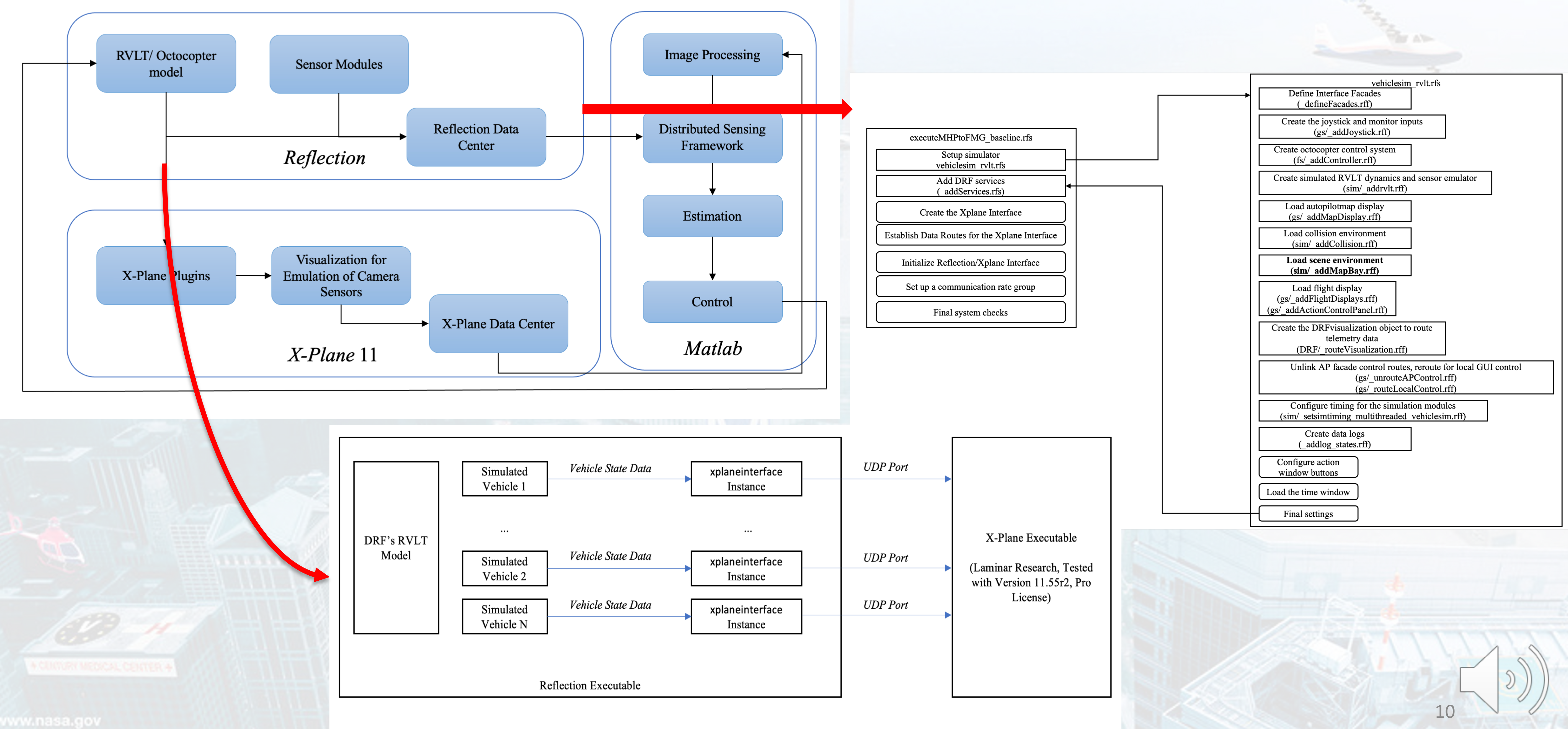
Simulation Architecture (RVLT)



Simulation Architecture (Octocopter)



Simulation Software Toolchain



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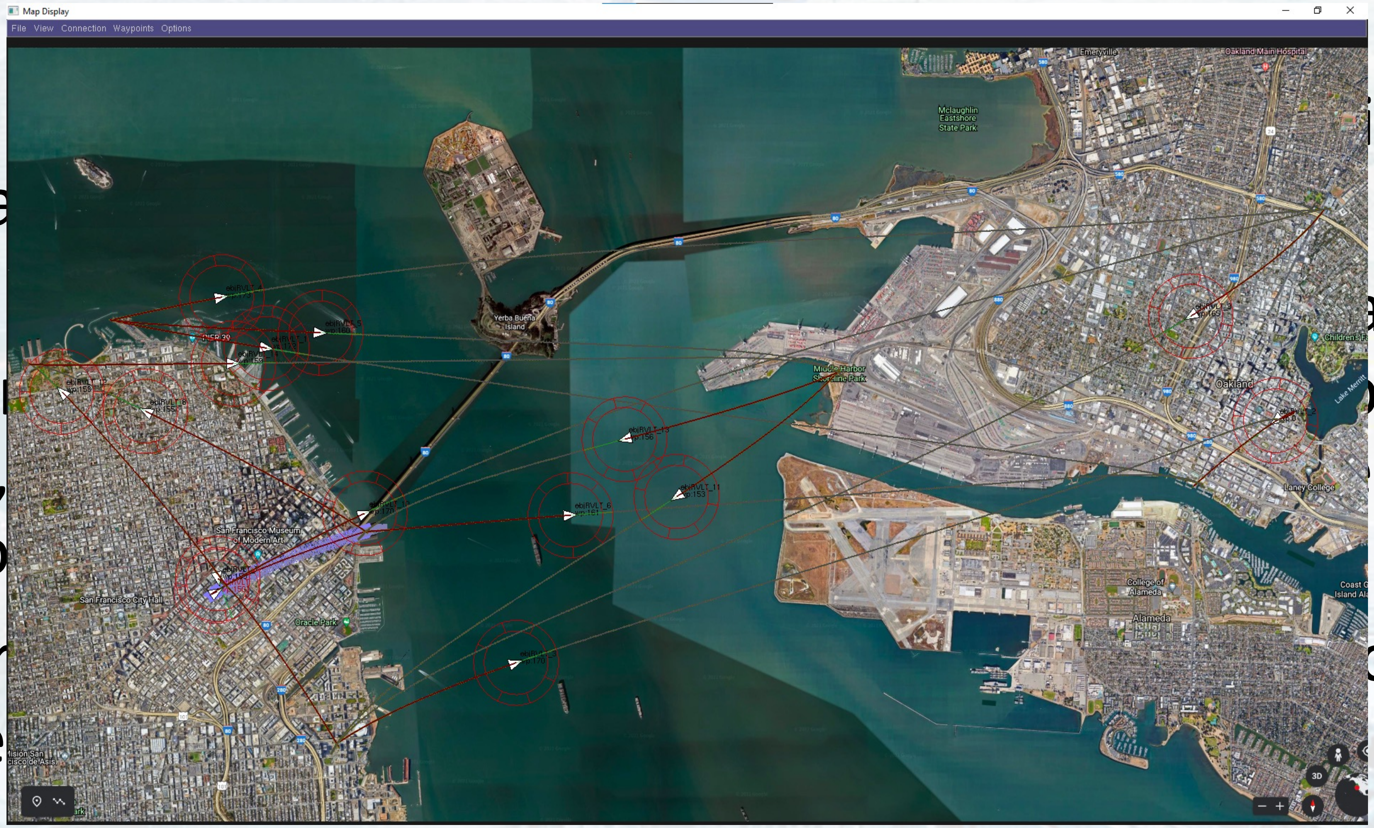
Simulation Goals

- Create a DS simulated environment for experiments and real-world applications and include hardware for field tests
- Implement multiple autonomous vehicles operating at the same time without any collisions
- Precision Approach and ides a solution for vertiport a
- Detect and Avoid (DAA) able and safe UAM vehicles i ping during cruise, approach, d sensors to ensure safe o
- Integrity Monitoring - Pr on of all sensors and estimate



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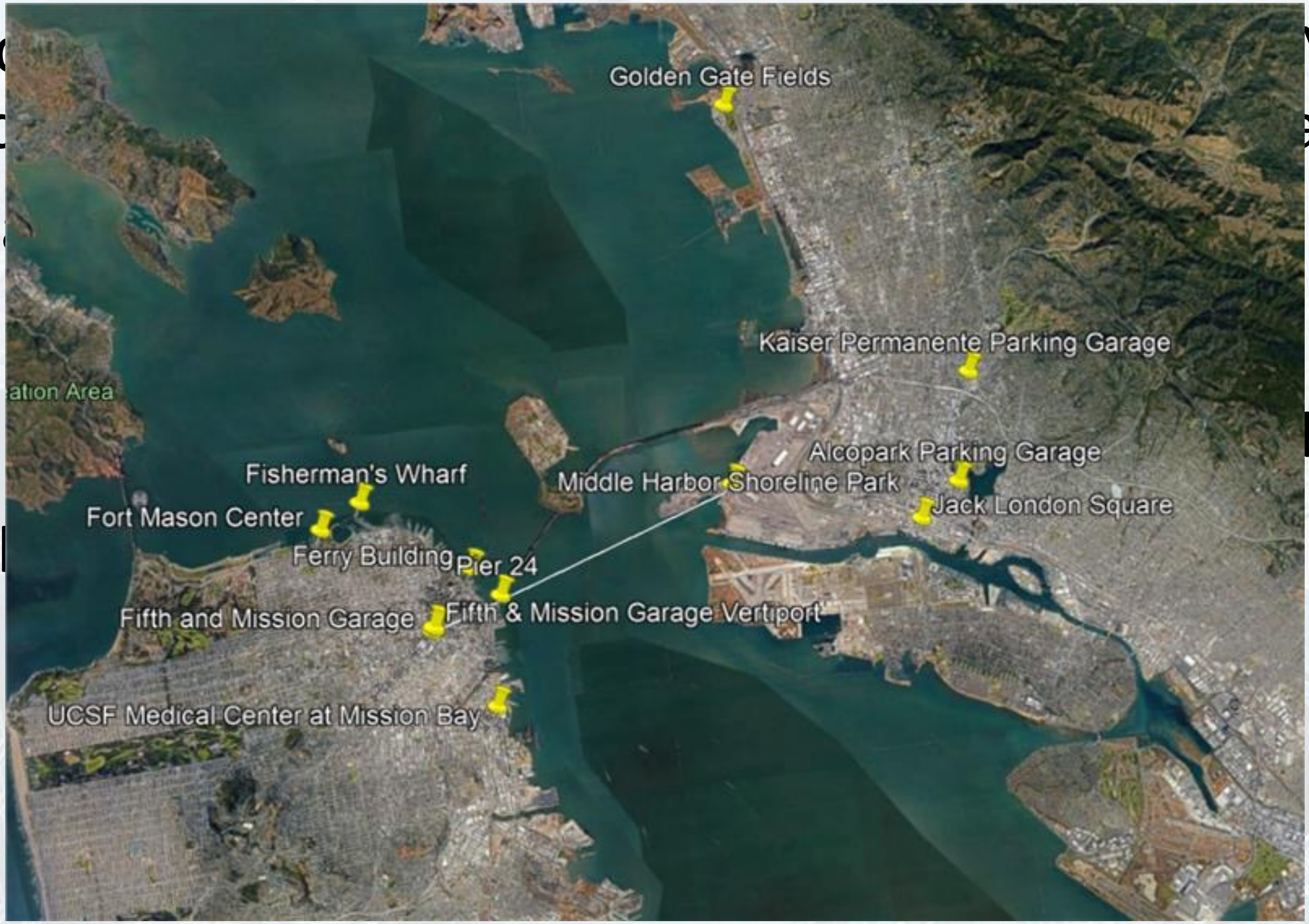
Simulation Scenarios

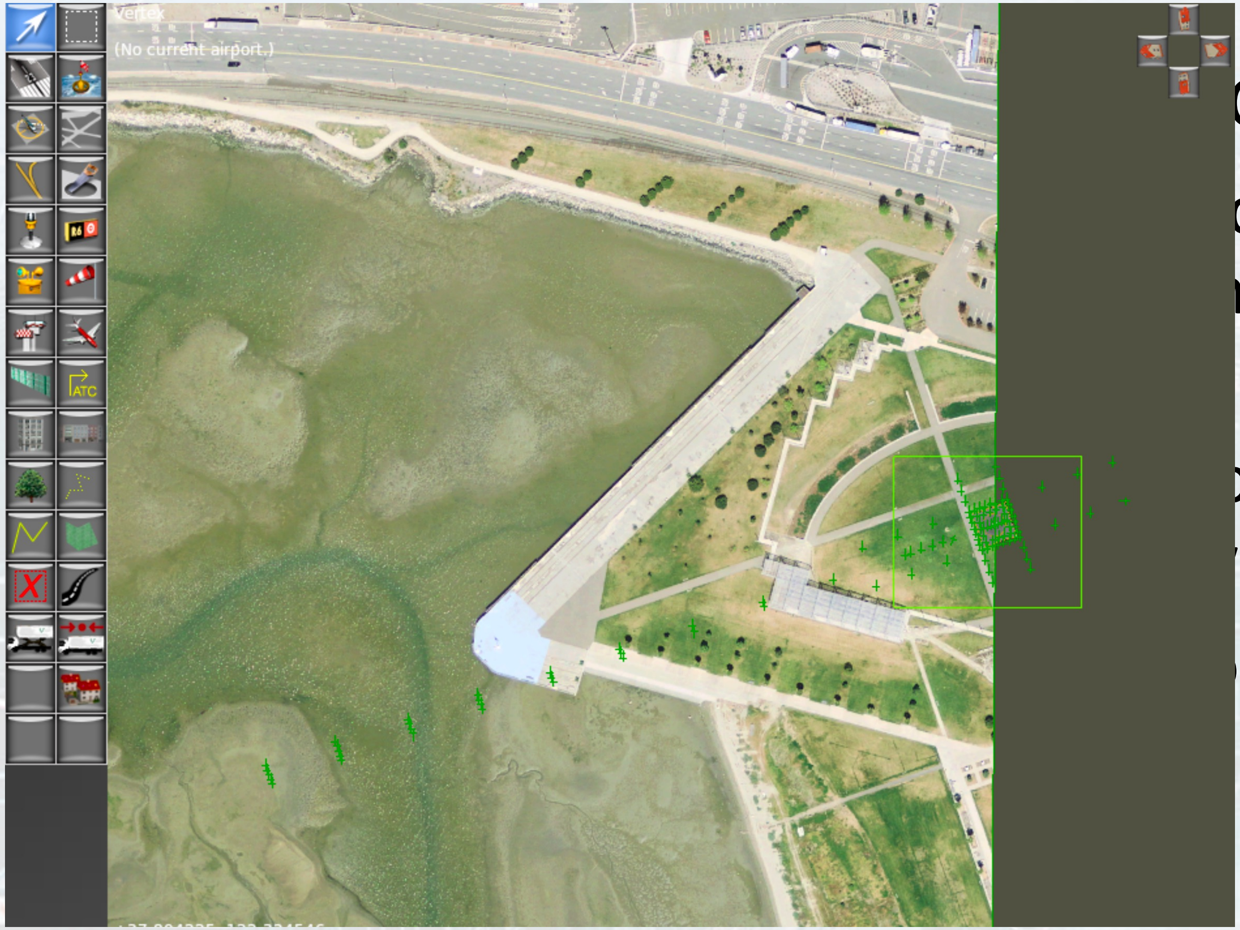
1. AAM regional operations simulation in San Francisco bay area
   - Middle Harbor Park (MHP) to Fifth and Mission Garage (FMG) scenario
   - Fifth and Mission Garage (FMG) to Middle Harbor Park (MHP) scenario
2. AFRC Vertiport Mockup – Precision Approach, Landing, and Terminal Area Operations
   - Parallel flight test activity at NASA AFRC supporting validation
3. Ames Smart Mobility Build 1 Flight Test Scenarios
   - Parallel flight test activity at NASA Ames supporting validation

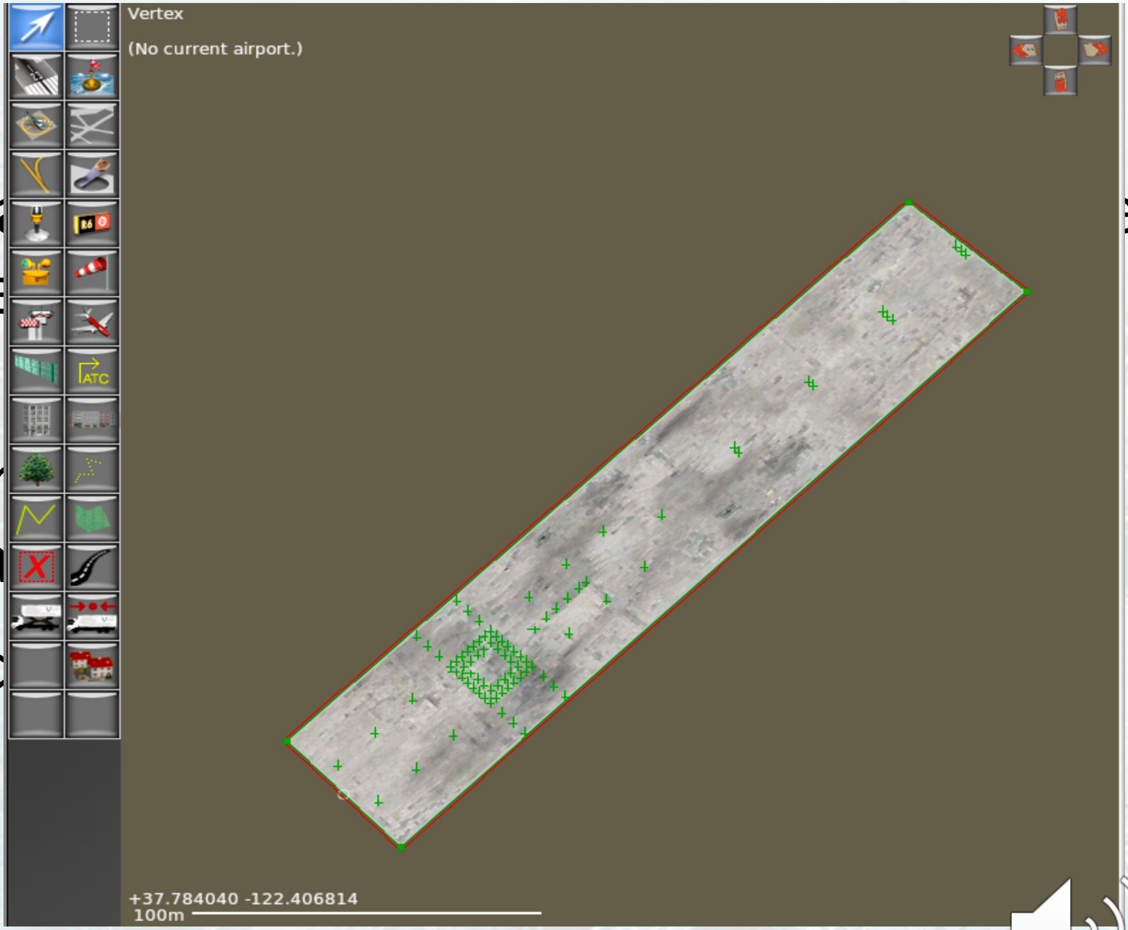
AAM regional operations simulation in San Francisco bay area

- Landing pa … Mission Garage (FMG) buil … ark (MHP) both
- cruise AGL
- 50 knots fo
- a 9-degree … L
- Other verti



MHP and FMG Vertiport Configurations

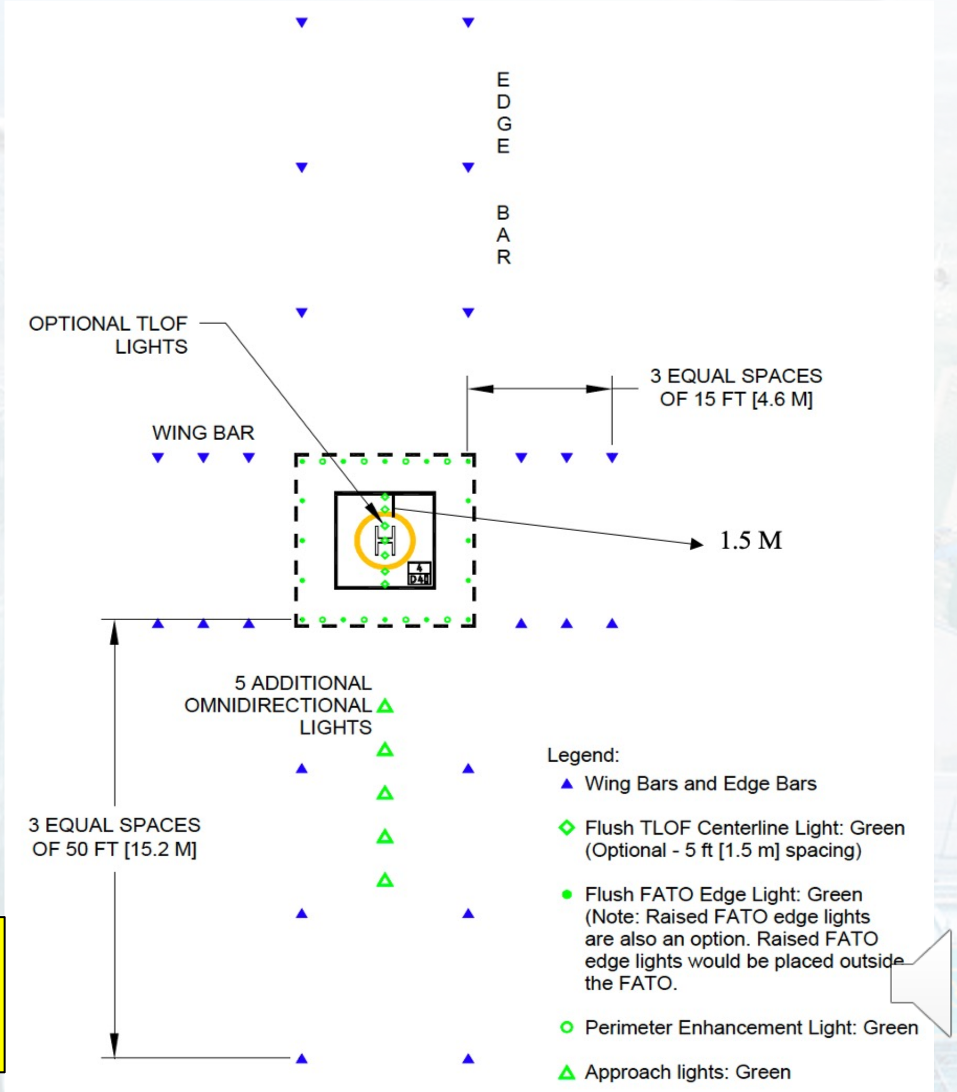




[1] Federal Aviation Administration, “AC 150/5390-2C - Heliport Design,” U.S. Department of Transportation, 2012. URL https://www.faa.gov/documentLibrary/media/Advisory_Circular/150_5390_2c.pdf.

Full-scale Lights Configuration [1]

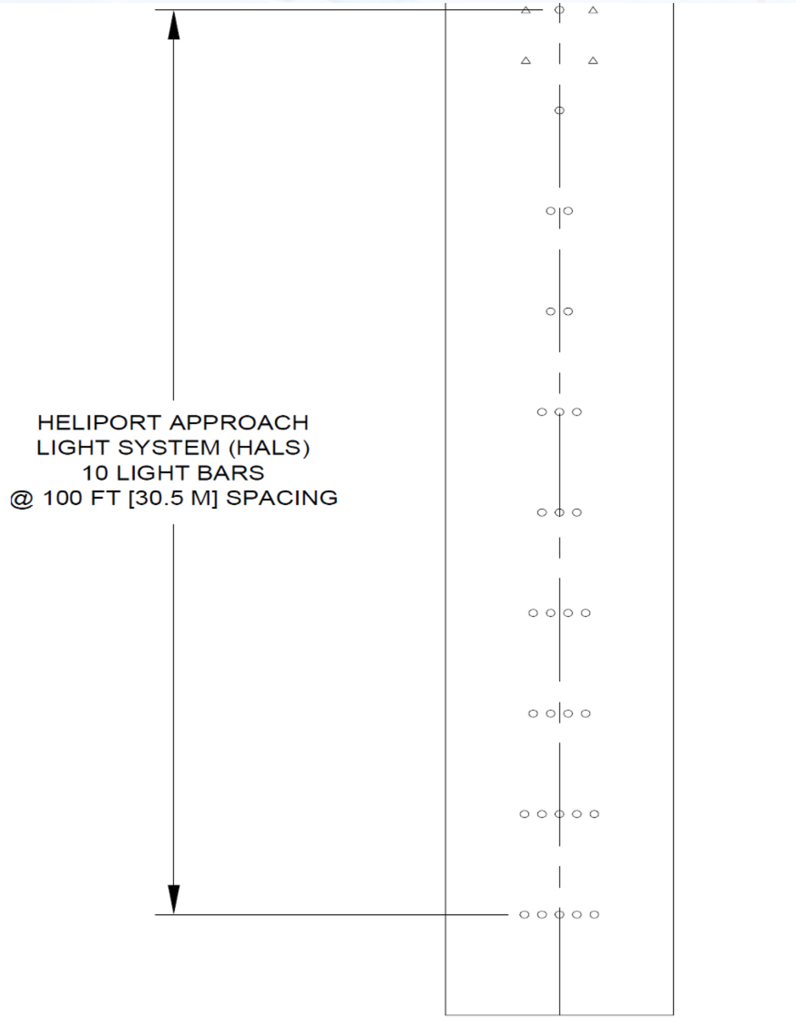
- 28 Final approach and takeoff area (FATO) Edge lights
- 16 Touchdown and liftoff area (TLOF) Edge lights
- 5 omnidirectional lights
- 7 helipad lights
- 24 wing and edge bars

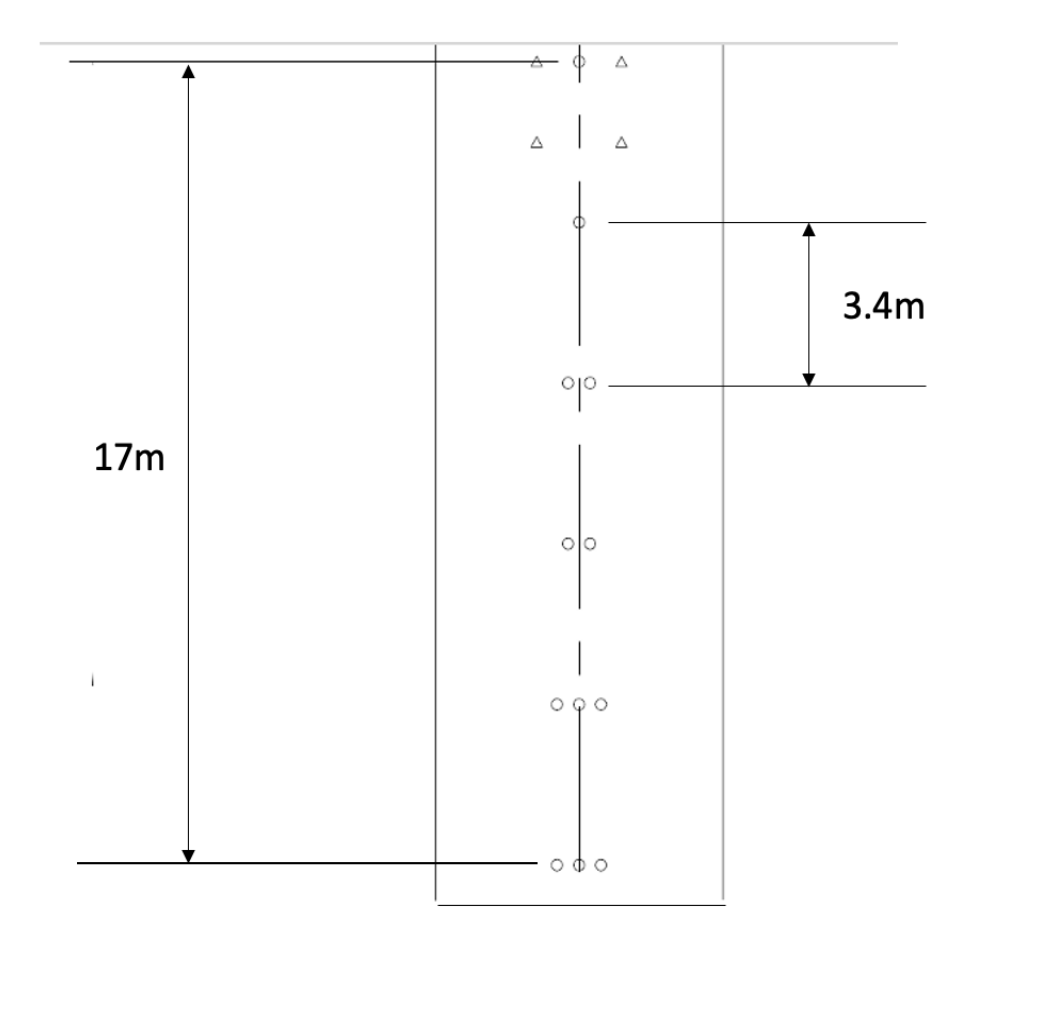


[1] Federal Aviation Administration, "AC 150/5390-2C - Heliport Design," U.S. Department of Transportation, 2012. URL https://www.faa.gov/documentLibrary/media/Advisory_Circular/150_5390_2c.pdf.

Full-scale Lights Configuration [1]

6-10 Heliport Approach Light System (HALS) light bars.





[1] Federal Aviation Administration, "AC 150/5390-2C - Heliport Design," U.S. Department of Transportation, 2012. URL https://www.faa.gov/documentLibrary/media/Advisory_Circular/150_5390_2c.pdf.

Full-scale Lights Configuration in X-Plane

MHP and FMG Ground Sensor Stations

Station Name	Description	Latitude (°)	Longitude (°)	Altitude (ft MSL)
MHP	Middle harbor shoreline park	37.8058777	-122.323633	6
ANS	Alameda Naval Station	37.782564	-122.332225	10
BBE	Bay Bridge East Span	37.815309	-122.358504	525
YBA	Yerba Buena Island Antenna tower	37.809956	-122.365332	341
BBW	Bay Bridge West Span	37.800911	-122.375117	526
SFT	Salesforce Tower	37.789782	-122.396968	1070
FMG	Fifth and Mission Garage Structure	37.78276666	-122.40600555	150

Table 2 The location of all the ground sensor stations in the simulation

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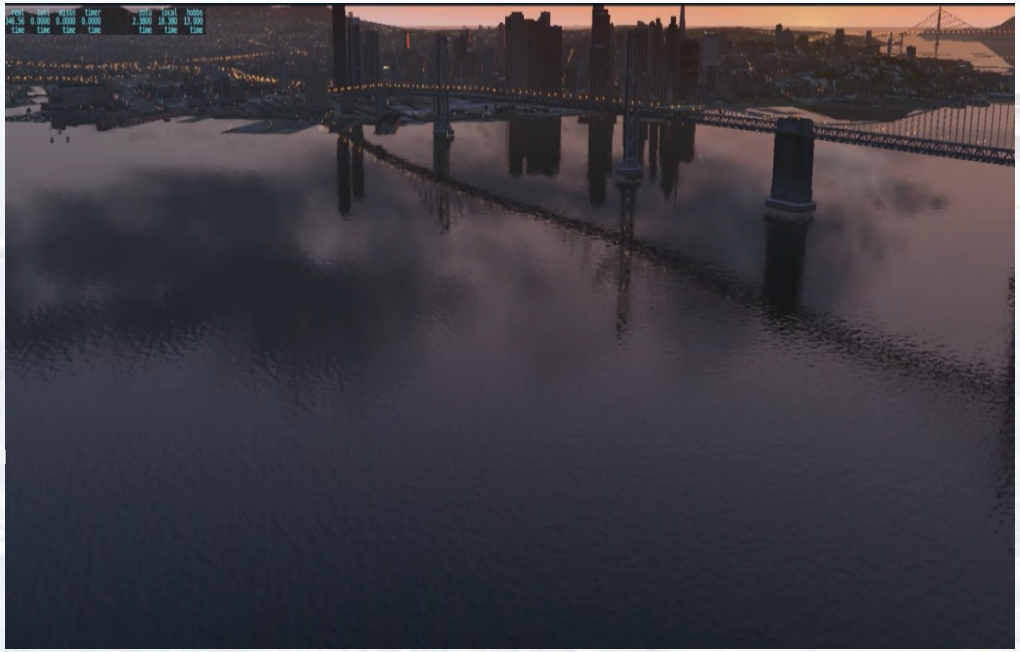
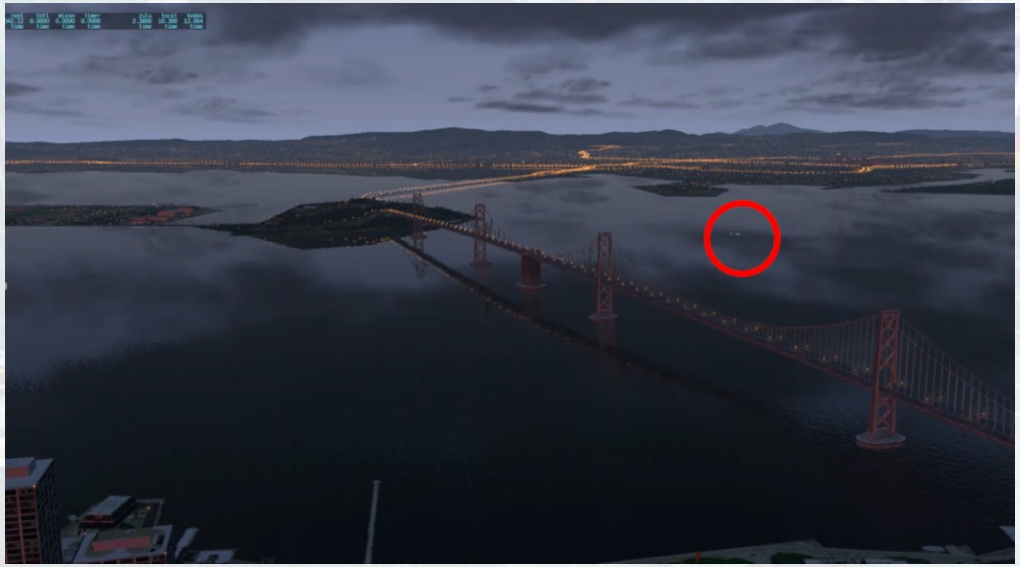
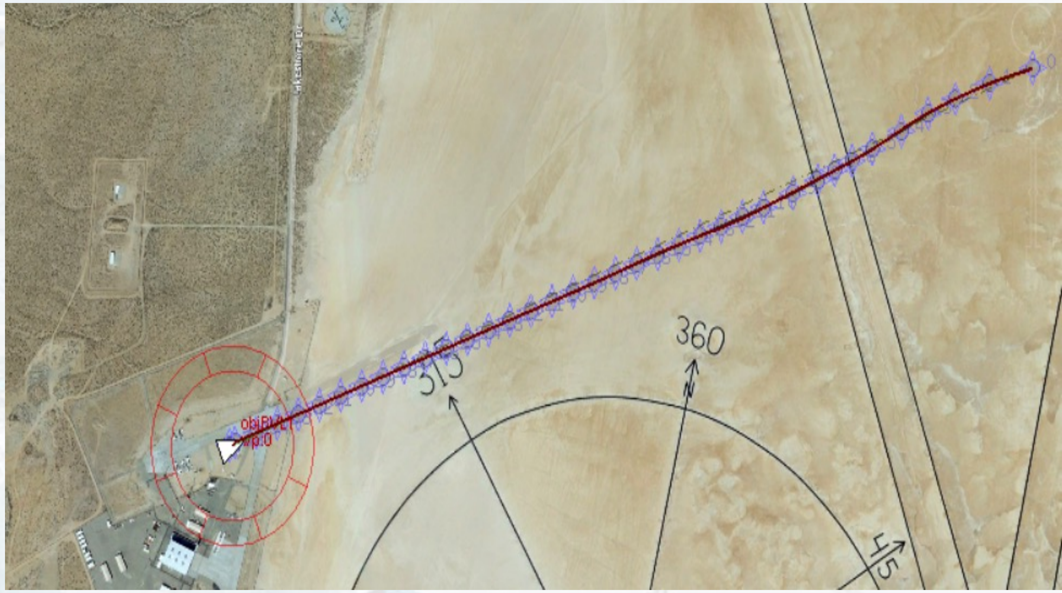
Simulated Sensor Views





AFRC Vertiport Mockup – Precision Approach, Landing, and Terminal Area Operations

- The vertiport and the landing lights use the same configuration as that of MHP
- Since the physical installation of the lighting system could be time consuming and expensive, AFRC flight test uses cones to replace the landing lights, which provides fiducials for vision-based AAM PAL [2,3]
- Simulation descent begins at an altitude of 498 ft with a speed of 70 knots which gradually reduces until touch down



[2] Kawamura, E., Kannan, K., Lombaerts, T., and Ippolito, C. A., “Vision-Based Precision Approach and Landing for Advanced Air Mobility,” AIAA SCITECH 2022 Forum, 2022, p. 0497.
[3] Kawamura, E., Dolph, C., Kannan, K., Lombaerts, T., and Ippolito, C. A., “Distributed Sensing and Computer Vision Methods for Advanced Air Mobility Approach and Landing,” AIAA SciTech 2023 Forum, 2023.

AFRC Vertiport Mockup X-Plane view

Ames Smart Mobility Build 1 Flight Test Scenarios

- Takes place in a region referred as "DART site" inside the NASA Ames Research Center for corridor surveillance.
- The flight cruises at an altitude of 50 feet AGL
- 4 ground sensor stations - each has a camera and a radar
- The post processing EKF in Matlab utilizes the outputs from these ground stations along with the onboard sensor suite [4, 5]

[4] Lombaerts, T., Kannan, K., Dolph, C., Stepanyan, V., George, G., and Ippolito, C., “Distributed Ground Sensor Fusion Based Object Tracking for Autonomous Advanced Air Mobility Operations,” AIAA SciTech 2023 Forum, 2023.
[5] Stepanyan, V., Kannan, K., Kawamura, E., Lombaerts, T., and Ippolito, C., “Target Tracking with Distributed Sensing and Optimal Data Migration,” AIAA SciTech 2023 Forum, 2023.

Ames Smart Mobility Build 1 X-Plane View

Current work involves updating the scenery of the DART site in X-Plane

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Conclusion

- The DS simulation framework enables testing of different scenarios under AAM concepts and operations while utilizing AAM/UAM vehicles
- Adequate simulations reduce the costs associated with flight testing in difficult urban areas
- Serves as a baseline for scientists and engineers to experiment multiple ideas and algorithms
- Future work
    - Expanding the simulated environment
    - Simulating multiple vehicles flying simultaneously
    - Integrating hardware testing platforms for flight tests

References

1. Federal Aviation Administration, “AC 150/5390-2C - Heliport Design,” 2012. URL https://www.faa.gov/documentLibrary/media/Advisory_Circular/150_5390_2c.pdf
2. Kawamura, E., Kannan, K., Lombaerts, T., and Ippolito, C. A., “Vision-Based Precision Approach and Landing for Advanced Air Mobility,” AIAA SCITECH 2022 Forum, 2022, p. 0497.
3. Kawamura, E., Dolph, C., Kannan, K., Lombaerts, T., and Ippolito, C. A., “Distributed Sensing and Computer Vision Methods for Advanced Air Mobility Approach and Landing,” AIAA SciTech 2023 Forum, 2023.
4. Lombaerts, T., Kannan, K., Dolph, C., Stepanyan, V., George, G., and Ippolito, C., “Distributed Ground Sensor Fusion Based Object Tracking for Autonomous Advanced Air Mobility Operations,” AIAA SciTech 2023 Forum, 2023.
5. Stepanyan, V., Kannan, K., Kawamura, E., Lombaerts, T., and Ippolito, C., “Target Tracking with Distributed Sensing and Optimal Data Migration,” AIAA SciTech 2023 Forum, 2023

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Thank you for listening! Questions?